

How Do Essential Oils, Candles, and Febreze Affect the Burrowing Time of Earthworms?

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ABSTRACT There have been many negative claims against essential oils, candles, and Febreze in recent years. Due to this controversy, some scientists decided to test the effects of these substances on earthworms. The worms would be placed in an exposure chamber with the contaminant for 15, 30, and 45 minutes at a time. The scientists recorded the worm's burrowing time and compared it to the burrowing time after being exposed to just air. It was found that essential oils and candles had a statistically significant effect on the burrowing time of the earthworms, while Febreze did not have a significant effect.

Introduction

Essential oils are concentrated hydrophobic liquid that has chemical compounds from plants. Distillation turns the plant's benefits and smell into a liquid form. Many people use essential oils to help their home smell nice. Essential oils are meant to reduce stress, treat fungal infections, and help against insomnia¹. The essential oils market peaked in 2017, with 9.7% revenue growth². As of 2020, that revenue growth is down to 1.68%.

Essential oils contain many plant based ingredients. This particular oil blend from Plant Therapy includes basil oil, orange fruit extract, cypress leaf oil, clary sage oil, and other varieties/ types of oil. Plant therapy claims to use 100% undiluted oils. On the SDF(safety data sheet) for the Respir Aid Essential Oil Blend³ the company does claim that the oil "Contains the 100% pure, undiluted essential oils of: Eucalyptus, Pine, Peppermint, Lavender, Spruce, Cypress, Marjoram."

Though many people love using essential oils because they are more natural, there are still many skeptics because of side effects of using some oils that have been brought to light in recent years. Essential oils are meant to be inhaled by a diffuser. The air is then breathed in

¹ "Health Benefits of Essential Oils - WebMD." 17 Nov. 2020, <https://www.webmd.com/diet/health-benefits-essential-oils>. Accessed 11 Jan. 2022.

² "Essential Oils Market Worldwide - Statistics & Facts | Statista." 29 Oct. 2021, <https://www.statista.com/topics/5174/essential-oils/>. Accessed 11 Jan. 2022.

³ "Respir Aid Essential Oil Blend | Plant Therapy." <https://www.planttherapy.com/respir-aid-essential-oil-blend>. Accessed 11 Jan. 2022.

through your respiratory system. Some people have reported coughing, choking, wheezing, and shallow breathing⁴ from inhaling these oils. It's no secret that consuming essential oils is toxic and will cause serious health problems. Over recent years, children who use essential oils as a natural remedy are at high risk for essential oil poisoning, even if they are not directly consuming the oil⁵.

Candles are another commonly used air refresher that has faced controversy. A candle is a block of wax with a central wick that you burn to produce light and sometimes a scent. Candles have become very popular in the U.S, and as of 2017, 7 out of every 10 households use candles⁶.

As stated, the basic ingredients of a scented candle are wax, a wick, and oil. Of course there are other ingredients put in the oil that is used to produce the desired scent. There are many different waxes used such as palm wax, soy wax, and paraffin wax. Paraffin wax is the least expensive, therefore the most popular used candle wax⁷. Paraffin wax doesn't have any additives in it, that's why it's also known as straight wax.

Paraffin is a very controversial wax because many people don't know how toxic it really is. The reason it is so toxic is because paraffin is a byproduct of making gasoline⁸. Not many people know that and do not check the candle label for their type of wax. Some candle packaging doesn't even tell the type of wax at all. Paraffin wax is also not biodegradable,

⁴ "Essential oils – Health warning - HealthyWA." https://www.healthywa.wa.gov.au/Articles/A_E/Essential-oils. Accessed 12 Jan. 2022.

⁵ "More Kids Accidentally Poisoned by Essential Oils - WebMD." 13 May. 2016, <https://www.webmd.com/children/news/20160513/more-children-accidentally-poisoned-by-essential-oils>. Accessed 12 Jan. 2022.

⁶ "Candle Industry Statistics | Join & Buy Scentsy." 26 Feb. 2017, <https://www.thrivingcandlebusiness.com/enlightening-candle-industry-statistics/>. Accessed 12 Jan. 2022.

⁷ "Choosing the Right Candle Wax For Making Candles - Candlewic." 25 Mar. 2020, <https://candlewic.com/learn/candlemaking-how-to/choosing-candle-wax/>. Accessed 12 Jan. 2022.

⁸ "Are Candles Bad for You? Myths and Potential Side Effects." 9 Jun. 2020, <https://www.healthline.com/health/are-candles-bad-for-you>. Accessed 16 Jan. 2022.

because it is also a byproduct of crude oil⁹. Though many are very against paraffin wax for the mentioned reasons, some believe it has no health damage at all. "The safety of paraffin wax was supported by a study in the Journal of Regulatory Toxicology and Pharmacology that found that scented paraffin candles do not pose any health risks when used under normal conditions¹⁰."

As well as candles and essential oils, another very popular air freshener is Febreze. Febreze is a liquid spray that is used to mask odors in rooms. Febreze is often scented with artificial scent. As of 2020, approximately 250 million U.S citizens use air freshener sprays¹¹.

Febreze contains ingredients of emulsifiers, preservatives, and perfumes(from Febreze SDS). Febreze is known to contain Benzaldehyde, which is a neurotoxin and has been linked to lung, eyes, and skin irritation¹². Febreze includes other neurotoxins and immunotoxins such as BHT, Methyl pyrrolidone, Butylphenyl methylpropion al, Linalool, and Limonene.

The most common known health effects of Febreze's ingredients are skin, eye, and lung irritation. Many find it concerning that Febreze and other fragrance fresheners are linked to lung irritation when you are supposed to breathe them in. Longer term effects of febreze are potentially asthma and hormone disruption¹³. There are claims that Febreze has caused illness and deaths in pets¹⁴.

⁹ "Is Paraffin Wax Sustainable? What You Should Know (+4 Alternatives)." 24 Aug. 2021, <https://citizensustainable.com/paraffin-wax-sustainable/>. Accessed 16 Jan. 2022.

¹⁰ "Candles: What do they emit when lit? | Office for Science and Society." 25 Jun. 2021, <https://www.mcgill.ca/oss/article/student-contributors-you-asked-general-science/candles-what-do-they-emit-when-lit>. Accessed 16 Jan. 2022.

¹¹ "• U.S.: usage of air freshener sprays and deodorizers 2020 | Statista." 2 Jul. 2021, <https://www.statista.com/statistics/275362/us-households-usage-of-air-freshener-sprays-and-deodorizers/>. Accessed 16 Jan. 2022.

¹² "The Dangers of Febreze - EZ Breathe Home Ventilation System." 11 Aug. 2021, <https://ezbreathe.com/the-dangers-of-febreze/>. Accessed 16 Jan. 2022.

¹³ "7 Reasons Why You Shouldn't Use Febreze—Or Other Chemical Air" 18 Sep. 2013, <https://cvskinlabs.com/7-reasons-why-you-shouldnt-use-febreze-or-other-chemical-air-fresheners/>. Accessed 16 Jan. 2022.

¹⁴ "Is Febreze Safe to Use?." <https://www.febreze.com/en-us/ingredients-safety/our-safety-standards>. Accessed 16 Jan. 2022.

Due to negative effects of essential oils, Febreze, and candles, some scientists decided to test these contaminants on earthworms. Scientists chose to use earthworms because their system functions very similar to a human's interior system. Earthworms have a digestive system that breaks down their food and turns it into nutrients for the blood to carry out into the body. Earthworms are also more humane and more available to use than other organisms.

There are lots of debates on if these contaminants are harmful or not to our bodies. The scientists' experiment will test how long it takes earthworms to burrow after being exposed to either essential oils, candles, or febreze. From this experiment, scientists will be able to conclude whether or not these contaminants are going to be actually harmful to the human body.

If scientists expose earthworms to either essential oils, candles, or Febreze, then will it have a negative effect on the worm's burrowing time? Since many people have claimed these contaminants to have harmful effects on living organisms the expectation is that these materials will cause the burrowing time to take longer. After the experiment, the scientists actually found that the contaminants did significantly alter the burrowing times of the worms, except for Febreze.

Methods

Materials

- 12 adult redworms from Carolina Biological Supply
- Lavender Febreze
- Lavender Essential oils, 3 drops (Young Living)
- Lavender tea candles, 6 (Shorties)
- 16 ounce solo cups, 8
- Essential oil diffuser
- Soil or dirt from school garden (have about 13 ounces for each burrowing chamber)
- Power source for diffuser
- Pipettes, 5
- Burrowing chamber
- Exposer chamber, 72 quarts

- Distilled water for diffuser
- Safety glasses
- Foam tray
- Clorox wipes
- Spray bottle
- Stopwatch and timer

To create the exposure chamber, the scientists used a plastic bin that held 72 quarts.

For the burrowing chamber, they took one 16 ounce solo cup and filled it about $\frac{3}{4}$ full of moist soil. When setting up the essential oil diffuser, fill it with the distilled water and three drops of the lavender essential oil.

Procedure

Step one: Set up the exposure chamber by placing the prepared oil diffuser in the chamber.

Make sure to plug it in.

Step two: Place 3 earthworms inside a solo cup with about 3 sprays of water. Place that cup inside the exposure chamber.

Step three: set a timer for 15 minutes. Make sure to record your observations.

Step 4: After 15 minutes, take the worms out of the exposure chamber and put them in the burrowing chamber.

Step 5: Set a stopwatch and record the time when you can no longer see each worm.

Step 6: repeat steps 1-5, but keep the worms in the exposure chamber for 30 minutes.

Step 7: After you have repeated the steps 1-5 after 30 minutes of exposure, expose the worms to the lavender essential oil for 45 minutes.

Step 8: After you've finished all the exposure times for the lavender essential oil, repeat steps 1-7 but expose 3 different worms to the 6 lavender tea candles. Make sure to record each worm's individual burrowing time.

Step 9: Once you have completed exposing the worms to 6 lavender tea candles for 15, 30, and 45 while recording their burrowing times, repeat steps 1-7 but expose three different worms to lavender Febreze.

Step 10: Make sure to have recorded all 9 worms burrowing times.

Step 11: Expose 3, completely clean worms to air in a 16 ounce solo cup with 3 sprays of water for 15 minutes in the exposure chamber.

Step 12: After 15 minutes, take out the worms and put them in the burrowing chamber.

Step 13: record the worms burrowing time with a stopwatch.

Step 14: Repeat steps 11-13 but expose the worms for 30 minutes, then 45 minutes.



The exposure chamber containing the diffuser and the worms being exposed.

Safety Concerns

Throughout the whole experiment, the scientists wore goggles and tied their hair back. A more experienced scientist would light the candles when needed. When working with the open flames of the 6 tea candles, the scientists pulled their sleeves back. After the experiments were conducted, the scientists would wipe the work counters off with Clorox wipes to prevent other experiments from contamination. The scientists would be sure to wash their hands after every experiment/ contact with chemicals.

Results

In The United States alone, more than 70% of households use candles¹⁵, 249.76 million people use air fresheners¹⁶, and the global essential oils market was valued at 18.6 billion USD¹⁷. Since many people use these products, the scientists believed it would be important to understand the effects these substances actually have on a human nervous system. .The scientists choose to test and expose earthworms to these contaminants because an earthworm's muscular system is similar to a humans¹⁸. The scientists believe that if they expose earthworms to either essential oils, candles, or Febreze, then it will have a negative effect on the worm's burrowing time because many people have claimed these contaminants to have harmful effects on living organisms.

For the experiment, the scientists used a 72 quart plastic bin as an exposure chamber. They would take 3 worms and put them in a 16 ounce plastic cup with 3 sprays of water. Then the scientists would place the cup with the worms in the exposure chamber with either 6 lavender tea candles, a diffuser with 3 drops of essential oils, or 3 seconds of spraying lavender febreze. The scientists would then close the exposure chamber for either 15, 30, or 45 minutes at a time. Once the worms were done being exposed to the contaminant, they would place the three worms on top of soil in a cup (the burrowing chamber). The scientist would observe the worm's behavior and movements as well as time each of their individual burrowing times. The scientists would repeat this process, but for each different contaminant they would use a

¹⁵ "Enlightening Candle Industry Statistics - Join & Buy Scentsy." 26 Feb. 2017, <https://www.thrivingcandlebusiness.com/enlightening-candle-industry-statistics/>. Accessed 13 Feb. 2022.

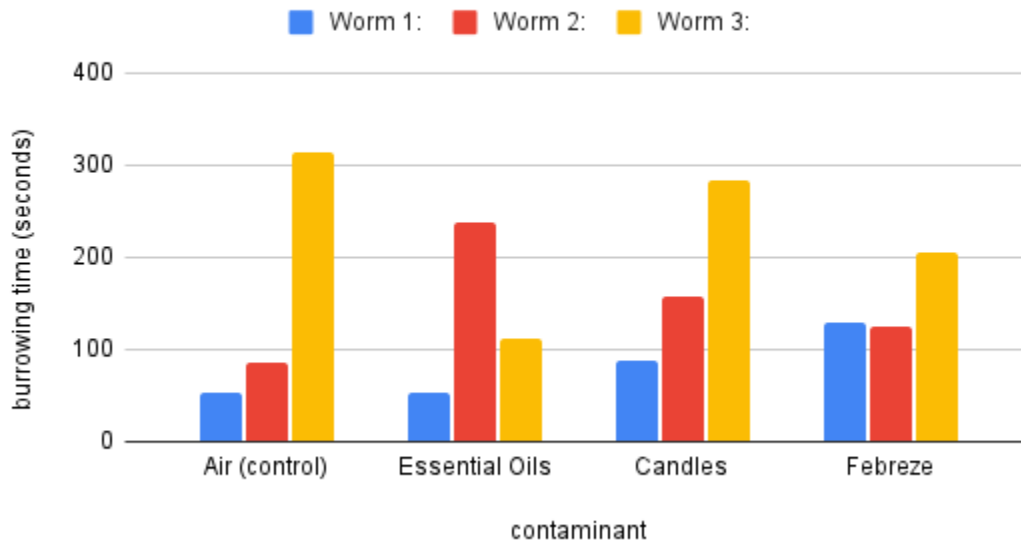
¹⁶ "• U.S.: usage of air freshener sprays and deodorizers 2020 | Statista." 2 Jul. 2021, <https://www.statista.com/statistics/275362/us-households-usage-of-air-freshener-sprays-and-deodorizers/>. Accessed 13 Feb. 2022.

¹⁷ "Essential Oils Market Size | Industry Report, 2021-2028." <https://www.grandviewresearch.com/industry-analysis/essential-oils-market>. Accessed 13 Feb. 2022.

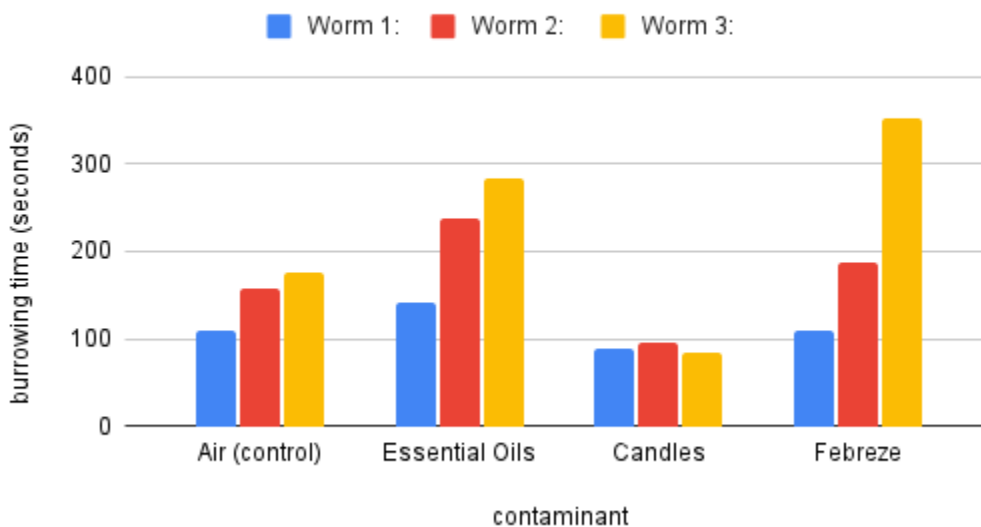
¹⁸ "A Worm is More Like a Human Than Previously Thought." 30 Mar. 2001, <https://www.news.ucsb.edu/2001/011459/worm-more-human-previously-thought>. Accessed 13 Feb. 2022.

different set of 3 worms. Each set of worms was exposed to their contaminant for either 15, 30, or 45 minute before being observed and burrowing.

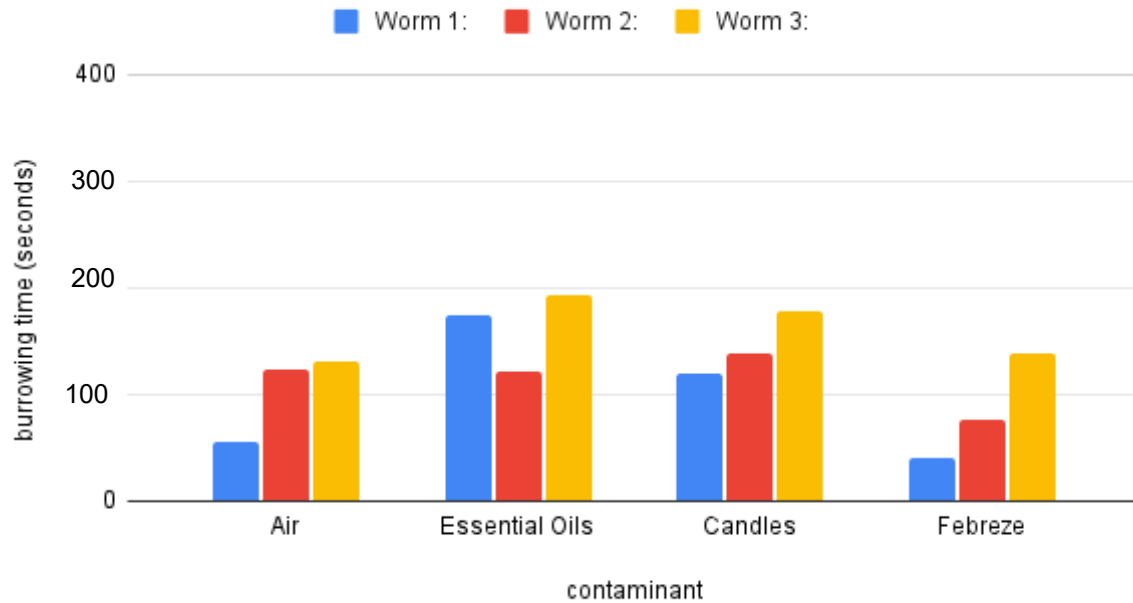
Exposure for 15 minutes



Exposure for 30 minutes



Exposure for 45 minutes



Mmmkzs Statistics

All statistical analyses were conducted using QuickCalcs Graphpad Software. The “yes” or “no” to if the data is statistically significant is measured by its t score. If the t score is less than one the data is not statistically significant, which means the data did not vary enough for it to have a noticeable effect on the earthworm's burrowing time. If the t score is greater than one, the data is statistically significant and the contaminant most likely played some role in the time it took for the earthworms to burrow.

15 minutes	Statistically significant?
Control vs Essential oils	NO
Control vs Candles	NO
Control vs Febreze	NO
30 minutes	
Control vs Essential Oils	YES
Control vs Candles	YES
Control vs Febreze	NO
45 minutes	
Control vs Essential Oils	YES
Control vs Candles	YES
Control vs Febreze	NO

The scientists found their results very interesting. In the chart, it shows that Febreze had no statistically significant effect on the burrowing time of the earthworm. In fact, none of the contaminants had a significant effect on the worms burrowing after the worms were exposed for 15 minutes. For exposure to essential oils for 30 and 45 minutes, that is when the worms took their longest to burrow, except for Febreze. The scientists did a controlled experiment where the worms were only exposed to air in the exposure chamber to be able to compare results. They found that these contaminants did have some effect on slowing down the worms when burrowing. When looking at all of the results, the scientists recognized a few outliers. For example, the worms who were exposed to lavender scented candles for 30minutes had a significantly shorter burrowing time than all other worms. It is seen that all categories of the results that candles and essential oils had a statistically significant effect on the worm's burrowing times. During the experiment where the scientists exposed worms to febreze for 30 minutes, it was noted that one worm took much longer to burrow than the others. This is very strange, because that is approximately 210 more seconds of burrowing than the slowest febreze

worm exposed for 45 minutes. In all, the scientists noticed the pattern that essential oils had a clear effect on the worm's burrowing time, while Febreze did not.

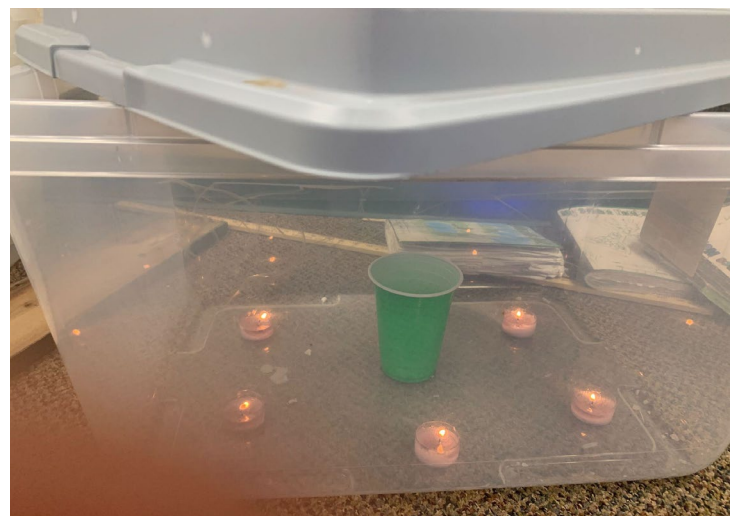
As well as statistically proven effects, there were many scientific observations made that show the worm's reactions to the contaminants directly after they were taken out of the exposure chamber. The worms who were exposed to candles, as well as the worms exposed to essential oils, were clumped together after being exposed for only 30 minutes. To add to the



observations from the exposure of the worms to essential oils, it was noted that after 45 minutes of exposure, the earthworms were moving slower and “seemed dazed.” Almost like they forgot about their natural instinct to burrow. With Febreze, after the worms were exposed for 15 and 45 minutes, the worms were reported to be jerking slightly, with slow

movement. While it is clear that most of the observations told of the worms burrowing slowly, the worms who were exposed to lavender candles for 30 minutes were said to have been burrowing “abnormally fast,” as reflected in the chart.

While the experiments were being conducted, the scientists were aware of possible conditions that could affect and harm the accuracy of the results. One danger that was observed during the experimenting with



candles, the lid of the exposure chamber would get very hot. The scientists did not want to risk

the top melting or heating up to a dangerous degree. So there was a decision made to crack the top open so air could still flow, but not so much that the experiment is completely compromised. The exposure chamber was never air-tight, so that was definitely a limiting factor to getting the most accurate results. The exposure chamber could never be air-tight, just for the safety of the worms.

The scientists also faced many environmental limiting factors such as space and the order of which the experiments were able to be conducted. When the scientists were conducting the experiments, they had a time limit. Due to that time limit, they were not able to do essential oils one day, candles another, febreze the next day, and finally a controlled experiment to compare. The contaminants were being used in the same exposure chamber with not much time to air out. Residue from Febreze or essential oils could have potentially tainted the other contaminants from being the only substance in the exposure chamber.

As explained, the scientists recognize the flaws in their experiment that probably harmed the accuracy of the results. Next experiment with multiple contaminants, the scientists have learned that they should use 3 different exposure chambers of the same material and size to better ensure that the substance being tested is the only one.

Discussion

As stated, the scientists view that essential oils and candles had a significant effect on the earthworm's burrowing, while Febreze did not have a significant effect. To return to the scientists original hypothesis, they stated that if they were to expose earthworms to essential oils, candles, and Febreze, then those contaminants would have a clear effect on the worm's burrowing time. From reviewing the results, they are seeing that their hypothesis was partially correct because essential oils and candles had an effect on the worm's nervous system. The scientists have chosen to accept their hypothesis for it is mostly correct that these substances

will have an effect on our systems. The scientists don't know if they can be completely certain in saying Febreze is still safe to use in homes.

They recognize the limitations in their experiment, and that just spraying the febreze in the exposure chamber might not have given the worm the proper exposure to gain accurate results. From the results, it is clear that essential oils and candles made the earthworms burrow slower after exposure. Why did this occur? Most people use essential oils and candles to relax and put them at ease. To be specific, the scientists tested with only lavender scented substances. The scientists used the Lavender Essential Oil by Young Living, which contains a key ingredient of linalool. Linalool has a "sedative effect¹⁹" on the body when it is used. Connecting back to the fact that the worms burrowed slower shows that the linalool in the essential oil was affecting the nervous system of the worms. This would also explain why the scientists described the worms as being "dazed" after exposure.

This effect may not seem negative to many people. Isn't the essential oil's job to relax people? Though that is true, the effects the scientists are discussing are not just of the worms being too relaxed to burrow. They are talking about how the worms are losing their natural instinct to burrow and to do it fast. If earthworms are losing a sense that has been with them since birth, then it is definitely not a good thing for the worms, and even humans, to be exposed to. These essential oils seemed to be acting as sedatives to the worms because of the linalool. Even though these worms were exposed for less than an hour, short term effects of sedatives can cause sluggishness, disorientation, and lack of coordination²⁰. All of that connects back to the slower burrowing times and the dazed movement of the worms. So, as explained, the essential oils are not doing their job as to just be relaxing.

¹⁹ "evidence for sedative effects of the essential oil of lavender after"
<https://pubmed.ncbi.nlm.nih.gov/1817516/>. Accessed 22 Feb. 2022.

²⁰ "Prescription Sedatives & Tranquilizers - Drug Free NJ." <http://www.drugfreenj.org/drug-encyclopedia/prescription-sedatives-tranquilizers/>. Accessed 22 Feb. 2022.

When reviewing the effects of candles on the worms, scientists had conflicting results. For example, after 30 minutes of exposure to candles, the worms burrowed abnormally fast. Even faster than the controlled experiment. The same brand and type of candles were used for the whole experiment, so this led the scientists to trying to come up with a flaw in the experiment. Was the lid of the exposure chamber too open? This wouldn't be the case because the lid was left partially open for all candle experiments for safety reasons. It was looked into by the scientists to see if there were any previous studies or evidence of candles speeding up movement and they weren't able to find anything. This left the scientists with no specific conclusion on why this outlier appeared.

The scientists believe that candles slowed down the worm's burrowing time for a similar reason essential oils also slowed the worm's burrowing time. Both substances are used for relaxation. Though these substances stimulate relaxation in different ways. Essential oils use linalool, and candles use their smells. Scents from candles stimulate your limbic system, the system that connects with behavioral and emotional responses²¹. Again, many view this relaxing slowing down effect of candles to be what they are there for. Though it is important to remember that these candles made worms hazy on their instinct to burrow. The candles may not have just made the worm's muscular system work slower, but the scent in the candle could have contacted something in the brain or system that made the behavior of how to burrow blurry. Worms do not have a limbic system, so it is most likely their muscular system was contacted and the behavior of that system was slowed down.

Why didn't Febreze have an effect? All the other substances did, so why not arguably the most controversial one? The scientists were also very surprised to figure out Febreze had no significant effect on how long it took the worms to burrow. The scientists simply believed this was because the worms didn't have a direct enough exposure. The design of the exposure

²¹ "The limbic system - Queensland Brain Institute." 24 Jan. 2019, <https://qbi.uq.edu.au/brain/brain-anatomy/limbic-system>. Accessed 22 Feb. 2022.

chamber was that it was very wide, but not very tall. There were only a few inches from the top of the cup and the top of the exposure chamber. The scientists think that the Febreze over time was just stuck at the bottom of the exposure chamber and wasn't getting into the cup. With essential oils and the candles, there was constant circulation and flow of the contaminants so they were able to be more direct in exposure with the worms. Febreze just didn't have that exposure it needed to have in order to convey accurate results.

Many people will be confused as to why society needs to care about the burrowing time of worms. The truth is, worms don't use essential oils, candles, or even Febreze. Though, humans do use those things, and they use them a lot. According to Statista, as of 2020, 19.38 million people use essential oils, 49.63 million use candles, and 178.11 use an air freshener spray²². When so many people use these substances the scientists tested, it is important to know how these substances are going to affect the human body. No matter if it is negative or positive, people should know and care about what they are allowing to enter their system. From the results of this experiment, it is clear that essential oils and candles cause people to be at risk of unwanted slowed behavior, dissociation, and other possible effects.

To further this investigation, the scientists would make the necessary changes and precautions to make this experiment more controlled and accurate. With the more accurate results, the scientists would be able to dive deeper into exact effects and changes contaminants like essential oils, candles, and Febreze have on the body systems. Do different amounts of the contaminant matter? Does the brand change results? Do different scents have different effects? All are potential questions that further experimentation and exploration will help to answer, and help to bring better conclusion into what is good for the body and what is not.

²² "most used types of air freshener sprays and room deodorizers 2020." 2 Jul. 2021, <https://www.statista.com/statistics/275370/us-households-most-used-types-of-air-freshener-sprays-and-room-deodorizers/>. Accessed 22 Feb. 2022.