Digging in the Dirt

Chemical and biological sensors could aid the search for hidden land mines

By CORINNA WU

Many people regard antipersonnel land mines as the worst form of pollution on the planet. An estimated 100 million of these small explosive packages, designed specifically to maim or kill when stepped on, lie buried around the world, remnants of past military maneuvers or terror campaigns. These devices have turned fields, forests, and villages into treacherous, unusable terrain.

Nations with the severest land mine problems include Afghanistan, Angola, Bosnia, and Cambodia, where years of war have littered the landscape with the deadly devices. In many parts of these countries, the activities of everyday life threaten civilians with possible injury or death. In Cambodia, 1 of every 250 people has lost a limb or limbs because of an encounter with a mine. These deaths and permanent injuries among the population exact a crushing economic toll from nations that can ill afford it.

With so many mines already in the ground, the problem of removing them seems almost insurmountable. Even if no more mines were laid, it would take 1,000 years to clear them all at current removal rates, says Ron Woodfin of Sandia National Laboratories in Albuquerque, N.M. A dramatic increase in the number of workers could speed up the demining process, but many people are hoping that new technology can quicken the pace.

Some of the more promising approaches now in development employ chemical and biological sensors to detect traces of explosives emitted by mines. Such sensors could enable a demining team to survey a large area and identify hot spots quickly and safely.

Perhaps more important, sensors can indicate where there aren't any mines. The ability to see that an area is safe would allow demining teams to focus their energies on the trouble zones, says Albert M. Bottoms, president of the Mine Warfare Association (MINWARA), an educational organization in Monterey, Calif. However, "even that is beyond our current technology," he says. Bosnia alone has an estimated 18,000 minefields. "To our utter dismay, we don't know how to do a survey of even one of them, let alone 18,000," he remarks.

CARE

Four different types of land mines (clockwise from upper left) from Germany, Italy, Romania, and South Africa.

The various designs of antipersonnel mines form a gruesome gallery of weapons. According to the humanitarian organization CARE in Atlanta, there are more than 600 types. Explosive blast-effect mines tear off a person's lower leg and drive dirt and bone fragments into the wound. Fragmentation mines are stuffed with ball bearings and metal scraps to pepper their victims with shrapnel. Mines nicknamed "bouncing Betties" pop out of the ground and explode at waist height, shooting out fragments on all sides.

The military can often use brute force to rid an area of antipersonnel mines. "They're not trying to remove the mines as much as defeat them," says Dick Davis, director for defense programs at Oak Ridge (Tenn.) National Laboratory. A heavily shielded, remote-controlled vehicle can quickly forge a safe, though limited, path for troops by turning up and detonating mines as it rolls along.

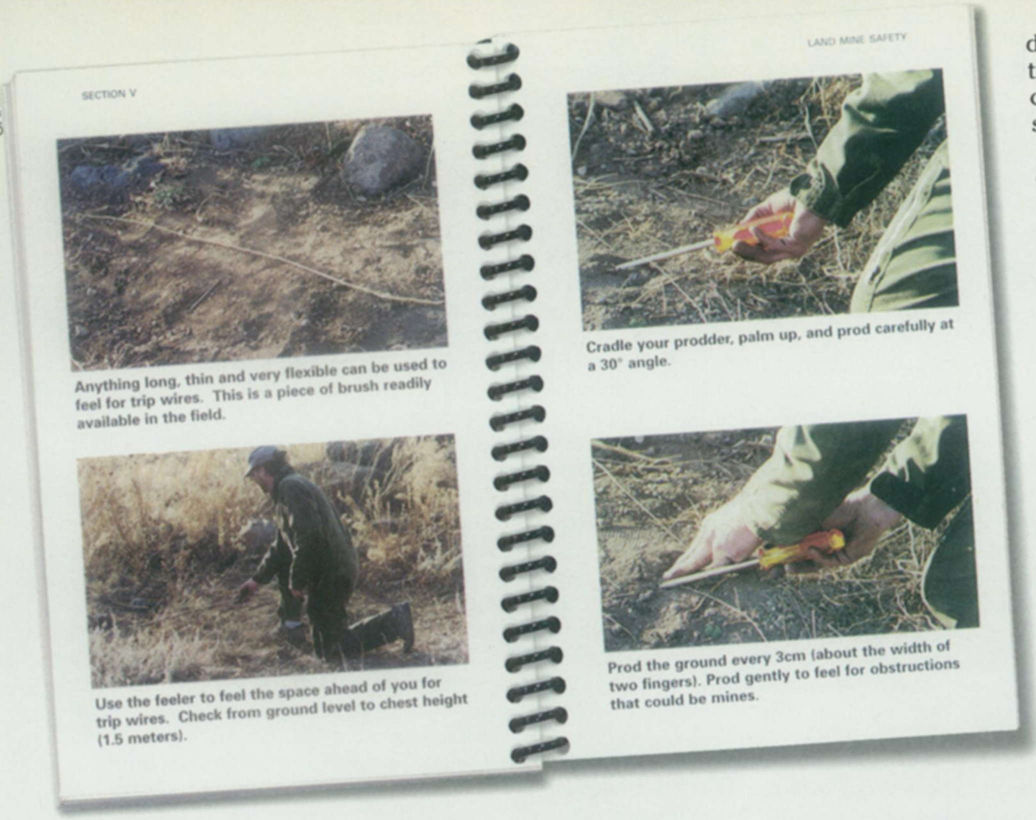
Demining an entire area for humanitarian purposes—so that children can play and families can move about free of fear—is much trickier. Workers, usually trained civilians, slide a rod at an angle into the soil, probing gently for any suspicious objects, which include both unexploded artillery and mines. This process, required to clear an area as thoroughly as possible, is dangerous and frustratingly slow.

Bottoms sees promise in new technologies that might make mine clearance safer and faster. He recalls a videotape he once viewed of "a line of peasants, walking across a field, poking the ground with sticks. Technology has to offer us something better than that."

Finding effective detection methods is particularly difficult because most of the mines are made of plastic instead of metal, rendering standard metal detectors useless for humanitarian demining.

Other types of imaging systems, such as infrared detectors or ground-penetrating radar, can alert deminers to objects buried in the ground, but they

CARE



The humanitarian organization CARE distributes a land mine safety handbook to staff. Many of CARE's development projects had ground to a halt because of mines, forcing the group to train its workers to find and remove them. These two pages from the book show that current techniques for detecting land mines are both dangerous and tedious.

don't distinguish among mines, unexploded shells, or innocuous metal fragments. "In Afghanistan, they find 115 [harmless objects] for every one that has explosives in it," says Woodfin. Nevertheless, each hit has to be carefully probed, wasting valuable time. The large number of false positives can also cause a deminer's attention to flag, with potentially disastrous results. "False positives are bad, but false negatives are even worse," says Bottoms.

In order to make detectors that don't cry wolf so often, several groups of researchers are focusing on the essential difference between benign objects and deadly mines: the presence of explosives. Since most mines leak a little bit of explosive into their surroundings, chemical and biological sensors can sniff them out (SN: 4/6/96, p. 223). Deminers can then ignore other buried objects.

These new sensing techniques are variations on methods developed to detect chemicals and hazardous waste in the environment.

Most of the "cheap and dirty" mines contain the explosive trinitrotoluene, or TNT, says Woodfin. Some use plastic explosives such as RDX, a favorite of terrorists.

At Oak Ridge, scientists are developing sensors that can identify the chemical signatures of these compounds. "None are perfected at this point," says Davis, "but they will prove beneficial in 2 to 4 years."

The sensors could be included in long-handled, handheld detectors or mounted on a robotic vehicle. Such devices could quickly indicate the presence of mines while the deminers maintain a safe distance.

Some researchers are working to make a standard laboratory apparatus portable enough to be taken to a minefield. Those at Oak Ridge have trimmed a chemical-sensing machine called an ion trap mass spectrometer to the size of a suitcase, says Davis. The current version, including batteries, weighs 60 to 70 pounds, making it "luggable, not quite portable." Their goal is to get the spectrometer to the size of an attaché case and run it off a car battery.

At Sandia, researchers are scaling down another type of mass spectrometer, originally developed to check airline passengers for explosives.

A different type of sensor under development depends on a tiny silicon cantilever just 1 micrometer wide that "looks like a small diving board," says Thomas G. Thundat, a scientist at Oak Ridge. A coating on the cantilever—platinum, for example—absorbs molecules of explosives. When the cantilever is heated, the miniature explosion occurs at a characteristic temperature, indicating the presence of the substance. Once the explosive burns off, the sensor can be used again within 1 second, says Thundat.

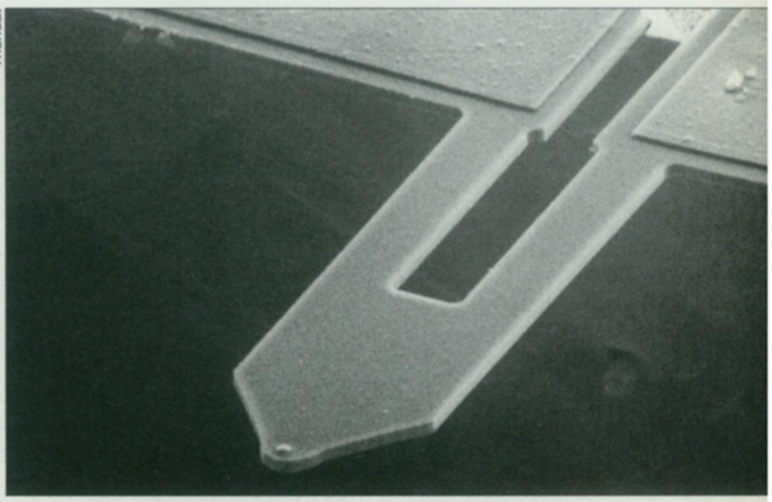
Other cantilever-based sensors have also been designed to detect individual chemicals by measuring vibrations instead of burn temperatures. Thundat and his colleagues have coated the cantilevers with different materials that selectively absorb a range of chemicals given off by explosives.

Absorbed molecules change the mass of the cantilever and, therefore, the frequency at which the cantilever vibrates. By focusing a laser on the end of the cantilever, researchers can detect the change in frequency. So far, Thundat says, they can detect environmental pollutants such as acetone, mercury, and toluene—but not yet its derivative TNT—using these devices.

In 1 square centimeter of a silicon chip, researchers can carve out 648 cantilevers using standard circuit manufacturing techniques. Such an array could serve as an artificial nose, sensing a variety of substances without using a lot of power.

Indeed, sensors can take lessons from some real noses. Dogs can smell explosives with "breathtaking" efficiency, says Bottoms, but they are expensive to train

Thundat



Miniaturized features are required to make sophisticated detectors small enough for field use. This electron micrograph shows a cantilever about 200 micrometers long.

and handle. Sandia scientists are assisting a company called Nomadics in Stillwater, Okla., in developing a chemical sniffer. Trying to emulate what dogs do when they inhale and exhale near the ground, the sniffer stirs up dirt particles, sucks them in, and electrostatically traps them. Traces of explosives that stick to the particles can then be identified.

"By far the largest percentage [of explosives] is adsorbed to soil particles," says Woodfin. "Only minor fractions are found in vapor." Soil concentrates the substances so that they can be analyzed more easily.

Organisms that can be added to soil also play a part in explosives detection. At Oak Ridge, researchers have genetically engineered bacteria to light up in the presence of TNT.

When certain bacteria ingest organic molecules, they turn on the production of regulatory proteins. By inserting a gene for a luminescent or fluorescent protein next to the gene for the regulatory protein, the researchers can induce the bacteria to produce both proteins whenever they come into contact with organic molecules (SN: 6/4/94, p. 358). In this way, glowing bacteria signal the presence of the explosive in the environment.

Robert S. Burlage and his colleagues at Oak Ridge have engineered several strains of the bacterium *Pseudomonas putida* to glow with visible or fluorescent light when they scavenge TNT and dinitrotoluene, a related chemical (SN: 11/9/96, p. 150). Burlage is presenting the results of this project at the Third International Symposium on Technology and the Mine Problem to be held at the Naval Postgraduate School in Monterey, Calif., next week.

Later this year, the group will test the bacteria on a small simulated minefield, spraying the plot of land with the bacteria and waiting 3 hours for them to produce the glowing proteins. Luminescent bacterial strains should be visible to the naked eye, whereas fluorescent ones will require ultraviolet light in order to be seen.

Burlarge expects eventually to apply the technique to real minefields, using a crop duster to shower an area with the engineered bacteria. Where the bacteria contact explosives, they will give off light that can be mapped from the air or viewed on the ground.

Burlage's team had previously engineered bacteria to report the presence of several environmental pollutants: toluene, naphthalene, and mercury. In 1996, the Environmental Protection Agency approved the use of these organisms for cleaning up polluted areas.

Mines lie buried in so many different environments that no single method can deal with them all. Researchers are therefore developing a variety of technologies. In some places, deminers may need to apply a combination of techniques, each based on a different physical principle, in order to reveal a minefield's secrets. Discovering how to use advanced data analysis to combine these disparate lines of information adds another layer of complexity to the challenge.

Some land mines create a shorter-term hazard than others. So-called smart mines self-destruct after a set period of time. The United States makes an effort to use only smart mines, says Bottoms. However, a country like China, which has a stockpile of 50 million conventional mines, probably won't replace them in the near future.

At the upcoming conference, a representative from the U.S. Army has been invited to speak on the Army's efforts to find alternatives to antipersonnel land mines, Bottoms says. "Offhand," he adds, "I can't think of what those would be." □

Biomedicine

An enzymatic sex difference

Why do so many men suffer from heart attacks earlier in life than women do? A new report hints that an enzyme in the blood may help explain the difference.

John E. Hokanson of the University of Washington, Seattle and his colleagues studied 25 men and 39 women, all of whom had normal concentrations of cholesterol—including low-density lipoprotein (LDL), the so-called bad cholesterol—in their blood. The researchers took samples of the volunteers' blood and measured the activity of an enzyme called hepatic lipase. They discovered that hepatic lipase activity was just over 50 percent higher in men than in women.

The researchers also found that the men had significantly lower concentrations of high-density lipoprotein, or good cholesterol, as well as more of a particular type of bad cholesterol—the small, dense LDL thought to be the worst of the bad cholesterol.

Hokanson and his colleagues believe that higher concentrations of hepatic lipase lead to the unfavorable lipid profile seen more commonly in men. Estrogen, the primary female sex hormone, appears to regulate hepatic lipase, leading the researchers to speculate that estrogen keeps concentrations of hepatic lipase low in premenopausal women.

After menopause, a woman's risk of heart disease starts to rise. Hokanson suggests that this risk is related to the increase in hepatic lipase enzyme. Hokanson presented the team's findings on March 20 at a meeting of the American Heart Association in Santa Fe, N.M. —*K.F.*

Cigars linked to disease of heart

Many cigar smokers believe they are protected from tobacco's nasty health effects because they don't inhale as much as cigarette smokers do. A new study dispels that myth.

Carlos Iribarren of the Kaiser Permanente Medical Care Program's research division in Oakland, Calif., and his colleagues studied the number of deaths among 225 men who smoked only cigars and compared them to deaths among 14,200 men who had never smoked any form of tobacco.

The researchers found that regular cigar smokers had a 25 percent higher death rate overall than the nonsmokers. In addition, the cigar puffers faced twice the risk of dying from all forms of cancer and from certain diseases of the circulatory system, such as cardiomyopathy, a disorder of the heart muscle. Iribarren described the group's results last week at an American Heart Association meeting in Santa Fe, N.M.

Iribarren speculates that toxic chemicals in cigar smoke may pass through the lining of the inner mouth and into the bloodstream. There, the toxins may damage the blood vessels or the heart. While other studies have linked cigar smoking to cancer, this is one of the first to link stogies and cardiovascular disease. "This finding needs to be confirmed," Iribarren notes. —*K.F.*

Migraine's link to heart problems?

People who suffer from chest pain are more likely to experience migraine headaches, according to a study presented last week at the American Heart Association's meeting in Santa Fe, N.M.

Kathryn M. Rose of the University of North Carolina at Chapel Hill and her colleagues studied 12,466 men and women and found that people who reported at least two attacks of angina were more likely to have suffered from migraine headaches. Angina is the pain that results when the arteries supplying the heart with blood constrict or are blocked. Migraines are caused by the narrowing of blood vessels leading to the brain.

The researchers don't know whether the link occurs by coincidence or whether the conditions stem from similar causes, says Rose. —*K.F.*