A New Way To Target Malaria in Africa
EXECUTIVE SUMMARY

This document presents an overview of a unique new mosquito control product which could have a major impact on the incidence of malaria in Africa.

Aquatain AMF is a silicone-based liquid which self-spreads across the surface of standing water, forming a very thin film and blocking the mosquito breeding cycle for 4 weeks.

Trials around the world have confirmed its effectiveness on anopheles (malaria-carrying) mosquitoes, as well as on other species including the aedes and culex mosquitoes.

As Aquatain AMF has a physical action rather than a chemical action, and does not contain any toxic chemicals, we urge you to consider it as part of your mosquito control program. In this way, many lives will be saved and the economy of Africa will benefit.
A New Way To Target Malaria in Africa

Introduction
350 million to 500 million cases of malaria occur annually. The disease is endemic in 107 countries and territories and threatens nearly 40 percent of the world’s population. If we are to change these statistics working together to slow the spread of malaria is a burden we all must share.

Forty six African countries were afflicted with malaria in 2009 and, of these, 21 countries had more than 1 million cases. At the top of the scale, Uganda recorded 12 million cases, and Kenya and The Democratic Republic of the Congo each recorded about 8 million.

An economic, health and social burden
Malaria robs the wealth of a country through the strain it places on the health system. In an economic assessment of the impact of malaria by the World Health Organisation (WHO), it is estimated that malaria can decrease the GDP growth by as much as 1.3% in countries with high disease rates. This would be equal to more than $15 billion based on the GDP of all African countries in 2009.

Additionally the physical and mental effects of the disease – blurred vision, fatigue, body aches, weakness and the inability to concentrate – reduce a person’s productivity level. For farmers this means fewer days in the field, leading to fewer crops and smaller harvests. For young people, malaria means fewer days in school, poor performance in class and a greater chance of dropping out.
**Mosquito Control – traditional methods**

During the past 50 years, vector control in Africa has focused almost exclusively on adult control – insecticide treated bed nets and insecticide fogging and indoor residual spraying. These methods are self-limiting and are not working. Why?

- Vectors are showing increased resistance to the chemicals used to treat the treated bed nets and spray the surfaces inside the homes where mosquitoes rest during daylight hours.
- Bed nets do not protect against outdoor biting vectors
- Discomfort – bed nets are uncomfortably hot to sleep under and many families simply choose not to use them
- Cost – many people cannot afford the associated cost
- The parasite responsible for Malaria is showing increased resistance to the drugs used to protect against and treat Malaria.

**Mosquito Control - A new approach**

If we are to change these statistics we **MUST** take a new approach. As well as targeting adult mosquitoes, it is vitally important to target the larvae and pupae – the juvenile stages of the mosquito which carries the deadly malaria parasite.

By controlling the mosquito larvae and pupae, stopping the mosquitoes breeding and preventing the emergence of adult biting mosquitoes, we can slow the transmission of malaria and begin to see a change in Africa.

**Aquatain AMF** is a silicone based surface film. It is effective in totally blocking the mosquito lifecycle in the aquatic phase. Once applied to the water surface it spreads quickly across the entire surface of the water (even around debris and vegetation), and prevents the immature stages of the mosquito from attaching their breathing tube to the under-surface of the water. The breathing tube becomes flooded with water and the larvae and pupae drown.

*By working together today we can make a difference for tomorrow.*
Aquatain AMF

How does it work?
Aquatain AMF has a physical action rather than a chemical action – no toxic chemicals!
The thin film on the water surface kills immature mosquito stages and disrupts the mosquito lifecycle.
A very simple principle, but a highly effective product.

How is Aquatain AMF applied?
No spray equipment required!
Simply apply directly onto the water surface (1ml per square metre).
Repeat application in 4 weeks.

Where can it be used?
Aquatain AMF can be safely used wherever mosquitoes breed. For example – blocked drains, discarded tires, pot plant bases, water tanks and dams. It can also be used in rice irrigation, large swamps and flooded fields.

How effective is it?
Independent trials both in Australia and international locations such as Uganda, Mexico and Sri Lanka have shown Aquatain AMF to be 100% effective in killing the immature stages of the mosquito and blocking the mosquito life cycle.
Aquatain AMF has been independently trialed by Universities, Health Ministries and other institutions, throughout the world including Australia, Uganda*, Sri Lanka*, Jamaica* and Singapore.

All trials have confirmed its rapid effectiveness in killing the mosquito larvae and pupae and blocking the mosquito lifecycle. Aquatain AMF also hinders oviposition (Egg laying).

*See Appendices 2, 3, 4

**TRIAL RESULTS**

- 100% mortality of L3, L4 larvae in 1-3 days
- 100% suppression of pupation
- 100% mortality of pupae within 3 hours
- AMF film discourages egg laying
**Excerpts from the trials**

<table>
<thead>
<tr>
<th>Country</th>
<th>Excerpts</th>
<th>Authors</th>
</tr>
</thead>
</table>
| Australia | “After 48hrs there was a marked difference in the quantity of egg rafts and dead adult mosquitoes in the treated and untreated oviposition cups with no egg rafts present in treated cups.”  
“Mean mortality of *Cx. quinquefasciatus* pupae in treated containers reached 94.7% after 60min and rising to 100% after 120min” | Dr. C. Webb and Dr. R. C. Russell from the Department of Medical Entomology, ICPMR and University of Sydney. |
| Singapore | “The study showed that AMF was able to control *Aedes aegypti* and *Culex quinquefasciatus* mosquito effectively in stage of larvae, pupae and oviposition.”  
“AMF was observed to cause no impact to non-target aquatic life. No signs of poor health were indicated from the aquatic life.” | Singapore Polytechnic                                                                                                                    |
| Venezuela | “AMF Aquatain the liquid film carried an efficient physical control of mosquito larvae *Aedes aegypti*, generating a 100% mortality on the fifth day of treatment with the silicon.” | Dr. M. Reyes-Lugo and Prof. Agregado from the Institute of Tropical Medicine of Central University of Venezuela |
| Sri Lanka | “100% mortality of the larvae were observed in the test area”  
“No mortality of fish or water snails were observed” | Dr. I. S. Weerasinghe, Entomologist from the Department of Entomology of the Medical Research Institute in Sri Lanka |
| Netherlands | "Aquatain has an advantage over Arosurf® MSF and Agnique® MMF due to its persistent spreading feature even around vegetation"  
"Aquatain AMF assures no adult emergence by its larvicidal and pupicidal effect as well as by preventing the inoculation of the breeding site with more eggs" | Dr. T. Bukhari, and A. Prof. B.G.J. Knols of Wageningen University |
| Jamaica   | “Both the lab and field results indicated that the product is effective in killing mosquitoes of the *Aedes aegypti* and *Culex* species.” | S. B. Grizzle and S. Huntley from the Vector Control Programme of the National Public Health Laboratory in Jamaica |
| Uganda   | “... the Ministry of Health is requested to plan quickly to start using Aquatain AMF for Malaria vector control in the Republic of Uganda.” | Dr Ndyomugyenyi, Programme Manager of the National Malaria Control Programme in Uganda |

This is what some of the researchers who did the trials had to say.
Environmental Aspects

Toxicology

Studies conducted on marine and fresh water fish showed no acute or sub-acute toxicity.

Research on bird toxicity showed no effect on survivability, egg laying, egg quality, hatchability or chick vitality even under highly exaggerated conditions of exposure.

No effect on the activity of aerobic and anaerobic microorganisms such as bacteria, fungi and phytoplankton.

Fate in Soil & Water

The product does not dissolve in water; it is naturally removed from water as a component of sludge.

The natural degradation result in a silicate by-product, which is already present in nature as sand.

Safety

Aquatain AMF is safe for addition to drinking water used for human consumption. Aquatain AMF is both eco-friendly and non-toxic.

It contains no petrochemicals, no alcohols and no isopropanol. Aquatain AMF has been extensively tested and certified to ANSI Standard 60 for addition to drinking water storages.

See Appendices 5, 6, 7 and 8.
Aquatain Products Pty Ltd – who are we?

Aquatain Products Pty Ltd is pioneering unique liquid silicone technology and has developed a portfolio of products specifically designed and engineered to address some of the most serious global challenges faced in the 21st century. Mosquito borne disease is emerging as an issue which is at the top of the agenda in government and corporate circles alike.

With a base in Melbourne, Australia, Aquatain Products Pty Ltd is a global supplier of high quality and innovative eco-friendly solutions to a large and diverse group of customers worldwide. We have built a strong and reliable production business in Australia. Our customer base includes Australia, The Caribbean, Sri Lanka, Singapore and the United Arab Emirates, and we are further developing and expanding our business throughout North, Central and Latin America, The Western Pacific and Asian regions.

Aquatain Products Pty Ltd is committed to sustainability and environmental conservation

Graham Strachan is the Director of Aquatain Products Pty Ltd. Graham has degrees in Civil Engineering and in Economics from Melbourne University. His career has spanned executive positions in the Federal Public Service, as well as in the private sector.

Kristy Parkinson is the Special Projects Manager. She is a Clinical Biochemist and has worked extensively in the medical diagnostics field. Kristy’s specialty areas include Immunology, Toxicology and Clinical Trials.

Tim Wong is the Special Projects Officer. He has a bachelor degree with Honors in Materials Engineering and is currently completing his Ph.D. in Materials Science at Monash University. Tim has a background in functional materials and metallurgy.
Conclusion – where to from here?

Malaria ranks in the top 3 of the most serious health and developmental challenges facing most of the poorest countries in the tropical and sub-tropical regions of the world. Malaria threatens almost 40 percent of the world’s population and affects hundreds of millions of men, women and children every year. 80 percent of those infected live in Africa.

To date malaria has been fought by spraying with toxic insecticides, sleeping under bed nets and through the use of drugs. Despite these efforts the malaria statistics are slowly improving in some countries. Mosquitoes are showing increasing resistance to insecticides used to control the mosquito responsible and the malaria parasite is now developing resistance to the drugs that were once an effective treatment.

New control strategies are urgently needed

In view of international initiatives to develop and deploy alternative products and methods of control, Aquatain AMF should be a vital part of your Malaria Control Program

Aquatain AMF has no adverse effect on water quality. It is environmentally friendly and does not pose a threat to biodiversity. As it is certified for use on drinking water, in addition to large vegetated breeding sites, Aquatain AMF is also suitable for the control of mosquitoes in breeding sites in both rural villages and urban environments. It can be safely used on water used as a source of drinking water or for other domestic purposes.

Aquatain AMF has a vital role to play in the control of malaria in Africa, and we urge you to consider the product as part of your malaria control program.
APPENDIX 1 - AQUATAIN AMF TECHNICAL DATA

Details of formulated product:

<table>
<thead>
<tr>
<th>Physical form</th>
<th>Liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Colourless</td>
</tr>
<tr>
<td>Boiling Point</td>
<td>&gt;65°C (149°F)</td>
</tr>
<tr>
<td>Flash point, open cup</td>
<td>&gt;101°C (214°F)</td>
</tr>
<tr>
<td>pH</td>
<td>6.25</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.97 (25°C/77°F)</td>
</tr>
<tr>
<td>Chemical stability</td>
<td>Hazardous polymerization will not occur. Strong oxidizing materials could cause a reaction – avoid contact</td>
</tr>
<tr>
<td>Product stability</td>
<td>Stable for not less than 2 years</td>
</tr>
</tbody>
</table>

Physical and chemical properties of the active ingredient:

<table>
<thead>
<tr>
<th>CAS registry number</th>
<th>63148-62-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common name</td>
<td>Silicone, polydimethylsiloxane (PDMS)</td>
</tr>
<tr>
<td>Chemical class</td>
<td>Siloxanes</td>
</tr>
<tr>
<td>Chemical name</td>
<td>Dimethyl-oxo-silane</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Structural formula</td>
<td>(CH3)SiO[SiO(CH3)2]nSi(CH3)3</td>
</tr>
<tr>
<td>Appearance</td>
<td>Colourless liquid</td>
</tr>
<tr>
<td>Colour</td>
<td>5(APHA), colourless</td>
</tr>
<tr>
<td>Melting Point</td>
<td>-26°C (-15°F)</td>
</tr>
<tr>
<td>Corrosiveness</td>
<td>NIL</td>
</tr>
<tr>
<td>Water partition coefficient</td>
<td>&gt;11Kow, high</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>0.97 (25°C)</td>
</tr>
</tbody>
</table>

Labelling:
Package labeling will conform to the requirements of the relevant authorities supplying safety, handling use and disposal information.

Disposal:
Under normal circumstances it could be expected that the container would be held by the customer until empty. Empty containers require no special disposal wrapping with paper and putting in garbage is all that is required. Containers are not to be reused for any purpose. Empty container should be disposed of in garbage.
APPENDIX 2 – UGANDA MINISTRY OF HEALTH FIELD TRIALS*

Introduction
The malaria problem in Uganda is too widespread to be solved by medical treatment alone. The Ministry of Health is committed to strengthen the Malaria Vector Control Program by adding the control of larva to the existing control methods of ITNS and IRS which target only the house dwelling adult mosquitoes. The aim of this field test was to determine the efficacy of Aquatain AMF on naturally occurring breeding sites of Anopheles and Culex mosquitoes.

Facilitators
The field test was conducted by the Uganda Ministry of Health Officers (Tom Byembabazi, Badru Mukasa, Uwineza Ernestine, Dramule Patrick, Kabodhogo Daniel) under the supervision of senior staff from the National Malaria Control Programme.

Trial Date and Location
Field test test took place in February 2010 in two districts: Wakiso (Kajjansi, Kakiri and Kasangati), Kampala (Kimwanye, Makindye and Kampala Central).

Types of mosquito species present
Anopheles and Culex species.

Results
Test in all locations were 100% effective against both Anopheles and Culex species. All larvae were dead within 12 hours post application of Aquatain AMF.

1. Checking for the presence of larvae in stagnant water
2. Applying Aquatain AMF to infested water

*Full trial report available on request
APPENDIX 3 – Sri Lanka Medical Research Institute Field Trials*

Introduction
The Department of Entomology at the Medical Research Institute in Sri Lanka undertook field trials to assess the efficacy of Aquatain AMF against mosquitoes naturally breeding in a polluted canal in the capital city, Colombo.
Larval monitoring was carried before and after the application of Aquatain AMF and was continued for 4 weeks post application. In addition to the mosquito larva, large numbers of fish, water snails and other water insects were found in both the control and treated areas.

Facilitators
The field trial was conducted by the Medical Research Institute of Sri Lanka. Dr I.S. Weerasinghe, senior Medical Entomologist supervised this field test.

Trial Date and Location
The field trial began 6th November 2009 and continued for 5 weeks. The selected site was the St Sebastian Canal Aluthkade, Colombo.

Types of mosquito species present
The larvae present at the time of the field trial were identified as Culex quinquefasciatus (Filariasis vector).

Results
Day 1 after application: 100% mortality of the mosquito larvae was observed in test site, but no reduction in the control site.
Week 1 and 2: 98% reduction of mosquito larvae in treated area
4 weeks following application: 91% reduction in mosquito larvae observed.

*Full trial report available on request
APPENDIX 4 –Jamaica Ministry of Health Field Trials*

Introduction
The Vector Control Programme unit of the Jamaican National Public Health Laboratory undertook laboratory and field trials to assess the efficacy of Aquatain AMF against mosquitoes naturally breeding in the parishes of St. James, Clarendon, St. Ann, Westchester, and Portmore. The purpose of the study was to determine the efficacy and residual activity of Aquatain AMF on both Aedes Aegypti mosquitoes and Culex Sp. Mosquitoes, which are responsible for the transmission of dengue fever, chikungunya, yellow fever and west nile virus.

Facilitators
The tests were done by Syddonna Brown Grizzle and Marlon Stephens of the Vector Control Programme of the Jamaican National Public Health Laboratory. The report was written by Syddonna Brown Grizzle and reviewed by Sherine Huntley.

Trial Date and Location
The first test on the Aedes Aegypti mosquito collected at Clarendon, St.James and St Ann took place in December 2009. The second test on the Culex Sp. Was done in April 2010 at Westchester drain, Portmore, and St. Catherine

Types of mosquito species present
Aedes Aegypti and Culex mosquitoes.

Results
Both the lab and field results indicated that the product was effective in killing mosquitoes of the Aedes aegypti and Culex species. The product was most effective after twenty four hours giving a mortality rate of approximately ninety percent (90%) in the case of the Aedes aegypti mosquito larvae. The product had a similar effect on the Culex mosquitoes after three days.

*Full trial report available on request
APPENDIX 5 – National Aquatic Resources Research and Development Agency (NARA)*

Introduction
The National Aquatic Resources Research and Development Agency of Colombo, Sri Lanka undertook laboratory trials to assess the impact of Aquatain AMF on selected fish and aquatic plant species. The test included edible fish species such as *Tilapia mossambicus* and *Labeo rohita*, and endemic fish species such as *Puntius cumingi* and *P. nigrofaciatus*. Endemic aquatic plant *Cryptocoryne wendity* was selected for the experiment.

Facilitators
The tests were done by a NARA research team composed of Dr. H. M. P. Kithsiri, Dr. P. K. M. Wijegoonawardena, Dr. Vasantha Pahalawattarachchi, G. R. Hemali Rupika, and Ranitha Laxmi.

Trial Date and Location
The test were done in 2010 at the National Aquatic Resources Research and Development Agency on Crow island in Colombo Sri Lanka.

Types of mosquito species present
None

Results
It was found that the application of Aquatain AMF has no adverse effect on the wellbeing of the fish and plants involved in the experiment.

*Full test report available on request
Degradation of Silicone Polymers in Nature

Many consumer products containing silicone polymer, or polydimethylsiloxane (PDMS), are used in a fashion which allows them to enter municipal wastewater treatment plants. Because PDMS is so insoluble in water, it partitions onto the sludge, causing no adverse effect on the operations of the treatment plant [1]. The sludge is then either destroyed by incineration, entombed in a landfill, or spread out on golf courses, woodlands, and agricultural fields as a fertilizer. This latter disposal technique allows PDMS to enter the soil environment.

In soil, the PDMS polymer can hydrolyze to small, water soluble silanols [2, 3, 4], with the ultimate product being the monomeric dimethylsilanediol (DMSD) [4, 5]. This hydrolysis is probably abiotic, because it can take months to years in wet soil, but only days as the soil dries [3, 6]. The phenomenon has been documented in a wide range of soils throughout the U.S. [7] and in 12 common soil minerals [6], meaning that the catalyst is widespread in nature. Although these experiments were done with pure PDMS, the incorporation of PDMS into sludge does not prevent the hydrolysis. It does, however, make the process more gradual [9], possibly because the PDMS must first diffuse out from the sludge before it can contact the soil surfaces and begin hydrolyzing. If the sludge is first composted, PDMS will remain intact with no effect on the composting process [10], and will then degrade after the compost is mixed in with soil.

The hydrolysis product, DMSD, can microbially degrade to CO₂ [5, 11, 12] and inorganic silicate [13], the latter of which should merge with the silicate already present in the soil [14]. The production of CO₂ from DMSD degradation varied from 0.4-1.6% per week [11]. In addition, DMSD volatilizes from soil at about 1-7% per week [15], with the higher losses occurring from sandy soils. These loss mechanisms suggest that DMSD will not persist in the soil environment. For example, only small amounts of DMSD were found in soils following the hydrolysis of sludge-amended PDMS [9], while an extensive program of field monitoring has found less DMSD than expected in sludge-amended soils showing loss of PDMS [16].

Once in the atmosphere, DMSD is expected to degrade by sunlight-induced reactions, much like other volatile siloxanes [17, 18, 19]. If it is instead washed out of the air in rainfall, DMSD can be oxidized in water by a similar sunlight-induced reaction [20], or it can be microbially oxidized in soil [5]. Downward movement through the soil profile is not expected because it was not observed in agricultural microcosms during PDMS degradation [9]. Moreover, neither PDMS nor its degradation products harmed soil microorganisms or affected the growth of wheat and soybeans [21].

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Degradation of Silicone Polymers in Nature

The above concepts were tested in field plots sprayed with PDMS emulsions [22]. Extensive losses of PDMS (half-lives of 1-2 months), coupled with dramatic decreases in molecular weight, were observed during a typical Michigan summer season. Only small amounts of DMSD (corresponding to <5% of the original silicone) were found, and deeper sampling revealed that the DMSD had not simply moved downward in the soil profile. This result is thus consistent with laboratory studies showing polymer hydrolysis followed by biodegradation and/or volatilization of the monomer to natural components (CO$_2$ and inorganic silicate). The overall reaction is:

$$\text{Me}_3\text{SiO(SiMe}_2\text{O)}_n\text{SiMe}_3 \xrightarrow{\text{Soil}} \text{Me}_3\text{Si(OH)}_3 \text{, followed by DMSD}$$

$$\text{Me}_2\text{Si(OH)}_2 \xrightarrow{\text{Microbes or light}} \text{CO}_2 + \text{Inorganic Silicate}$$

An apparent contradiction to the degradation of silicones in nature is that these polymers are used for many outdoor applications because of their stability to high temperatures and their resistance to UV and O$_2$ exposure. This stability during the polymer's intended use is a bulk phenomenon. However, when PDMS is disposed down-the-drain and is eventually applied to the soil as a component of sludge, it becomes dispersed at low concentrations on soil minerals. This allows the PDMS to contact the catalysts needed to begin its depolymerization, which eventually results in its complete conversion to natural components. The conclusions in this fact sheet are being further examined in an ongoing program of laboratory and field research.
Polydimethylsiloxanes Do Not Bioaccumulate

Why are there Concerns about Bioaccumulation?

Bioaccumulation is the process where a substance is taken into a living organism, either from the water or through food, and steadily increases in concentration (bioconcentrates) as it is stored in the tissue [1]. As an example, a substance may enter a fish directly from the water through the gills, or as a result of the fish eating a worm or insect which contains the substance. The substance may thus be transferred up the food chain and increase in concentration (biomagnify) with each step until, for "top-predators" including humans, it may reach a toxic concentration.

The most likely substances to bioaccumulate are those which are poorly soluble in water, but which are highly soluble in the fatty (lipid) tissues of fish and other organisms. These materials have a strong tendency to partition from water to an organic solvent such as octanol, which serves as a model for fish lipids. They are thus described as having a high octanol-water partition coefficient (K<sub>ow</sub>). Due to its very low water solubility [2,3], PDMS (polydimethylsiloxane) has a high octanol-water partition coefficient which increases with increasing molecular weight. For example, the log K<sub>ow</sub>s of PDMS polymers of molecular weight 1050, 1124, and 1198 are (respectively) 11.3, 11.9, and 12.5 [4]. It is thus reasonable to ask whether PDMS can bioaccumulate.

Definition of PDMS

PDMS is a shorthand notation for polydimethylsiloxane. It has the structure Me<sub>n</sub>SiO(Me<sub>n</sub>SiO)<sub>3</sub>SiMe<sub>n</sub>, where Me = methyl groups and n varies from ~15 for small polymers with a viscosity of 10 centistokes, to ~1000 for large polymers of 100,000 centistoke viscosity. PDMS is thus a family of large, linear polymers with viscosities ≥ 10 centistokes, molecular weights ≥ 1000 [5], and with essentially no water solubility [2,3] or volatility [3]. They represent an estimated 90% of the linear dimethylsiloxane fluids sold by Dow Corning, and they are the focus of this Update. The other ~1% are low molecular weight dimethylsiloxanes; these materials are volatile and should partition to the atmosphere, where they will degrade in sunlight [6].

The Importance of Molecular Weight

In order for a substance to bioaccumulate, it must be taken into the tissues of a living organism. This means that the substance must first pass through a biological membrane, such as the membranes which line the intestinal wall or the gills. The size of a molecule is important in determining whether it can physically pass through the membrane.

A major principle in bioaccumulation is that molecules which are above a molecular weight of about 600 are too large to cross biological membranes and thus do not bioaccumulate in living organisms [7,8].
Polydimethylsiloxanes Do Not Bioaccumulate

Environmental Information - Update

This principle was confirmed by Annelin and Frye [9], who showed that a dimethylsiloxane of ~ 600 molecular weight was not absorbed by the fish [9]. Opperhuizen et al [10] reached a similar conclusion, and showed that after fish had eaten food amended with PDMS (molecular weight > 1000), they did not absorb the PDMS but excreted it within 3 days. As a third example, Bruggeman [4] reported a molecular weight of ~850 above which dimethylsiloxanes should not be absorbed. The difference in cutoff values for the three studies (molecular weights of 600 vs. 850 vs. 1000) probably reflects different experimental techniques used by the three research groups, but a conservative view indicates that PDMS fluids (molecular weight > 1000) cannot pass through biological membranes, and therefore will not bioaccumulate.

Exposure Routes for PDMS

Many consumer products contain small amounts of PDMS. Normal use of these products allows them to enter municipal wastewater treatment plants, in which the insoluble PDMS partitions almost completely to the sludge [11]. The majority of the sludge is either incinerated, landfilled, or added to land as a fertilizer, and thus the major mode of entry of PDMS into the environment is to the soil, where it degrades to natural components [5, 12]. However, small particles of sludge can escape the treatment plant through the effluent, carrying trace amounts of PDMS to surface waters [13], where the PDMS sludge sinks to the sediments and is in contact with aquatic organisms.

Aquatic Organisms

The fact that PDMS is so insoluble in water means that it readily partitions to the sediments. Kukkonen and Landrum [14] thus studied aquatic worms which live in the sediments and found that PDMS did not bioaccumulate in these worms. Similarly, when midge larvae were raised in sediments containing PDMS, they showed no ability to bioaccumulate PDMS [15].

Other experiments have attempted unsuccessfully to dissolve PDMS in water to test bioaccumulation from the water column. For example, Watanabe et al. reported that fish in laboratory studies could take up PDMS from water [16], but in the actual environment they could find no evidence of silicone uptake in fish above silicone contaminated sediments in Japan [17]. This discrepancy was explained by Annelin and Frye [9] as adsorption of floating PDMS globules (in laboratory experiments) to the outside of the fish. To avoid this problem, they washed the outside of their fish and found no bioaccumulation of a dimethylsiloxane (molecular weight ~ 600) by either rainbow trout or fathead minnows [9]. Similarly, no uptake or bioaccumulation of PDMS from the water was found in bluegill sunfish [18], while exposure of guppies to PDMS-amended fish food resulted in no absorption or bioaccumulation of PDMS [4]. Another study showed that when guppies and goldfish were fed PDMS-amended food, the PDMS passed through the gastrointestinal tracts of the fish and was soon eliminated from the body, resulting in no bioaccumulation [10].

Other investigators have added PDMS (as an aqueous emulsion) to seawater to test the potential for PDMS to be transferred up the food chain [19, 20, 21]. They showed that PDMS did not bioconcentrate in plankton, the lowest level of the food chain. In addition, organisms which fed on the plankton, including sediment-dwelling worms, crustaceans (which fed on the worms), filter-feeding molluscs, and fish (both bottom-feeding and open-water), often contained PDMS at even lower concentrations than in the plankton, thus showing no food chain transfer (no biomagnification). PDMS was also judged to have a very low, if any, acute toxicity to these various species.
Environmental Information - Update

Terrestrial Organisms

When 14C-labeled PDMS was added in a sludge to soil microcosms (10 ppm) in which soybeans and wheat were grown to maturity in a greenhouse, the PDMS was not taken up into the plants. Trace amounts (1-2% of the 14C), however, may have been taken up as the soil degradate, 14C-dimethyldisiloxanediol, or sorbed as 14C-PDMS to the outside of the plant shoots during the course of the study [22]. The plants grew well and produced a good crop with no harm from the PDMS [23]. The wheat grain had no 14C in it, and the amount of (unidentified) 14C-tracer in the soybeans was so low (0.02%) that, even if it were PDMS or dimethyldisiloxanediol, no biomagnification could result from a human eating the soybean.

When earthworms were grown in organic soil amended with very high levels (100 and 1000 ppm) of PDMS, the earthworms ingested the PDMS during their normal course of ingesting the soil. The PDMS did not accumulate in the earthworms, but was instead eliminated with the soil within about 2 days [24].

Summary

In summary, PDMS fluids of commercial interest (i.e., linear dimethyldisiloxanes with viscosities ≥ 10 centistoke and molecular weights ≥ 1000) do not bioaccumulate in living organisms because they are too large to be absorbed by biological membranes.

For more information, contact Dr. Robert G. Lehmann at Health and Environmental Sciences, Dow Corning Corporation, Midland, MI 48666-0994, or Christine Stevens (tel. int. +32-(0)2-655.25.13), in Health, Environmental and Regulatory Affairs, Dow Corning Europe

References


*Full article available on request*