October 5, 2007

Dear Ms. Lambert:

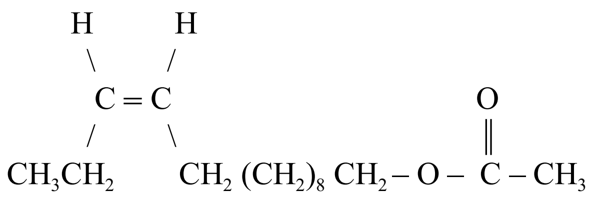
You asked me to review an article in the Friday, September 28, 2007, issue of the *Santa Cruz Sentinel*, which allegedly lists several of the components (ingredients) in the Checkmate products manufactured by Suterra and proposed by the California Secretary of Agriculture for aerial spraying to control the light brown apple moth. For the sake of the discussion here, I have commented on that list as well as information publicly available through Suterra's website (specifically, the material data safety sheets or MSDSs and the technical data sheets for the Checkmate products). I am concerned that some of the materials reported by the *Sentinel* as components may in fact not be components, and I have noted this below. The discussion is obviously contingent upon the correctness of the reported formulation. Since the formulation is regarded as confidential business information, proprietary, or a trade secret under various laws or regulations, I cannot be more specific.

A summary of my credentials may be helpful. I have a Ph.D. in chemistry from Purdue University and worked for the EPA's National Risk Management Research Laboratory for six years. My Ph.D. research was concerned with the equilibrium, kinetics, and mechanisms of chemical reactions. I have authored or coauthored about 40 papers in the peer-reviewed literature, mostly on the analysis of drinking water for trace and ultratrace contaminants and the fate and transformation of these contaminants in water and soil, including a number of review articles. In addition, I was formerly an associate editor of *Journal of Environmental Management* and a member of the International Advisory Board of *Journal of Environmental Monitoring*. My work on perchlorate chemistry is probably best known to most California environmental scientists, including editing a book, *Perchlorate in the Environment*.

I have represented the comments with bold-face, unitalicized Arabic numerals, as is one of the convention in the chemical literature. The first two compounds are reportedly the synthetic pheromones, which are the active principles.

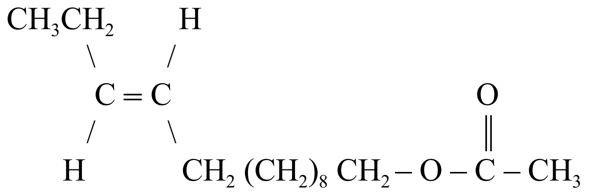
1: (*Z*)-11-tetradecenyl acetate, this is an active ingredient; it is on the *Sentinel's* list and in the manufacturer's MSDS)

2: (*E*)-11-tetradecenyl acetate, this is an active ingredient, but it is not represented correctly on the *Sentinel's* list (it is in the manufacturer's MSDS on its website)



$$\begin{array}{l} \mathrm{H}\quad\ \ \mathrm{H} \\ \ \ \backslash\quad / \\ \ \ \mathrm{C=C} \\ \ \ /\quad \backslash \\ \mathrm{CH_3CH_2}\quad \mathrm{CH_2\,(CH_2)_8\,CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3} \end{array}$$

Compound **1** (could also be named as *cis* because the two hydrogens are together)



$$\begin{array}{l} \mathrm{CH_3CH_2}\quad\ \ \mathrm{H} \\ \ \ \backslash\quad / \\ \ \ \mathrm{C=C} \\ \ \ /\quad \backslash \\ \mathrm{H}\quad \mathrm{CH_2\,(CH_2)_8\,CH_2-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3} \end{array}$$

Compound **2** (could also be named as *trans* because the two hydrogens are across)

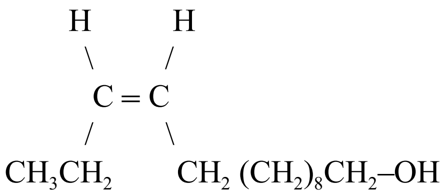
Compounds **1** and **2** are both on the manufacturer's MSDS. Note that compound **2** is missing from the *Sentinel's* list. The designations (*E*) and (*Z*) refer to the geometric isomers about the double bond that occurs at carbon 11 (hence, the locant 11). *E* stands for *entgegen* (German for opposite, meaning the higher priority groups are on the opposite sides of the double bond); *Z* stands for *zusammen* (German for together, meaning the higher priority groups are on the same side of the double bond). Carbon 1 is bonded to the acetate. Normally, only one of the geometric isomers has significant biological activity.

As a rule, we would not anticipate these types of esters to have significant physiological activity. Esters are one of the most benign functionalities. Glyceride fats are the esters of various fatty acids with the triol glycerine (also known as glycerol). It is called a triol because there are three –OH groups on it. Unfortunately, when esters hydrolyze, they are converted to the parent carboxylic acid and the parent alcohol. In this case, the parent carboxylic acid is acetic acid, which is extremely benign. At the concentrations that would be encountered from hydrolysis, this acetic acid exposure would be less than a drop of vinegar in glass of water. The article does not list acetate explicitly, but I believe this may be an error due to the way that compound **4** is listed. I would anticipate some acetic acid or sodium acetate to be present from the manufacturing process. However, it may be that the concentration is below a reportable limit or has not been measured.

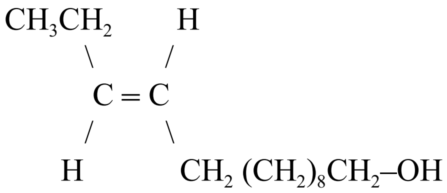
I suspect that the next two compounds (**3** and **4**) probably have very little effect on any light brown apple moth mating behavior; these types of long-chain alcohols can be repellent to insects. The locant 1 is superfluous; if omitted (along with its hyphens), the name would represent the same compound. The isomeric designation is required, however. Both **3** and **4** are leftover starting materials or hydrolysis byproducts. They would be treated as inert ingredients because they do not contribute to the activity of the product for its intended use, not because they are biologically or chemically inert in a more general sense. I have some concern that these alcohols, especially because of the alkene functionality, may exert some irritant effects on the mucosae, but there have been no studies done to support such an assertion so far as I know. I would suggest avoiding aerosols of these materials because of their extremely low solubilities. There are no OSHA permissible exposure limits or American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values, which makes it difficult to assess the physiological impacts of exposure. Also, risks from exposures are predicated on time-average values based on a combination of time and concentration. Therefore, it is difficult to extrapolate from the types of worker exposures for which the manufacturer recommends personal protective equipment to the types of exposures that would occur from the aerial spraying authorized by the California Secretary of Agriculture. Whether compounds **3** and **4** are in fact present as leftover starting materials in the formulation when applied is largely irrelevant because they will form as the active principles (**1** and **2**) hydrolyze (react with water).

3: (*Z*)-11-tetradecen-1-ol , this would be expected as a leftover starting material (but is not on the *Sentinel's* list)

4: (*E*)-11-tetradecen-1-ol, this should be a leftover starting material (However, it appears to be written incorrectly on the *Sentinel's* list as an acetate—the compound as named in the article cannot exist; I suspect the *Sentinel* may have reported commingled names of compounds **2** and **4**.)



Compound **3** (also *cis*)



Compound **4** (also *trans*)

The active ingredients are most likely synthesized via an esterification reaction between either compound **1** or **2** and acetic acid, CH_3CO_2H:

3 + $CH_3CO_2H \rightarrow$ **1** + H_2O (1)

4 + $CH_3CO_2H \rightarrow$ **2** + H_2O (2)

5: tricaprylylmethyl ammonium chloride, a detergent or dispersant (on the *Sentinel's* list, not in the MSDS)

$[CH_3(CH_2)_7]_3NCH_3^{(+)}\ Cl^{(-)}$

Compound **5**

The caprylyl group is better known as the octyl group, but the trivial name is still used industrially. *Caprylyl* is a throwback trivial name; caprylic acid is naturally produced as goat's milk becomes rancid since the milk is rich in octyl glycerides. The name refers to this fact; *caper* means goat. All of the mid- to long-chain quaternary ammonium compounds can act as a cationic surfactants. This particular choice seems kind of odd in that it is not an especially good detergent, but it would be low-foaming, so that may be the main reason it was selected. Spraying tends to generate foam, which would reduce the efficiency of the process, so a low-foaming surfactant would be preferable.

Caprylic (*n*-octanoic) acid has an acrid smell and is somewhat irritating, but I can think of no obvious mechanism by which it could produced here. On the other hand, 1-octanol (caprylol) would be produced by the hydrolysis of the quaternary ammonium cation. The reaction rate increases with increasing pH or temperature. At sufficient quantities, 1-octanol can be quite annoying. As with other alcohols with a chain length of 4–12 carbon atoms, the following can be stated: (1) it has an oily feel, (2) it is not especially soluble in water, (3) it has a somewhat sweet—but annoying—smell, and (4) it can exert tussive effects (promotes coughing) at higher concentrations. Some people are far more sensitive to it than others.

Most cationic surfactants naturally have some level of antimicrobial properties. These properties vary among organisms, and can be devastating to populations of some organisms. For example, *Pseudomonas aeruginosa* is relatively immune to their effects, and this can lead to overgrowths of pseudomonads as the competing bacteria are suppressed or killed. In addition, minor changes in surface tension brought about by surfactants can affect the more vulnerable crustacean zooplankton such as copepods or branchiopods (e.g., daphnids, brine shrimp). Although large scale fluctuations in population (major die-offs) are unlikely, localized disturbances could occur, especially in shallower estuarine waters or along shorelines, where there is a potential for a greater exposure.

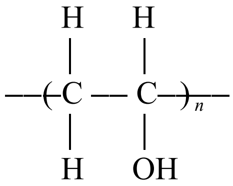
The significance depends partly on how much surfactant is present in the formulation. You say that you observed foaming after a rainfall. To cause foaming, the concentration of a surfactant has to be reasonably high (in terms of practices of surfactant usage)—usually high enough to expect impacts on vulnerable organisms, especially some types of aquatic life. As I will discuss below with phosphate, the watershed issue is one of total loading as well as the topology and hydrology that permit the rapid influx of stormwater run-off into surface waterways. Given the large regions proposed for spraying, the total surfactant loading appears to be significant and should be evaluated by persons with appropriate credentials in hydrology, soil attenuation, and watershed management.

6: sodium phosphate, a buffer to control pH (on the *Sentinel's* list, not in the MSDS)

Although the name used is sodium phosphate, the actual speciation would be distributed among a mixture of the various conjugate acid-base pairs so as to serve as a buffer. One would expect the solution to be buffered to a slightly acidic pH (maybe 5–6) to avoid alkaline hydrolysis. In that case, the distribution would be dominated by $H_2PO_4^-$ and HPO_4^{2-}, which would be present at much higher concentrations than either H_3PO_4 or PO_4^{3-}. These materials are entirely harmless to humans at the exposure levels that could be reached via aerial spraying.

On the other hand, if the concentrations are sufficiently high, there could be ecological consequences for the watershed. I do not know what the phosphate concentrations are in the product, but it is important to remember that the amount of hard surface (parking lots, building roofs, roadways) that will be exposed is high. Even though the product is substantially diluted, vast areas of impermeable surface will be covered with phosphate. During a rain storm, this soluble phosphate is rapidly mobilized and carried into storm sewers and open waterways. I am unfamiliar with the civil engineering structures used to control, contain, and divert stormwater in the Monterey County region, so soil sorption and soil microbe consumption are possible mitigating factors. Nonetheless, I can say that it would be unfortunate if a significant phosphate bolus were delivered to any natural waterway because phosphate is associated with eutrophication. Certainly, the total loading and (hydrological) rate of loading of phosphate to the watershed must be carefully considered for possible impacts. High available phosphate in a watershed can lead to severe algal blooms and sometimes to secondary adverse ecological effects (mainly die-offs of marine life, e.g., shrimp, bivalves, fish). In addition, these blooms create aesthetic and sanitary problems (e.g., algal mat wash-up and malodorous algal rot). In the 1960s and 1970s, problems with algae and foaming were associated largely with phosphate-laden municipal sewage effluents resulting from the use of laundry detergents containing phosphate builders. Agricultural run-off was implicated to a lesser degree. It is wise to remember that phosphates have been almost completely eliminated from laundry detergent formulations for ecological reasons, thus putting a stop what was termed the "cultural eutrophication" of rivers and lakes in the United States.

7: poly(vinyl alcohol), a rheological modifier or emulsifier (on the *Sentinel's* list, not in the MSDS)



$$-\!\!\left(\overset{\displaystyle H}{\underset{\displaystyle H}{\overset{|}{\underset{|}{C}}}} - \overset{\displaystyle H}{\underset{\displaystyle OH}{\overset{|}{\underset{|}{C}}}}\right)_{n}\!\!-$$

Compound **7**

Depending on the size of the polymer, poly(vinyl alcohol) can serve a number of functions. Poly(vinyl alcohol) or PVA will modify the physical properties of a fluid. The various PVAs are well-known, widely used materials generally regarded as safe. The smaller ones are soluble in water, while the larger ones are not. My initial reaction to learning that there are PVAs is to think that they have been added to help keep the microcapsules suspended in the water. In low concentrations, PVAs are likely to have that effect. The polymers tend to stick to surfaces (which the microcapsules have in abundance); however, the benefit comes from the hydrophilicity of the –OH groups in the PVAs, which would help to increase the suspendability of the microcapsules. Without more information, however, this is not much more than a guess. Alone, these materials are harmless, but they could increase the risks associated with other agents by affecting dispersion, fluid dynamic properties, or bioavailability.

8: polymethylene polyphenyl isocyanate (on the *Sentinel's* list, not in the MSDS)

(no structure provided)

Everything I have read about Checkmate products up to now has suggested that the microcapsules are composed of urea-formaldehyde polymers, which is an industry standard for microencapsulation. Therefore, I am surprised to see PMPPI (**8**) listed among the components. I think this is suspect and needs to be verified directly with Suterra. Methylene polymers are often produced from formaldehyde (hence the name urea-formaldehyde); it is unsurprising to see polymethylene in the name. It is surprising to see polyphenyl isocyanate. For stiffness, phenyl groups are often incorporated into foaming polymers. Normally, PMPPI is used to make foam insulation that is sprayed on and allowed to harden. I suppose it could be used to generate the microcapsules. PMPPI would certainly be more resistant to degradation than a urea-formaldehyde polymer, perhaps too resistant.

Aerial spraying of PMPPI microcapsules or PMPPI dust over areas where humans are likely to be exposed directly (that is, where humans may be outside) is ill-advised, in my opinion. For all intents and purposes, this product can only be degraded physically. It is not subject to reasonable rates of hydrolysis or oxidation. Although this is an oversimplification, imagine putting foam packing peanuts in your blender and then breathing in the dust. These kinds of fine dusts have been associated with a variety of adverse health effects. Exposures that are higher and chronic lead to various diseases, e.g., asbestosis, silicosis, and coal miner's lung. Fortunately, the types of exposures associated with these disabling diseases are substantially greater than the occasional, short-term exposure from the aerial spraying proposed by the Secretary. Nonetheless, it would be reasonable to expect vulnerable subpopulations (those predisposed to pulmonary or respiratory problems, e.g., asthmatics, emphysematics) to potentially suffer acute reactions.

I have been told (but have been unable to verify) that Suterra claims the microcapsules are primarily in the size range of 100 to 150 μm. While that may be true, there will always be a distribution, even if it tails off sharply. Accordingly, it would be critical to know the levels of fine particulate matter (PM) produced by spraying, specifically, PM2.5 (airborne particles below 2.5 μm in size) and PM10 (airborne particles 2.5–10 µm in size). Fine particulates can penetrate more deeply into the lungs, can interfere with white blood cell function in the lung tissues, and can lead to general irritation of the bronchial or alveolar mucosae. Most disturbing is that these particles could be there essentially forever and the effects of dusts of these polymers specifically are not well-studied. In addition to the microcapsules themselves, I note that polymer dusts can result from the normal manufacturing processes (e.g., from broken, abraded, or malformed microcapsules). I do not know if fine dusts are present at significant levels in these products (perhaps the manufacturing process is well-controlled), but I would want to know this before I advocated dispersing an aerosolized mist of the products over populated areas where direct contact with humans would occur. Because the dusts would not contain the active principles, I note that such dusts ought to be classified as inert ingredients.

Please note that I find parts of the newspaper's report highly suspect. If you can verify that the material reported in the newspaper is accurate, then I would have reservations as I have explained above. If the material is a urea-formaldehyde polymer (or some very similar polymer), I would be less concerned because the dusts are biodegradable. No matter what, I am concerned about inhalation of surfactants, especially because there seems to have been no monitoring at ground level for them.

In conclusion, I would argue that an adequate, well-defined monitoring plan for all components (not just the active principles) is critically necessary for several reasons: (1) it ensures the active principles have been delivered in a sufficient dose to have the desired entomological effect, (2) it ensures that spraying is being done in a suitably systematic fashion so that distribution of the material is roughly uniform, (3) it ensures that overdoses and underdoses are not occurring, thereby wasting money and/or failing to have the desired impact, and (4) it ensures that human and ecological exposures of all components are within levels that are considered acceptable. From the information I have been able to review, I am unconvinced that the Secretary has instituted an adequate, well-defined monitoring plan, although there appears to be some sort of monitoring in terms of minimizing the carry-over to buffer zones and no-spray zones. The plan should be subjected to public and expert peer-review scrutiny prior to any further spraying.

In addition to the matter of proper environmental monitoring, I would argue for both (1) development of an information clearinghouse to handle complaints of suspected human or ecological adverse impacts *and* (2) a requirement to investigate and evaluate such claims by trained professionals who are skilled in the use of epidemiological, toxicological, and ecological methods in the development of public health and environmental policy. Moreover, I would argue that those investigators and evaluators must be granted the force of public health law to carry out their investigations and evaluations. Lastly, they must have sufficient trained clinical (medical) personnel at their disposal to interview persons and to assess histories, symptoms, laboratory findings, and clinical findings (or to order additional examination and testing if deemed prudent). This clearinghouse should be tasked to provide appropriate statistical reports and conclusions regarding impacts of spraying on wildlife, surface water quality, and human health. I believe that the California Office of Environmental Health Hazard Assessment (OEHHA) has much of the expertise necessary to carry out such a comprehensive program in-house, but an externally run program would work just as well and may be easier/faster to establish.

In addition to these matters, it would be nice to know what the lifetimes of the product and its degradates are in the soil or in the water. Suterra probably has some of these types of data on hand since it registered the product with the EPA as a pesticide (even though it is technically not a pesticide in the sense of being an insect poison). Also, if the product or its degradates are persistent (I suspect the tetradecenyl alcohols are somewhat persistent), then the next obvious question is whether the cumulative effect of multiple aerial applications can lead to accumulation in the surface soil, the water, or other environmental reservoirs. I would be most concerned about accumulation in small ponds, for example, and the impacts on phytoplankton and zooplankton. Fortunately, the compounds are all straight chains, which have the highest rates of biodegradation. Moreover, the presence of the alkene in both the alcohol and the ester offers a hope of regioselective oxidation or electrophilic addition.

Overall, I am concerned that the Secretary of Agriculture has not considered all of the environmental, ecological, or toxicological effects of this aerial spraying activity. I suspect that the rush to stop the spread of the light brown apple moth has led to compartmentalization of hazard and risk. This compartmentalization has failed to take into account the big picture impacts of such activities in terms of accumulation and loading to surface waterways. Until all of these matters are satisfactorily addressed by the Secretary, I would discourage continued aerial spraying.

Although I am happy to provide you with this letter, please be aware that I cannot serve as an expert witness in court due to restrictions imposed by my current employer, who prefers not to be revealed.

Sincerely,

Edward Todd Urbansky, Ph.D.