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European Defence Challenge 5th edition

"Towards a Safer Tomorrow: Multidisciplinary Approaches to Landmine Clearance and Security Enhancement"

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Biotechnological Innovations for Landmine Neutralization: Leveraging **Termites and Shewanella**

1. ABSTRACT

Coming from Lebanon, a country that has continuously experienced war, the detection and removal of landmines in the post-war period is a critical and ongoing challenge. In South Lebanon, where a significant number of landmines remain, the process of detecting and defusing them is time-consuming and complex. Tragically, undetected mines have already claimed the lives of many civilians.
Our research aims to develop safer and more cost-effective solutions for mine clearance in our country. Similarly, in Ukraine, which is currently enduring a war, the issue of landmines is also significant, highlighting the global importance of finding innovative approaches to address this problem, our ultimate goal is to create a safer tomorrow in a world free from landmines.
This paper discusses the issue of landmine identification and clearance in Ukraine, a country with 40% of its territory affected by landmines. **The paper proposes a project focusing on efficiency, cost-effectiveness, and environmental sustainability for landmine clearance in Ukraine, in around 5400 words.** The approach is tailored to anti-personnel mines, using genetically modified insects trained to detect tripwires and genetically engineered bacteria designed to degrade these wires. The paper outlines the biotechnological components essential to this approach, including CRISPR Technology for the detection of anti-personnel land mines and the use of genetically modified insects to disrupt the tripwire material.

2. INTRODUCTION

In this paper, we address the subject of landmine identification and clearance, specifically in the setting of Ukraine and Russia. Today, landmines affect around 40 percent of Ukrainian territory, such percentage cannot be neutralized without extensive clearance efforts. About 174,000 square meters of Ukraine's soil have been mined since Russia's full-scale invasion, making it one of the most mined nations in the world. Thus, this does not solely represent a mere weapon but a long-term hazard to national reconstruction, agricultural recovery, and human safety. Unfortunately, a strategic plan for landmine clearance is not yet available. The biggest demining humanitarian organization operating in Ukraine at the moment is the HALO Trust. Over 36,000 explosive devices have been removed by HALO since Russia's full-scale invasion, and 7.1 million square meters of land—nearly a thousand full-sized football fields—have been declared secure. The military situation in Ukraine has reached a critical state, extending beyond the front lines to vast areas where landmines pose a persistent threat to civilian safety. However, the decision to supply additional mines—complementing the anti- tank mines already provided by the United States—raises substantial diplomatic and humanitarian concerns. This issue is particularly significant given Ukraine's commitment as a signatory to the 1997 Anti-Personnel Mine Ban Convention. According to Major General James Cowan, CEO of the landmine charity The HALO Trust, demining is a prerequisite for any mineral extraction agreement between Ukraine and the United States. Speaking at the Munich Security Conference in February 2023, he emphasized the severity of the issue:

> "The landmine problem in Ukraine is huge. The Ukrainian Government estimates that 138,000 square kilometers of its territory has been affected by hostilities and so likely to be contaminated with mines and explosive debris. The mines are laid on the most productive farmland in Europe and are significantly damaging Ukraine's economy."[1]

Cowan also recognizes the immense difficulty of the task, stating that if The HALO Trust were solely responsible for clearing two million landmines in Ukraine, the process would take approximately 127 years, assuming stable funding conditions.[2]

Our project is dedicated to addressing landmine clearance in Ukraine, with a particular emphasis on efficiency, cost-effectiveness, and environmental sustainability. Specifically, our proposal prioritizes:

- Time efficiency, ensuring the rapid clearance of heavily mined areas,
- Cost-effectiveness, optimizing resource allocation for maximum impact, and
- Environmental sustainability, preserving soil integrity throughout the demining process.

Given that anti-personnel mines are the most prevalent in Ukrainian minefields, our approach is tailored exclusively to this type of ordnance. The proposed solution is rooted in biotechnology, leveraging advanced tools to enhance demining efforts. **This paper outlines a novel strategy involving genetically modified insects trained to detect the trip wires of anti- personnel mines, alongside genetically engineered bacteria designed to degrade these wires, thereby neutralizing the threat**. The following sections provide a detailed breakdown of the biotechnological components essential to this approach. This paper will explain the use of genetically modified insects specifically through CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) Technology first, for the detection of anti-personnel land mines through the nylon coat fishing of the tripwire by the use of "Termites" our genetically modified insect conditioned to target nylon-covered wires recognizing them as its food source. Second, after the detection process, the deactivation of the anti-personnel mine itself will happen through the use of our other genetically modified insect called "Shewanella" that already have a distinctive feature of interacting with metals. We will engineer these insects to disrupt the trip wire material by releasing corrosive chemicals effectively disabling the trip wire.

[1] "Ukraine's Landmines Need to Be Cleared before Minerals Can be Mined – Ukraine." *Relief Web.* Available at https://reliefweb.int/report/ukraine/ukraines-landmines-need-be-cleared-minerals-can-be-mined

[2] Perdue, Mitzi. "An Explosive Choice: Landmines and Ukraine." *CEPA*, 22 Nov. 2024. Available at https://cepa.org/article/an-explosive-choice-landmines-and-ukraine/

3.1 Anti-personal Landmines

Source: euro posters

The red sign, featuring a skull and crossbones along with the warning "Danger mines!", serves as a stark reminder that in areas of Ukraine once contested or occupied by Russian forces, the threat of war lingers beneath the surface, even in regions reclaimed or defended by Ukraine.

Russia's large-scale invasion has rendered Ukraine one of the most heavily mined countries globally. In under two years, the conflict has created what may be one of the most significant demining challenges since World War II.

The threat includes anti-tank mines, designed to target vehicles but incapable of differentiating between military equipment and civilian transport. Additionally, anti-personnel mines are deployed with the intent to injure or kill individuals, alongside improvised explosive devices such as booby traps that serve similar purposes.[3]

Source: Ukrainian government, 2023.

This image features a map identifying all known minefields in Ukraine, as well as areas that may be hazardous due to the potential presence of landmines.

One of the most distinctive features of the type of landmines we are tackling "anti-personnel" landmines is their unique attachment to a tripwire**. Anti-personnel landmines are made especially to push back or reroute foot forces from a certain region**. These mines, which are set off by tripwire, remote detonation, or direct pressure (such coming into touch with a person), have the potential to kill or paralyze their victims. Additionally, there are smart mines that, after a predetermined period of time, automatically deactivate.

[3] Kirby, Jen. "There Are Now More Land Mines in Ukraine than Almost Anywhere Else on the Planet." *Vox*, 30 Nov. 2023, available at https://www.vox.com/world-politics/2023/11/30/23979758/ukraine-war- russia-land-mines-artillery-humantarian-crisis

Anti-personnel mines can be classified into three primary categories:

1. **Blast:** Usually set off by someone standing on the pressure plate, a blast antipersonnel mine is only a few centimeters deep. In addition to destroying an object nearby and inflicting innumerable leg injuries, these mines are made to shatter the target object into pieces, which can lead to amputations and secondary infections.
2. **Bounding:** Usually, only a little portion of the igniter is buried with these. The mine is raised around a meter into the air by the igniter, which ignites a propelling charge. The mine then ignites a main charge that protrudes from the ground, injuring a person's head and chest. These mines are triggered by tripwires or pressure. Another name for this kind of mine is "Bouncing Betty."
3. **Fragmentation:** These mines may be set up to send pieces in a single direction (directional fragmentation mines) or discharge fragments in all directions. These mines shoot metal particles that can injure people up to 200 meters away. Both ground-based and bounding fragmentation mines are possible.[4]

A trip wire in an antipersonnel landmine is a triggering mechanism designed to detonate the mine when tension is applied to the wire. It is one of the simplest yet most effective ways to set off an explosive device, ensuring that any unsuspecting victim who disturbs the wire activates the detonation sequence. The trip wire is carefully positioned, often barely visible, stretched between two points or anchored to a mine's fuse. However, designed to blend into the environment, it is extremely difficult to detect.

3.2 Termites – The Detection process

Hence, the most effective method for detecting such landmines is to directly identify the tripwires themselves. **Within this context, our proposed approach involves the genetic modification of termites to specifically target and degrade nylon fishing line coatings that cover the trip wires in anti-personnel mines.** By conditioning these insects to recognize nylon-covered wires as a food source, they can be utilized for controlled degradation. This genetic modification can be achieved through various methods, including altering termites' digestive systems to process synthetic materials or modifying their chemical receptors to misidentify synthetic substances as natural food sources. A feasible approach to attain such modifications involves editing the genes responsible for chemoreception in termites using CRISPR technology. Once the desired genetic modifications are successfully implemented, the termites could be deployed across minefields via aerial dispersion, enabling them to detect the nylon- coated tripwires and gradually consuming the tripwires by forming linear feeding patterns along the wires.

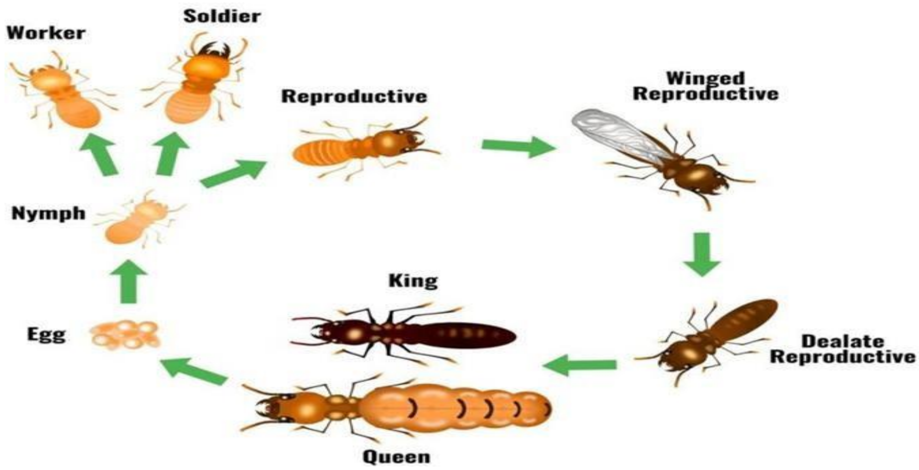
What are termites?

To begin with, it is essential to understand the basic biology and characteristics of termites. Since they are linked to cockroaches, termites are now included within the Blattodea order. Blattodea is an insect order that includes both cockroaches and termites. Previously classified separately as Isoptera, termites were reclassified under Blattodea after genetic research confirmed their evolution from cockroach ancestors. Despite differences in behavior— cockroaches being mostly solitary and termites eusocial—they share biological traits, including digestive symbionts that help break down organic materials.[5]

[4] Bonsor, Kevin. "How Landmines Work." *HowStuffWorks Science*, 22 Nov. 2023, available at https://science.howstuffworks.com/landmine.htm?s1sid=mde93t4zcm6tc6dgm4duw4j7Csrch_tag=4pvp tpwrbulg7bzfujh2yawb3kytrnxs

[5] "Termites Are Moving in with Cockroaches, Taxonomically" *Smithsonian*, 5 March 2018, available at https://www.smithsonianmag.com/smart-news/termites-are-moving-cockroaches-taxonomically-180968332/#:~:text=As%20far%20back%20as%201934,of%20the%20cockroach%20family%20tree

The termite life cycle is similar to that of cockroaches in that it consists of three stages: egg, nymph, and adult. Unlike bees, butterflies, and other insects with a full life cycle, developing termites do not have an inactive pupal or resting period. Termites are cooperative creatures. This indicates that they coexist in colonies with overlapping generations and caste-based labor divisions. Adult termites are divided into three main castes within each colony: workers, soldiers, and reproductives.



Source: ecoguardpestmanagement, termite-life cycle

Worker termites are small, pale insects that play a crucial role in the survival and growth of a termite colony. They are responsible for constructing and repairing the nest, foraging for food, feeding other members, and caring for the eggs, young, and queen. These workers are highly social and cooperative, communicating through chemical signals and pheromones. Soldier termites are specialized members of the colony, protecting it from threats like predators or other termite colonies. They have large, powerful heads and mandibles, which are their primary defense tools. Soldier termites are unable to feed themselves, so they provide pre-digested cellulose through trophallaxis

Reproductive termites play a vital role in the success of a termite colony. There are three main types: primary reproductives, secondary reproductives, and swarmers. Primary reproductives are responsible for reproduction and establishing new colonies, while secondary reproductives maintain the population size. Alates, or swarmers, are crucial for expanding the termite population. [6]

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[6] Media, Shoreline. "Termite Life Cycle: What Termites Look like at Each Stage." *Flick Pest Control,* 5 Mar. 2024, available at https://www.flick.com.au/blog/termite-life-cycle-what-termites-look-like-at-each-stage/?utm_source

What Do Termites Eat?

Source: greneaxe

Termites are primarily known for feeding on cellulose, a complex carbohydrate found in plant materials. Their diet, however, is not limited to wood. Key components of a termite's diet include:

- **Wood:** The main food source for termites, they consume both hardwoods and softwoods, making any wooden structure, from timbers to furniture, vulnerable to damage.
- **Plant Matter:** Termites feed on a variety of plant materials, including leaves, grass, roots, and even paper products made from plant fibers.
- **Other Cellulose Materials:** Termites also target cellulose-rich materials in human environments, such as cardboard, insulation, and certain fabrics.

In addition, there are several influences that affect termites feeding behavior, some of which include:

- **Moisture Levels:** Termites prefer humid environments and are drawn to areas with high moisture, such as damp wood or soil, which aids in the decay of cellulose, making it more appealing.
- **Temperature:** Termites thrive in warm, subtropical climates (24°C to 35°C) but may seek shelter indoors in colder regions to maintain optimal feeding and reproduction conditions.
- **Colony Needs:** Worker termites focus on foraging to meet the nutritional needs of the colony, guiding their feeding choices based on the colony's collective requirements.

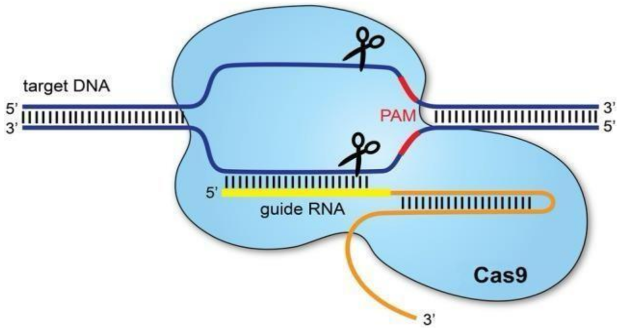
Termites can digest cellulose due to their symbiotic relationship with protozoa in their digestive systems. These microorganisms break down wood using enzymes that convert cellulose into sugars and nutrients. Termites that haven't reached maturity rely on mouth-to-mouth feeding from worker termites for nourishment. Nonetheless, Termites rely on their senses, as they are unable to see the location of food. Worker termites, which don't have eyes, navigate by trial and error during their tunneling. Once they discover cellulose, they return to the colony to recruit others and exploit the new food source.[7]

The main question here is, <u>how can we genetically modify termites conditioning it to detect nylon-covered wires of anti-personnel mines recognizing them as its food source?</u>

To begin with, genetically modifying terminates to detect nylon-coated tripwires requires a deep understanding of their biology, behavior and specific mechanisms concerned in sensing and responding to external stimuli this would combine both behavioral conditioning and genetic modification to alter terminate behavior. Termite colonies are made up of largely blind individuals that rely significantly on chemicals to identify food, detect infections, avoid predators, and execute intricate social communication. Termites, which function as "superorganisms" to attain ecological success and seriously damage structures through the wood products they eat, are greatly influenced by pheromones, the chemical markers they produce, and other chemical cues from their surroundings.

It has been evident in various studies that termites have mechanoreceptors that help them sense vibrations and physical interactions. Modifying genes involved in these receptors might enable termites to detect the specific tension, resistance, or vibrations created by nylon-coated tripwires. Also, one genetic modifications could make termites more sensitive to chemicals that may leach from the nylon coating, allowing them to associate the material with a threat or even as a source of food.[8] In insects, the antennae serve as the primary olfactory organs, playing a crucial role in detecting and interpreting chemical stimuli from their environment. These chemical signals, which may originate from conspecifics, natural predators, or host plants, are perceived through antennal sensilla and influence various behavioral decisions, including mate selection, host location, and predator recognition.

The behavior conditioning and genetic modification of termites to detect nylon coated tripwires in anti-personnel land mines can be done with the application of CRISPR-Cas9 technology that would condition termite sensory capabilities in tripwire detection. Initially, it is crucial to gain a thorough understanding of Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated protein 9 known asCRISPR-Cas9 technology in order to grasp how the process operates. Prior to that, it is important to comprehend the foundation of gene editing which involves modifying genetic material (DNA), whether by altering specific genes or an entire sequence.



Source: National Library of Medicine

Two crucial elements make up the gene-editing technique known as CRISPR/Cas9: an endonuclease called Cas9 (CRISPR-associated protein 9) that breaks double-stranded DNA to allow for changes to the genome, and a guide RNA that matches a desired target gene. RNA is produced by transcription of the CRISPR segments. This RNA has a guide sequence that matches the body's natural DNA. According to Dr Timothy Chan (a genomics and immunotherapy expert at the Cleveland Clinic), "that guide sequence can be tailored to whatever you want." "With a high degree of accuracy, you can then make specific changes or mutations in a part of the genome that you are targeting."[9]

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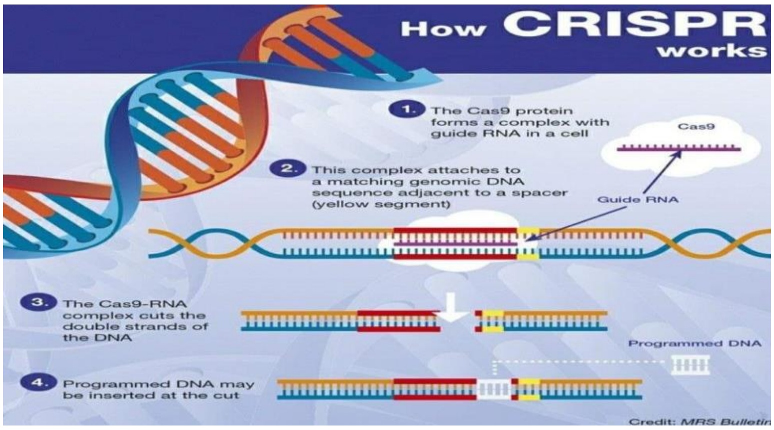
[7] Termi Home C Commercial. "What Do Termites Eat?" *Termi Home & Commercial*, 30 Jan. 2025, available at https://www.termihc.com.au/what-do-termites-eat/

[8] "Directional Vibration Sensing in the Termite Macrotermes Natalensis" *the Company of Biologists,* 15 Jul. 2014, available at https://journals.biologists.com/jeb/article/217/14/2526/12126/Directional-vibration-sensing-in-the- termite?



Returning to the core of our proposal, theoretically, termites can be trained to recognize nylon-coated tripwires in antipersonnel landmines using CRISPR-Cas9 technology, which blends behavioral conditioning and genetic engineering.

This can be accomplished through several methodologies:

- **Chemoreception:** Termites are able to identify chemical signals sent into their surroundings, such as pheromones. It may be feasible to alter termite genes that produce olfactory receptors to increase their sensitivity to certain compounds if nylon-coated tripwires leach them
- **Mechanoreception:** Termites use specialized organs, such as the subgenual organ, to sense vibrations and physical interactions. Termites rely on these organs to detect vibrations in their environment, a trait that is essential for communication and awareness. Termites may be able to detect the tension and vibrations created by a tripwire coated in nylon if genes linked to these mechanoreceptors are modified.[10]

CRISPR-Cas9 may be used to modify termite DNA and improve their sensory capabilities when the target genes have been determined.
There are two main strategies to think about:

- Increasing Sensitivity to Chemical Residues of Nylon-Coated Tripwire: We may make termites more sensitive to particular compounds that can leak from the nylon covering by altering the genes linked to their chemoreception pathways (for example, odorant receptor genes). For example, termites may be designed to better identify these substances if the tripwires generate distinct chemical fingerprints when they come into contact with soil or moisture.
- Enhancing Vibration Sensitivity: CRISPR-Cas9 may be utilized to alter genes that control the subgenual organ, which is essential for ground vibration detection. Termites may be trained to respond to the particular mechanical disruptions brought on by the tension or movement of a tripwire by fortifying the neural pathways involved in vibration detection. Their capacity to detect these vibrations remotely may be enhanced by genetic alterations.[11]

  Following the genetic modification of termites using CRISPR-Cas9, the next phase involves their behavioral conditioning. Behavioral conditioning is necessary for termites to acknowledge tripwires as a threat.

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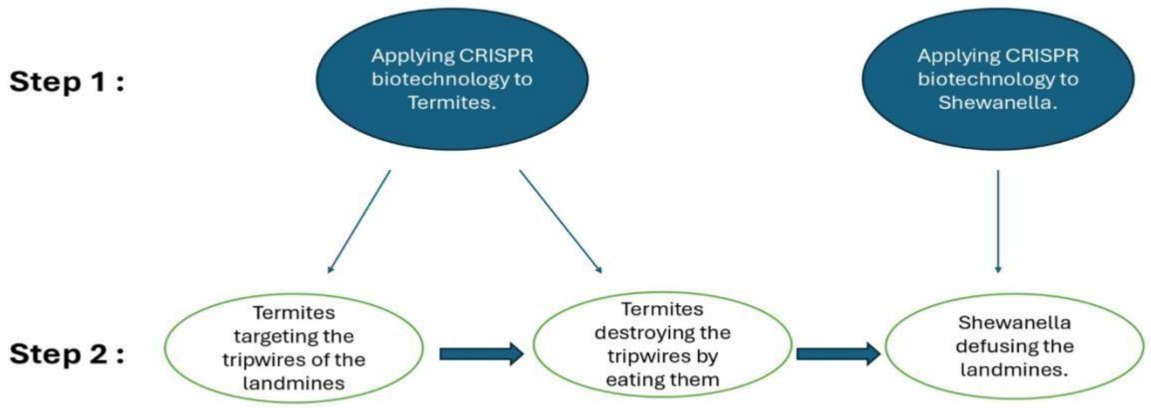
[9] "CRISPR Gene Editing 101." *Cleveland Clinic*, 15 Jul. 2024, available at https://health.clevelandclinic.org/crispr-gene-editing

Termites may be made to correlate the presence of tripwires covered in nylon with a certain behavioral reaction, such as gathering near the tripwires. In insects, such as pheromone-based communication, this kind of associative learning is a well- established occurrence.

After, these genetically modified terminates can be aerially sprayed in minefields, where they would be able to detect the nylon-coated tripwires because they have been genetically modified and behaviorally conditioned to do so. Their enhanced sensitivity to the chemical or mechanical cues would allow them to sense the tripwires forming linear lines on the tripwires themselves. Such an idea is highly feasible and possible to implement practically. Many organisms, including insects like flies and mosquitoes, have successfully undergone genetic changes utilizing CRISPR-Cas9. Although termite gene editing has not yet been investigated, it is theoretically possible to improve termites' sensory capacities using comparable methods. Considering termites' very simple genetic makeup, it's feasible that CRISPR-Cas9 might be used to alter their genetic makeup. Reasoned Method: The rationale for using CRISPR-Cas9 is based on the notion that termites are already naturally able to recognize certain chemical and physical stimuli. Increasing their sensitivity to particular tripwire characteristics by genetic alteration might improve their capacity to carry out a duty that promotes human safety.

3.3 Shewanella – Deactivation of the Landmines



Once the termites detect the landmines, the next phase of the process involves using Shewanella to neutralize them. The genus Shewanella comprises over 20 species, each possessing distinct properties and capabilities. However, this research focuses specifically on *Shewanella oneidensis* which is a group of Gram-negative, facultatively anaerobic bacteria recognized for their exceptional metabolic adaptability. These bacteria can reduce a wide range of electron acceptors, including metals, sulfur compounds, and even electrodes. They are commonly found in aquatic environments, such as marine and freshwater ecosystems, as well as in soil and sediments. Shewanella particularly is notable for its ability to transfer electrons to external electron acceptors, including metals and certain organic compounds.

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[10] Mitaka, Yuki, et al. "Caste-Specific and Sex-Specific Expression of Chemoreceptor Genes in a Termite." *PlOS ONE*, Public Library of Science, available at https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0146125

[11] Chen, Xien, and Subba Reddy Palli. " Genome Editing in Pests: Basic Science to Applications - Journal of Pest Science." *SpringerLink*, 24 Jan. 2024, available at https://link.springer.com/article/10.1007/s10340-023-01736-z?u

This unique trait allows it to perform respiration in oxygen-deprived environments by utilizing metals like iron and manganese. Due to this capability, this bacterium has been extensively studied for its applications in bioremediation, as it can break down toxic substances like TNT and other environmental pollutants. Additionally, its interactions with metals have led to research into its potential uses in bioenergy and biotechnology**. It is widely utilized in various scientific and industrial fields due to its ability to reduce diverse substances**. In environmental science, it plays a crucial role in bioremediation by detoxifying heavy metals such as uranium, chromium, and arsenic, as well as degrading organic pollutants like oil under anaerobic conditions. This makes it a valuable tool for environmental cleanup. Moreover, Shewanella contributes to microbial fuel cells (MFCs) by generating electricity from organic waste through electron transfer to solid surfaces like electrodes. In industry, it is employed for metal recovery and bioleaching, assisting in recycling metals by reducing iron and manganese oxides.

Beyond these applications, it serves as a model organism in research for studying extracellular electron transport and metabolic flexibility, which are essential for synthetic biology and bioengineering. Additionally, it is being investigated for its role in antimicrobial resistance and the production of bioactive compounds. Overall, Shewanella is a vital organism in advancing clean energy, environmental remediation, and innovative biotechnological solutions.

How can we engineer Shewanella to disrupt tripwires?

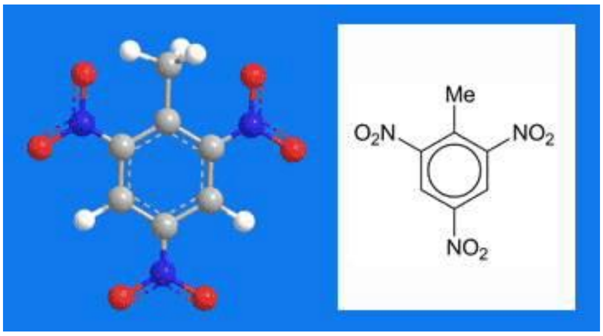
Landmine trip wires, often composed of metal, can be effectively targeted using *Shewanella*'s natural ability to degrade metals. Through genetic modification, these bacteria can be engineered to secrete corrosive compounds, such as acids or chelating agents, in response to the detection of metal trip wires. This genetic programming could utilize advanced molecular tools, including CRISPR-Cas9 and gene expression systems, to develop sensor-responsive circuits that activate the bacteria upon identifying specific environmental cues, such as the chemical signatures of explosives or the composition of trip wire materials. **The release of corrosive substances would gradually weaken and dissolve the metal components of the trip wires, rendering them structurally unstable and non-functional. This approach ensures the safe neutralization of landmines without triggering accidental detonation**. Furthermore, the same strategy could be adapted to degrade other structural elements of the landmine, including plastic or synthetic casings, effectively dismantling the device while leaving behind only inert remnants. The bacterium primarily consumes simple organic compounds, such as lactate, acetate, and pyruvate, while also using various inorganic electron acceptors, including iron (Fe^{3+}) and manganese (Mn^{4+}) oxides, sulfates, nitrates, uranium, and chromium—especially in contaminated environments. Due to this metabolic flexibility, *Shewanella oneidensis* plays a critical role in bioremediation, breaking down heavy metals and other pollutants in low-oxygen environments. Additionally, Shewanella can interact with components found in explosives, such as trinitrotoluene (TNT), a common substance in landmines. The nitro groups ($-NO_2$) in TNT can serve as electron acceptors during microbial respiration, allowing *Shewanella* to reduce these groups through its metabolic processes. This capability facilitates the breakdown of TNT into less toxic byproducts, further demonstrating the bacterium's potential in environmental decontamination and landmine disposal.[12]

[12] "Shewanella Oneidensis." *Shewanella Oneidensis* – an Overview, *ScienceDirect Topics,* available at https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/shewanella- oneidensis

The following describes how Shewanella oneidensis breaks down landmines in four processes for defusing them:

1. **Reduction of Nitro Groups** Trinitrotoluene (TNT) and other explosives include nitro groups ($-NO_2$), which Shewanella oneidensis targets. As electron acceptors, these groups receive electrons from the bacteria during metabolism, transforming TNT into less hazardous metabolites such as aminodinitrotoluenes.
2. **Activity of Enzymes** By lowering the nitro groups in TNT and other explosive substances, the bacteria create specialized enzymes called nitro reductases that facilitate their destruction.
3. **Transfer of Electrons Outside Cells** Shewanella is highly skilled in moving electrons to materials outside of its cells, such as explosive remnants in polluted soil, so it may interact with and break down these molecules directly.
4. **Synergy in Bioremediation** Shewanella frequently works with other microbes in contaminated situations to completely break down explosives into innocuous materials like water, carbon dioxide, and nitrogen compounds.

Molecule of Trinitrotoluene



<u>What is the method for deploying Shewanella into minefields?</u>

Innovative delivery techniques would be necessary to guarantee that the bacteria reach the landmines efficiently. To shield Shewanella from environmental stresses such changes in soil pH, moisture content, or temperature, they might be encased in biodegradable carriers or gels. Drones, robotic devices, or conventional methods might then be used to distribute these carriers over minefields. With the use of such delivery systems, Shewanella might enter the wire or casing of landmines and start the corrosion process without outside intervention. The bacteria might potentially be designed to function in cooperative microbial systems, where distinct bacteria specialize in decomposing different landmine components including explosives, metals, and plastics, in order to increase efficiency.

Moreover, Shewanella may be tasked with more than just neutralizing explosives or trip wires. Ecosystems are contaminated for decades by the hazardous leftovers left in the soil by many landmines, such as TNT or heavy metals. Shewanella might be used to simultaneously clean up the environment and make mine-infested areas safer for people, animals, and crops by reducing toxins and heavy metals. Shewanella offers comprehensive treatment by addressing the structural elements of landmines as well as the nearby pollutants. This dual purpose would address both short-term safety issues and long-term environmental effects by disabling landmines and restoring harmed ecosystems. Especially that Classical demining techniques, including controlled detonations or mechanical removal, can have serious ecological effects, such as contaminating the soil, destroying nearby ecosystems, and increasing the possibility of unintentional explosions. Shewanella-based systems, on the other hand, are a far more sustainable option since they work via biological processes that naturally break down dangerous substances. It is feasible to target certain landmine components, such metal trip wires or explosive ingredients, and interfere with their operation without endangering the environment by employing genetically modified microbes. By doing this, the ecological impact of landmine removal operations is reduced, protecting the nearby soil and aquatic habitats.

In terms of price, Shewanella offers a less expensive substitute for conventional demining techniques. The labor-intensive and costly equipment needed for manual demining may not be available in landmine-affected areas. Landmine-affected areas, particularly those in developing nations, may not have access to the costly and labor-intensive equipment needed for manual demining. Additionally, mechanical devices are expensive to deploy and have a significant chance of damage. However, **the cost of producing genetically engineered Shewanella bacteria is far lower, and delivery systems like drones or biodegradable containers are reasonably priced**. Furthermore, these bacteria can operate independently once they are deployed, which eliminates the need for ongoing human supervision and lowers operating expenses over time. Shewanella is a potential option for safe, sustainable, and reasonably priced landmine neutralization because of their cost-effectiveness and environmentally beneficial qualities. Finally, Shewanella can be used for purposes other than landmines. Other dangerous situations, including clearing up unexploded ordnance, reducing industrial waste, or even developing microbial fuel cells to power distant demining equipment, can benefit from their capacity to interact with metals and contaminants.[13]

Criteria	Traditional Methods	Shewanella-Based Methods
Approach	Mechanical removal, detonations, manual clearance, by animals	Biological degradation using Shewanella bacteria
Environmental Impact	Potential soil and habitat damage	Eco-friendly, minimal disruption
Cost	High due to labor and equipment	Low; bacteria are inexpensive and scalable
Risk to Humans	High; danger of accidental explosions	Low; bacteria work autonomously
Speed	Slow; labor-intensive	Faster; bacteria can cover large areas
Precision	Limited; risk of triggering undetected mines	High; bacteria can be engineered for specific targets
Safety	Accidental explosions and collateral damage	Safer; kill switches can deactivate bacteria

4.Conclusion

In conclusion, our proposal suggests a biotechnological method for detecting and defusing landmines in a faster, cheaper, and eco-friendly way, which is far better for the environment than traditional methods of landmine disposal. Our solution targets anti-personnel mines.

This proposal begins with the use of genetically modified termites. By applying CRISPR biotechnology, these termites are programmed to recognize nylon-coated tripwires in anti- personnel landmines as their biological food source. These genetically modified insects will help us detect where landmines are exactly located after they sense the tripwires and form into straight lines. Beyond their role in landmine defusing, these termites improve the ecosystem by aerating the soil, enhancing nutrient cycling, and contributing to its overall fertility, making previously dangerous and unusable land productive again.

To spread the termites efficiently, we propose using aerially spraying them in minefields or even suspected minefields.

The second step in our proposal involves employing our bacteria; Shewanella oneidensis, which is a highly versatile bacterium known for its ability to degrade harmful compounds through extracellular electron transfer. This bacterium can target and break down the explosive residues in the soil, such as TNT, by reducing their toxic components into harmless byproducts like water and nitrogen compounds. Not only does Shewanella contribute to rendering the area safe, but it also helps detoxify the environment, restoring polluted land for future use.

We can deploy **Shewanella oneidensis** using drones or by introducing it into the soil near landmine-affected areas. Since the bacterium can rapidly spread and interact with explosive residues, it can effectively neutralize hazardous compounds, making the land safe and ready for use again. After deploying Shewanella into minefields, it will slowly disrupt the electron flow of the tripwires leading to their complete deactivation.

This two-step biotechnological solution not only addresses the urgent need for landmine removal but also ensures long-term environmental benefits by rejuvenating soil health and promoting ecological sustainability.

Countries with the highest number of landmines typically have a history of conflict or ongoing instability. Recent data shows that countries like Afghanistan, Cambodia, Angola, Colombia, Iraq, Yemen, Myanmar, Syria, Ukraine, and Somalia face significant challenges due to unexploded ordnance, often the result of past wars, civil conflicts, or ongoing hostilities. Lebanon, our country too, is heavily affected by landmines, particularly in the south, where we saw these landmines by ourselves, as this problem remains a serious concern.[14]

As of 2024, approximately 110 million landmines are estimated to be buried or scattered across nearly 70 countries and territories worldwide. These mines pose significant risks to civilians, hinder economic development, and impede access to essential resources. The cost of removing each mine ranges from $300 to $1,000, making the demining process both challenging and expensive.[15] Nonetheless, despite these challenges, ongoing international efforts aim to clear contaminated areas and mitigate the dangers posed by landmines.

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