Quantifying Outgassing from Plastics Used in Plastics for High or Low Tunnel Systems

Andrew Petran

CERES Research Report

Organic farmers use plastic in their production systems, such as mulch and coverings on low and high tunnels. However, this increase in use of plastics has taken place without considering the potential risks of contamination from molecules released, or outgassed, from plastics exposed to high light, high temperature environments. There is a presumption of safety, contrary to the precautionary principle used to decide if a new product should be allowed in certified production systems. Outgassing from plastics is a well-documented problem, and the plastic coverings used in high and low tunnel season extension in organic production systems could be a source of outgassed contaminates. These contaminates, if absorbed by the plant, might adversely affect yield and/or be a source of low level unwanted synthetic compounds in organically grown vegetables. The nature of the plastics used in these systems need be better understood, so organic farmers can make informed decisions.

One of the most difficult aspects of this project was developing a methodology to determine if there are outgassed volatile organic compounds (VOCs) coming from plastics routinely used in organic production. I devised a way to capture VOCs in a controlled environment to help answer if VOCs are indeed released from agricultural plastics used in organic production and if so, identify them to determine if they potentially are a risk of contamination. Plastic outgassing is well documented in other systems, and capturing, identifying and analyzing compounds has been performed before; combining both of these ideas into an assay required novel modifications of other methodologies to fit the needs of this particular project.

The methodology developed involved UV-induced outgassing from the plastics inside a sterile capture chamber (Figure 1). An internal UV source was provided to simulate sunshine and photo degradation. Silicon tubing, commonly used for absorbing VOCs, was cut into uniform pieces, cleaned, and placed into the capture chamber along with the UV source. The tubing was allowed to absorb for 24 hours and samples were taken and analyzed with gas chromatography – mass spectrometry. Identification of compounds that were present in the chamber was then performed.

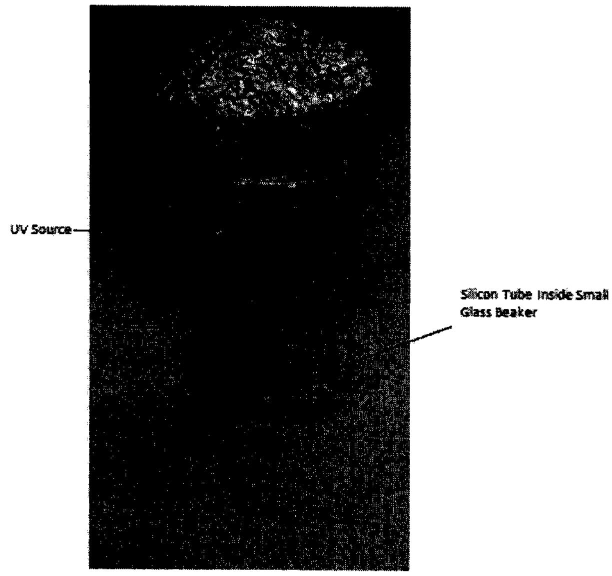

Figure 1: Capture Chamber prepped for negative control absorption. Plastics load into chamber above UV source.

After baseline compounds were identified, the next step was analyzing for VOCs from plastics. The four treatments used in this experiment are described and the plastics are pictured in Figure 2:

1. Control – empty capture chamber
2. Custom Cut Sun Master Pull and Cut Greenhouse Plastic (regular plastic)
3. Black 9738 Solar Mulch Plastic (black plastic) purchased from Johnny's Seeds.
4. Custom Cut Sun Master Infrared Anti-condensate Thermal Greenhouse film (IR-AC plastic) purchased from FarmTek,

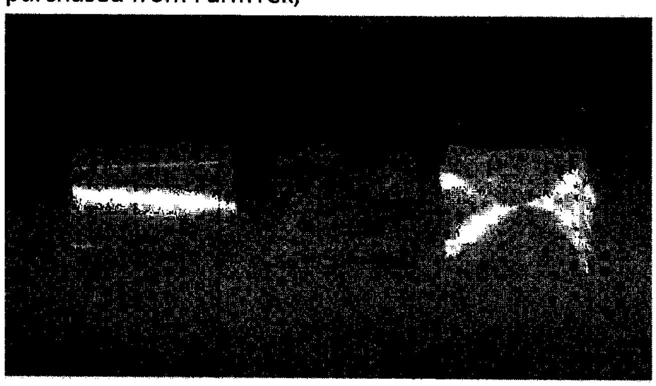

Figure 2: From left to right, regular plastic, black plastic, IR-AC plastic.

The control plus the three plastics were exposed to UV conditions in the capture chamber for either 24 or 48 hours. VOCs were collected within the chamber, and analyzed using gas chromatography-mass spectrometry. The control in the 24-hour trial contained two confirmed VOCs, plasticizing agents known as phthalates. Since these exact phthalates were also found in the three plastic treatments in the 24-hour trial as well, they were regarded as universal contaminants and not considered to be novel outgassed VOCs from the plastics. The 24-hour plastic treatments, however, all contained three other confirmed VOCs (Figure 3).

The control from the 48-hour trial also contained the same two phthalate contaminants, so these were again subtracted from the total VOC count in the plastic treatments. The regular plastic in the 48-hour trial contained ten confirmed VOCs, the IR-AC plastic contained thirteen confirmed VOCs, and the black plastic contained eleven confirmed VOCs (Figure 3).

After comparing the control to each of the plastic treatments, especially in the 48-hour trial, we concluded that UV irradiation of plastics caused a buildup of VOCs in the capture chamber. Thus we can reasonably assume that prolonged exposure to ultraviolet light contributes to outgassed VOCs from plastics approved for use in organic systems.

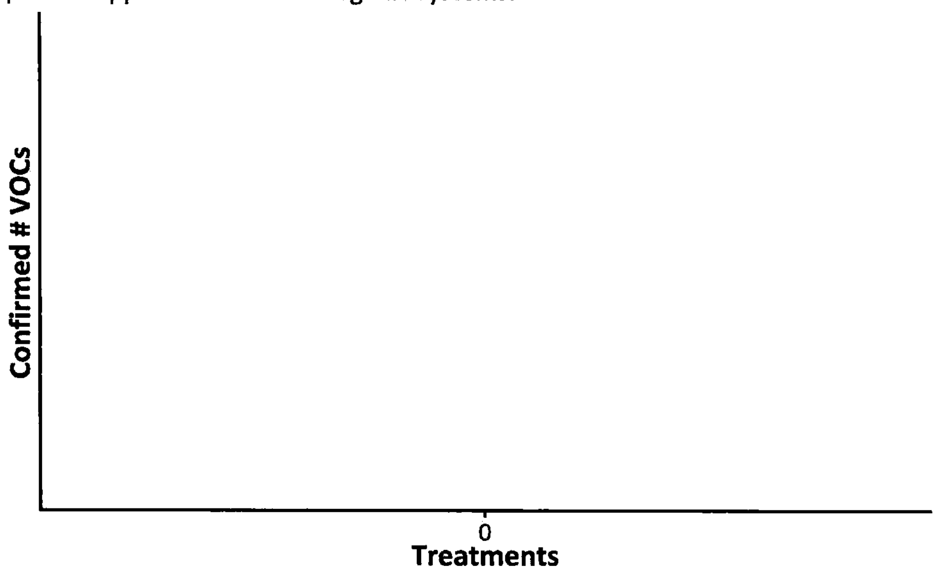

Figure 3: Quantitative summary of confirmed VOCs found in plastic trials.

We then identified the VOCs. The plastic treatments in the 24-hour trial each had three VOCs: 13-Docosenamide, Hexadecanoic acid and glycine. The plastics in the 48-hour trial yielded thirteen different VOCs, most of which were different forms of chemical compounds called siloxanes (Figure 4). Siloxanes contain silicon bonded to oxygen and hydrocarbon groups. The 48-hour trial also yielded adipic acid, lauric acid and octadecane.

Names of unique VOCs identified 24 and 48 hours after treatment	
24 hours	48 hours
13-Docosenamide	Ethyl iso-allochate
Hexadecanoic acid (palmitic acid)	B-D-Glucopyranosiduronic acid
Glycine	1-monolinoleolglycerol trimethylsilyl ester
	Hexanedioic acid (Adipic acid)
	Dodecanoic acid (Lauric acid)
	Hepta Siloxane
	Octa Siloxane
	Octadecane

	3',8',8'-Trimethoxy-3-piperidyl-2,2'-binaphthalene-1,1',4,4'-tetrone
	1,2-Benzenedicarboxylic acid
	Oxiranedodecanoic acid
	Glycine
	2,4-Imidazolidinedione

Figure 4: Identified VOCs found in plastic trials.

We have noted three general trends: (1) In each trial, there are VOCs in the plastic treatments not present in the control, (2) Within each trial, each of the three plastic treatments elute similar VOCs in similar concentrations, and (3) the plastic treatments in the 48-hour trial have more VOCs than the plastic treatments in the 24-hour trial. Not only does this indicate that VOCs are indeed being outgassed under UV irradiation, but also that the quantity of VOCs being outgassed increases as time exposed to UV irradiation progresses.

Every VOC that has been identified is known to be involved and used in at least one aspect of plastic production. Siloxanes are plastic additives that are used to provide flexibility, abrasion resistance and heat resistance. Adipic acid is a key ingredient in making polyester polyols, and 13-Docosenamide is added to plastics to increase anti-static qualities. Some VOCs discovered were compounds that aren't intended to be found on the final plastic product, but are still used in the production process. Hexadecanoic acid, also known as palmitic acid, is used in plastic production as a releaser agent to help remove plastics from their moulding material. Lauric acid and octadecane are used as lubricants.

While most of the VOCs we found are classified as non-toxic, palmitic acid has been shown to promote insulin resistance in the brain and central nervous system. Insulin is a critical component in the appetite-suppressing signals created in the brain, and insulin resistance has been shown to contribute to obesity. The World Health Organization places palmitic acid on the same level as trans-fatty acids in terms of it's potential to increase the risk of developing cardiovascular disease.

Further research will need to be conducted to determine if outgassed VOCs accumulate in plant material when being grown with plastics in the production system.