TECHNOLOGY SCIENCE JOURNAL FOR TEENS

JANUARY 2020

Can graphene in your clothing stop mosquito bites?

Authors:
Cintia Castilho, Dong Li, Muchun Liu, and others
Associate Editors:
Gogi Kalka & Madeleine Corcoran

Abstract

Wouldn't it be great if there was clothing out there that could fully protect us from mosquito bites? This could reduce itching *and* the spread of *mosquito-borne diseases*. To find out, we tested whether a super thin but really strong substance, *graphene*, has the potential to make clothing mosquito proof. In a lab experiment, we exposed humans wearing a) no protection or b) *cheesecloth* or c) cheesecloth plus graphene to mosquitoes. And we found that the graphene indeed kept mosquitoes from biting people. We were surprised to realize that it not only acted as a physical barrier for the insects' mouthparts, but also blocked important chemical signals that mosquitoes use to detect humans. Under dry conditions, our graphene layer therefore showed double potential for protection. However, sweat or water made it less mosquito-proof. But we found a modified form, "reduced graphene", that protected humans even when it was wet.

Introduction

Mosquito bites are not just a nuisance, but can come with serious consequences. No other bite kills more humans, or makes more of us sick. Mosquitoes serve as the most important *vector* for many *infectious diseases*. People frequently use chemicals to protect themselves from mosquitoes. However, these chemicals can have many unpleasant side effects, both for humans and the environment. People are also advised to wear long clothes to protect themselves from getting bitten. However, mosquitoes have a very sophisticated biting apparatus made out of six super skinny needles and saws, which allows them to bite through some clothing (and of course our skin).

We wanted to know if we could add a non-toxic *nanomaterial* to clothes that would make them *impenetrable* for mosquitoes. A good candidate seemed to be *graphene* – a material made of carbon in very thin sheets that is already being used on clothes for various other applications – to make them UV-protective or bulletproof, for instance. However, no one has ever tested if this material could be used for mosquito protection.

We conducted a couple of experiments with live humans and live mosquitoes, coupled with some mathematical calculations, to figure this out.

Methods

For our lab experiments, we recruited volunteers who agreed to be bitten by *Aedes aegypti* mosquitoes in a controlled setting. (The mosquitoes we used had been bred in sterile lab conditions and did not carry any diseases.)

The volunteers exposed a small patch of skin on their arm or hand to roughly 100 mosquitoes for five minutes at a time in a modified Plexiglas glove-box (Fig. 1)

We tested three different scenarios in a *randomized* order:

Mosquitoes on...

- Naked skin
- Skin covered in cheesecloth
- Skin with a thin graphene layer and then covered in cheesecloth

We then recorded and quantified the behavior of the mosquitoes (whether they landed on the skin, how long they stayed there, and whether they started to suck blood) with a video camera.

We also counted how many bites each volunteer received in all these scenarios based on the number of swellings that developed on their skin afterwards.

Finally, we observed what happened if we dripped a little water or sweat on top of the cheesecloth, and we also tested a slightly different version of our graphene layer, called "reduced graphene".

In addition to our live mosquito experiments, we also tested the physical ability of tiny needles to puncture our graphene materials, and ran a computer simulation to find out if mosquito mouthparts had enough strength to penetrate the graphene.

Figure 1:
Aedes aegypti mosquitoes on a patch of bare skin in our lab. Exposing bare skin to the mosquitoes provided our control case. The yellow arrows indicate biting behaviours.

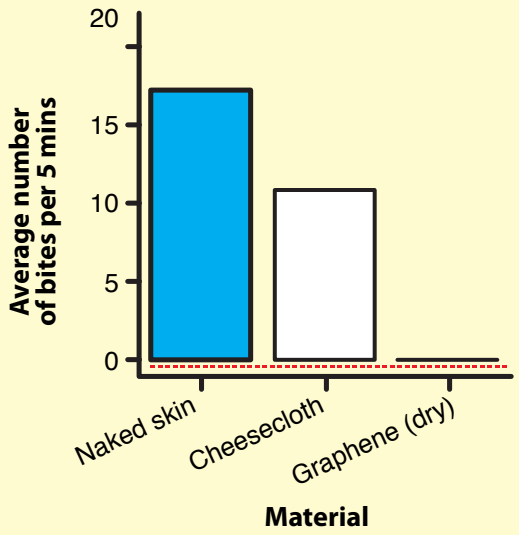
Results

- Excitingly, we found that the thin graphene layer under the cheesecloth prevented mosquitoes from biting people - mosquitoes never bit through it and no swellings developed (Fig. 2).
- Bare skin got the most mosquito bites (about 16 on average), followed by skin only covered by cheesecloth (about 10 bites per 5 min exposure).
- Mosquitoes also landed fewer times and spent less time overall on the skin covered with graphene.
- On naked skin or skin covered in cheese cloth, the mosquitoes landed about 23 times on average, and stayed for 1-2 minutes. In comparison, fewer than 10 mosquitoes on average landed on the graphene layer, and they stayed there for much shorter periods.
- Our bite force experiments with needles as well as our computer simulation confirmed that mosquitoes do not have enough force to bite through the dry graphene layer.

Please see Figure 2 Page 3

Figure 2:
Average number of mosquito bites per square inch in a 5-minute time period on 3 different materials (naked skin, cheesecloth and graphene layer with cheesecloth).

Question:
Which material was most effective at protecting against bites?



Discussion

Graphene was clearly effective at preventing mosquito bites. We were also struck by how much less the mosquitoes landed on graphene covered skin. It looked as if they did not even try to bite through the graphene! This told us that something else was going on: What if the graphene also blocked chemical signals from the skin that the mosquitoes needed for locating their victims?

We wanted to be sure so we applied water or sweat on top of the graphene layer. All of a sudden the mosquitoes landed again, and started to bite through the material.

This tells us two things:

1. The dry graphene is likely also keeping mosquitoes off by keeping necessary chemical cues from reaching the mosquito.
2. Water or sweat breaks down the graphene layer and makes is penetrable for mosquitoes.

Luckily, we could restore the chemical and physical barrier by slightly altering the graphene material, which reduced mosquito bites in both in dry and wet conditions.

However, this version of graphene is less breathable than our original graphene material.

We hope that our research will inspire others to make graphene-covered clothes that do not let mosquito bites through even in wet and humid conditions, but are still breathable and comfortable to wear.

Conclusion

Even though mosquitoes are just trying to feed themselves, the diseases they sometimes carry can seriously harm us. The best protection from getting sick is to not get bitten at all.

- Wear protective clothing when in mosquito prone areas. It is better to wear long sleeves and pants even if you don't have graphene layered clothing!
- Sleep under a mosquito net.
- Tip away all standing water (where mosquitoes lay their eggs).
- When travelling to mosquito prone areas, make sure you take the right medication and use appropriate repellent.

Glossary of Key Terms

Cheesecloth – a loosely woven, gauze-like cloth made from cotton.

Graphene – a substance purely made out of carbon that forms very thin layers. For our experiments, we used a version that is technically "graphene oxide" (GO), and a slightly modified version with less oxygen content called "reduced graphene oxide (rGO)". Graphene has been called the "world's strongest material", and is already being used for all kinds of applications: solar panels, tennis rackets, or on clothing to make it more UV or bullet proof, for instance.

Mosquito-borne diseases – diseases that are transmitted by mosquitoes. Often, the mosquitoes only carry the microorganisms that cause the disease, but are not actually harmed by them. When the mosquitoes bite humans or animals and start sucking blood, they inject some liquid into the wound first to keep the blood from clotting. That's how they pass on the disease causing agents to us or animals. These diseases include malaria, yellow fever, dengue, and Zika virus.

Impenetrable – A surface that can't be pierced by an object. For example, the mosquitoes mouth-parts could not get through the graphene layer.

Infectious diseases – diseases such as malaria, Dengue fever and schistosomiasis caused by organisms such as viruses, bacteria, or other microorganisms. Some can be passed from person to person, but some can be transmitted by mosquitoes or other animals.

Nanomaterial – a material that is super thin. In the case of graphene, scientists even call it "two-dimensional", because it is only one layer of atoms thick!

Randomized – a method based on chance alone by which study participants are assigned to a certain treatment in order to minimize the influence of other factors. In our case, we randomized the order in which volunteers either offered the mosquito their bare arm, arm with just cheesecloth, or arm covered by the graphene layer.

Vector – a carrier for microorganisms, such as bacteria or viruses, that make people sick. Mosquitoes are significant carriers of a lot of different diseases, but they don't necessarily get sick from the disease themselves.

Check your understanding

1. Why should we be concerned about mosquito bites?
2. Can we not just spray chemicals against mosquitoes?
3. How did we find out that graphene kept mosquitoes from biting people?
4. Why did we think that graphene did not act as a mere physical barrier for the mosquito biting apparatus?
5. How did we confirm our hypothesis that graphene acted as a chemical barrier, too?
6. What was the problem when water or sweat was applied to the graphene?

REFERENCES

Cintia J. Castilho, Dong Li, Muchun Liu, Yue Liu, Huajian Gao, and Robert H. Hurt (2019): Mosquito bite prevention through graphene barrier layers. PNAS
https://www.pnas.org/content/116/37/18304

Brown University: Press release
https://www.brown.edu/news/2019-08-26/moquitoes

What is graphene?
https://www.digitaltrends.com/cool-tech/what-is-graphene/

9 Ways graphene is transforming the world around us
https://www.digitaltrends.com/cool-tech/9-amazing-graphene-applications/