Thank you for taking the time to review this paper on Minimum Risk Pesticides, I think you will find it helpful and informative. I have been saving different articles and peer reviewed papers and thought I would bring the most pertinent data together in this paper, although many of the trials are in agriculture the information lends itself well to landscaping and organic land care. Some of this can get a bit technical but I think you will be able to compare results and understand them.

First what are Minimum Risk Pesticides? This is a designation by the EPA "Minimum risk pesticides are a special class of pesticides that are not subject to federal registration requirements because their ingredients, both active and inert, are demonstrably safe for the intended use." The EPA has created a list of mostly plant extracts (below) "The active ingredient of a product is the ingredient that kills, destroys, mitigates, or repels pests named on the product label."

25b exempt active ingredients (not a complete list)

Castor oil	Linseed oil	Cedar oil	Malic acid
Cinnamon oil	Mint and mint oil	Citric acid	Peppermint oil
Citronella	2-Phenethyl propionate	clove oil	Corn gluten meal
Garlic and garlic oil	Lemongrass oil	Eugenol	White pepper

Another interesting fact is the labeling law is much different than its chemical counterpart; here is a quote from the EPA site. "The label cannot include any false or misleading statements, and claims that minimum risk pesticides protect human or public health are prohibited. For example, since these products are exempt from federal registration, label language implying federal registration, review or endorsement, such as "It is a violation of federal law to use this product in a manner inconsistent with the label," or the use of an EPA registration or establishment number is not allowed."

So minimum risk pesticides will typically not have a CAS number (except in the MSDS) for you to keep in your records and will have no reference to EPA rules of labeling that is typical of chemicals, they also do not have the buffer issues with streams and lakes as the toxicity to mammals is almost nonexistent except in very large quantities. Although minimum risk pesticides are considered safe, cautions should still be taken not to inhale fine sprays, wash after applications, common sense safety measures should be taken by you and your crews. A term you will also see used by the EPA is "Generally Regarded As Safe" or GRAS.

Let's get to the meat of the subject, below is general information and testing data to give you an idea of how they work, why we would use them and what is considered a lethal dose (LD50) and lethal concentration (LC50)

One of the reasons residual and toxicity issues of pesticides have been so acute lately is from a USGS study done on over 5000 locations across the country from 1992 to 2001 and updated in 2005.Released in 2007 the study tested water, sediment and fish in bodies of water all over the country, the testing results showed that 97% of the water tested contain at least one pesticide, 25% tested contained 10 or more with 11% of the water tested above human consumption levels, the full report is here - http://pubs.usgs.gov/circ/2005/1291/

Essential Oils as Green Pesticides: Potential and Constraints, OPENDER KOUL
The environmental problems caused by overuse of pesticides have been the matter of concern for both scientists and public in recent years. It has been estimated that about 2.5 million tons of pesticides are used on crops each year and the worldwide damage caused by pesticides reaches $100 billion annually. The reasons for this are two fold: (1) the high toxicity and nonbiodegradable properties of pesticides and (2) the residues in soil, water resources and crops that affect public health. Thus, on the one hand, one needs to search the new highly selective and biodegradable pesticides to solve the problem of long term toxicity to mammals and, on the other hand, one must study the environmental friendly pesticides and develop techniques that can be used to reduce pesticide use while maintaining crop yields. Natural products are an excellent alternative to synthetic pesticides as a means to reduce negative impacts to human health and the environment. The move toward green chemistry processes and the continuing need for developing new crop protection tools with novel modes of action makes discovery and commercialization of natural products as green pesticides an attractive and profitable pursuit that is commanding attention. The concept of "Green Pesticides" refers to all types of nature-oriented and beneficial pest control materials that can contribute to reduce the pest population and increase food production. They are safe and ecofriendly. They are more compatible with the environmental components than synthetic pesticides (Isman and Machial, 2006).

Recent investigations indicate that some chemical constituents of these oils interfere with the octopaminergic nervous system in insects. (the octopaminergic nervous system are the neurons that carry the electric pulse within the nervous system) As this target site is not shared with mammals, most essential oil chemicals are relatively non-toxic to mammals and fish in toxicological tests, and meet the criteria for "reduced risk" pesticides. Some of these oils and their constituent chemicals are widely used as flavoring agents in foods and beverages and are even exempt from pesticide registration. This special regulatory status combined with the wide availability of essential oils from the flavor and fragrance industries, has made it possible to fasttrack commercialization of essential oil-based pesticides. Though well received by consumers for use against home and garden pests, these "green pesticides" can also prove effective in agricultural situations, particularly for organic food production. Further, while resistance development continues to be an issue for many synthetic pesticides, it is likely that resistance will develop more slowly to essential-oil-based pesticides owing to the complex mixtures of constituents that characterize many of these oils. (et al Koul, 2008)

In Table 1 you can see the LD50 for mammals; in most cases extremely high doses are needed. Although regarded safe these plant extracts at extremely high rates can be toxic to mammals, so we should treat minimum risk pesticides with the respect that they deserve (notice milligram/kg instead of microgram)

Table 1. Mammalian toxicity of some essential oil compounds

Compound	Animal tested Route	LD50 (mg/kg)
2-Acetonaphthone	Mice Oral	599
Apiol	Dogs Intravenous	500
Anisaldehyde	Rats Oral	1510
trans-Anethole	Rats Oral	2090
(+) Carvone	Rats Oral	1640
1,8-Cineole	Rats Oral	2480
Cinnamaldehyde	Guinea pigs Oral	1160
	Rats Oral	2220
Citral	Rats Oral	4960
Dillapiol	Rats Oral	1000–1500
Eugenol	Rats Oral	2680
3-Isothujone	Mice Subcutaneous	442.2
d-Limonene	Rats Oral	4600
Linalool	Rats Oral	> 1000
Maltol	Rats Oral	2330

Here is data from Journal of Economic Entomology testing 3 different sources of cedarwood oil on mosquitoes, ticks and fleas, what surprised me about this data is the concentrations that are lethal to these pests, lethal concentration in almost every case is well below 1%

Table 1.	**Susceptibility of mosquitoes, ticks, and fleas to three wood-derived essential oils after 24-h exposure**					
Test species	Essential oil	Slope : SEM		Concn (mg/ml)		
			LC50	95% CI LC90		95% CI
Ae. aegyptib	Incense	4.28 : 0.31	0.005*a*	0.002, 0.007	0.047	0.039, 0.054
	Port-Orford	1.69 : 0.91	0.051	0.003, 0.06	0.17	0.08, 0.24
	Western juniper	2.32 : 1.12	0.041	0.02, 0.05	0.11	0.09, 0.21
I. scapularis	Incense	2.69 : 0.24	0.096*a*	0.079, 0.1	0.29	0.23, 0.38
	Port-Orford	1.32 : 0.12	0.31	0.16, 0.53	2.68	1.75, 7.79
	Western juniper	1.39 : 0.12	0.29	0.24, 0.4	2.58	1.72, 4.43
X. cheopis	Incense	3.41 : 0.31	0.24*a*	0.09, 0.27	0.31	0.19, 0.39
	Port-Orford	6.11 : 0.81	1.21	1.01, 1.34	1.85	1.61, 3.34
	Western juniper	11.6 : 1.65	0.31	0.22, 0.26	0.93	0.28, 2.31

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Here is another table on efficacy on 3 different types of mosquitoes comparing essential oil concentrations to commonly used chemicals, although in some instances the chemicals were used in much smaller concentrations, resistance issues are not typical with essential oils, refer to RR values.

Table 1.	**Lethal doses for components of tree essential oils tested on *An. gambiae***					
Chemical	Mosquito strain	*N*	Slope (SE)	LD_{50} (95% CI, _g/mg)	LD_{95} (95% C, _g/mg)	RR
Thymoquinone	G3	370	0.002 (0.00021) 9.79	1.425 (1.277-1.570)	2.812 (2.546-3.198)	
	RSP-ST	413	(1.00)	0.933 (0.875-0.995)	1.865 (1.634-2.259)	0.65
	P+DLRC+R+	447	0.004 (0.0004)	1.170 (1.083-1.253)	1.950 (1.808-2.149)	0.82
	AKRON	381	0.0024 (0.0004) 4.88	1.507 (1.311-1.691)	2.712 (2.377-3.357)	1.06
Nootkatone	G3	441	(0.47)	1.460 (1.190-1.726)	5.861 (4.785-7.676)	
	RSP-ST	421	3.17 (0.33)	1.633 (1.335-1.954)	13.900 (9.655-23.705)	1.12
	P+DLRC+R+	382	1.53	2.089 (1.802-2.344)	5.039 (4.565-5.713)	1.47
	AKRON	406	0.0009 (0.0001)	2.502 (2.236-2.775)	5.636 (4.046-6.498)	1.71
Carvacrol	G3	308	0.0011 (0.0001) 8.15	2.649 (2.378-2.905)	5.283 (4.731-6.171)	
	RSP-ST	547	(0.72)	1.791 (1.675-1.908)	4.117 (3.631-4.888)	0.68
	P+DLRC+R+	421	12.28 (1.21)	2.031 (1.925-2.141)	3.526 (3.195-4.060)	0.78
	AKRON	368	9.57 (0.94)	2.088 (1.950-2.237)	4.238 (3.715-5.112)	0.79
Permethrin	G3	485	2.03 (0.33)	0.000214 (0.000130-0.000291)	0.00598 (0.00312-0.0203)	
	RSP-ST	365	2.72 (0.35)	0.00358 (0.00285-0.00442)	0.0432 (0.0260-0.0987)	16.42
Propoxur	G3	496	2.82 (0.24)	0.000719 (0.000590-0.00874)	0.00797 (0.00546-0.0132)	
	AKRON	379	3.79 (0.47)	3.628 (3.088-4.246)	25.079 (16.830-47.619)	5,046
Dieldrin	G3	485	0.47 (0.04)	0.00455 (0.00404-0.00503)	0.0108 (0.00981-0.0121)	
	P+DLRC+R+	536	3.10	6.104 (4.9267.622)	151.470 (91.920-296.225)	1,318

(the program used to paste the information into this sheet did not recognize the symbol for "micro" and put a question mark instead, apologies for not having the time to fix it before this paper was due)

Table 1 summarizes the results for all the tests. The LD50 value for thymoquinone ranged from 0.933 g/mg (confidence interval [CI], 0.875Đ0.995 g/ mg) in RSP-ST to 1.507 g/mg (CI, 1.311Đ1.691 g/ mg) in AKRON. The range of LD50 value for nootkatone was 1.460 g/mg (CI, 1.190Đ1.726 g/mg) in G3-2.502 (CI, 2.236Đ2.775 g/mg) in AKRON. The carvacrol LD50 value ranged from 1.791 g/mg (CI, 1.675Đ1.908 g/mg) in RSP-ST to 2.649 g/mg (CI, 2.378Đ2.905 g/mg) in G3. The LD50 value for permethrin was 0.000214g/mg in G3 and 0.00358g/mg in RSP-ST. Propoxur had an LD50 value of 0.000719 g/mg in G3 and 3.628 g/mg in AKRON, whereas for dieldrin the LD50 value was 0.00455 g/mg in G3 and 6.628 g/mg in P+DLRC+R+. Resistance ratios (RRs) were calculated for each compound tested. A ratio of <1 indicates the "resistant" strain is more susceptible than the "susceptible" strain; however, in this study all RRs were close to 1 for the tree oil components. The thymoquinone RR was 0.65, 0.82, and 1.06 in RSP-ST, D+DLRC+R+, and AKRON, respectively. Nootkatone RR was 1.12, 1.47, and 1.71, and carvacrol RR was 0.68, 0.78, and 0.79 for the same mosquito strains in the same order. This contrasts dramatically with the RRs calculated for the resistant strains and insecticides known to affect the target sites containing the mutations conferring resistance. Propoxur, a carbamate, inhibits acetylcholinesterase; dieldrin, a cyclodiene, acts by inhibiting GABA; and permethrin, a pyrethroid, works on the gated sodium channel (Ware 1991). The RR for permethrin in the RSP-ST strain with resistance to pyrethroids was 16.42. The RR for propoxur was 5,046 in the AKRON strain with organophosphate and carbamate resistance. The RR for dieldrin in the P+DLRCL+R+ strain with cyclodienes resistance was 1,457.

It was expected that if any of the three tree compounds, thymoquinone, nootkatone, or carvacrol, were affecting one of the target sites represented in the three resistant strains then a similar greatly increased RR would be observed. Because this was not the case and all resistance ratios were close to 1, it can be inferred that their mode of action is different from pyrethroids, organophosphates, carbamates, and cyclodienes. This represents a significant finding as these compounds may prove invaluable in maintaining our ability to control populations of mosquitoes that are resistant to currently available insecticides. However, formulations, best application methods and environmental studies still need to be conducted before they are commercialized and registered.

Here is a label from the company Brandt, it is their essential oil product for agriculture, ornamentals and turf. This is to give you an idea of the mode of action on one particular essential oil product

Broad Spectrum Insecticide Miticide

Paradox is a unique insecticide/miticide with two modes of action. Research has shown that the patented combination of essential oils in Paradox block octopamine neuroreceptors in insects and mites, and also provide a temporary covering to the pest's outer membrane leading to a smothering effect.

Octopamine regulates the insect's movement, heart rate, behavior, and metabolism. Blocking such receptors causes quick knockdown and death of the target insect. As an essential oil, a temporary covering of the insect's outer membrane with a spray of Paradox leads to suffocation of the pest. Paradox's natural origin provides the benefit of effective pest control combined with environmentally safe properties.

Derived from a patented blend of non-hazardous botanical oils, Paradox provides maximum control of insects with a minimum of environmental or human impact. An emulsifiable concentrate, Paradox will provide comparable results to that of conventional chemicals with virtually none of the hazards.

Let's look at some observational data on how long these applications persist.

Bioassays to determine residual activity of the most effective products were conducted at 1, 2, 4, and 6 wk after initial treatment. Residual LC50 values for nootkatone (cedarwood oil) did not differ significantly at 4 wk post-treatment from the observations made at the initial 24 h treatment. The ability of these natural products to kill arthropods at relatively low concentrations also represents an alternative to the use of synthetic pesticides for control of disease vectors (Panella et al., 2005; Dietrich et al., 2006).

The focus in this paper has been mostly on cedarwood oil and its efficacy, mode of action and residual, although there are over 130 other essential oils out there on the market that have different levels of efficacy and target pests. What I had hoped to do in this paper is dispel some of the myth about organic products that are out there like it doesn't work as well, you need twice as much, it's too expensive. By showing peer review and scientific data on efficacy, residual and application rates I am hoping to have cleared the air a little.

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The target pests for our own cedarwood oil product called CedarCure are below, if I can answer any questions that you may have about this product or any of our other products please contact me at bill@ictorganics.com or at the office at 410-997-5450
You can find our products on our website www.ictorganics.com if you also sell retail we have a complete retail line at www.EarthHarvestOrganics.com

Turf: White Grubs, Mole Crickets, Ants, Armyworms, Billbugs, Chinch Bugs, Crickets, Cutworms, Earwigs, European Crane Flies, Grasshoppers, Leafhoppers, Millipedes, Pillbugs, Sowbugs, Sod Webworms, Ticks, Fleas, and other turf pests.