SCIENCE NEWS of the week

After Bhopal: Tracing Causes and Effects

Shortly after midnight on Dec. 3 last year, a cloud of deadly methyl isocyanate vapor escaped from a storage tank at a Union Carbide chemical plant in Bhopal, India. Within hours, more than 2,000 people died and tens of thousands were injured. Since then, two questions have dominated investigations of the Bhopal tragedy: Why did it happen, and could such a disaster occur in the United States?

The answer to the first question is slowly emerging, although findings so far are incomplete and controversial. Last week, Union Carbide Corp., based in Danbury, Conn., reported the results of its investigation. A team of seven engineers and scientists did about 500 experiments in trying to match the chemical residues in the leaking storage tank in order to reconstruct the events at Bhopal. They conclude: "This incident was the result of a unique combination of unusual events."

The study suggests that somehow a large volume of water — between 120 and 240 gallons — was "inadvertently or deliberately" pumped into one of three tanks storing liquid methyl isocyanate. The investigators did not rule out sabotage. The presence of water triggered a heat-generating chemical reaction. The high temperature allowed chloroform, a solvent contaminating the methyl isocyanate, to decompose. The resulting chloride ions corroded the stainless steel tank, releasing iron, which catalyzed another "runaway" reaction. At some point, the tank could no longer withstand the steadily increasing temperature and pressure, and in the end about 50,000 pounds of methyl isocyanate escaped.

The Union Carbide report notes that several "critical" violations of company safety procedures also contributed to the disastrous leak. A refrigeration system that was supposed to keep methyl isocyanate cool and relatively unreactive had been shut down five months before the accident. A flare tower designed to burn off vented gases was not operating. An alarm meant to warn of rapid temperature rises did not sound at the time of the accident.

Responsibility for safety lies chiefly with local plant managers. Says Union Carbide Chairman Warren M. Anderson: "That plant should not have been operating."

Partly because the Indian government denied Union Carbide investigators access to important documents and to plant employees, uncertainty still surrounds the events in Bhopal. A spokesman for the Indian Embassy in Washington, D.C., protested that Union Carbide's implication that Indian plant personnel failed to do their jobs properly was "unjustified and unacceptable." The Indian government is conducting two inquiries of its own into the causes of the Bhopal disaster.

In addition, S. Varadarajan, India's chief scientist and leader of a technical team studying the accident, stands by his team's conclusion that only a small amount of water entered the storage tank, initiating a somewhat different but equally devastating sequence of chemical reactions. Indian scientists are preparing to open the storage tank for a more complete study.

Nevertheless, says Anderson, "We can say with a great deal of confidence what went wrong technically at Bhopal." Adds Jackson B. Browning, Union Carbide's vice president for health, safety and environmental affairs, "Now, after the investigation, ... we can confidently say: It can't

To honeybees, a picture is worth a thousand line angles

Honeybees are finicky foragers when it comes to searching for nectar — and for good reason. Some flowers provide a heartier meal; others are dangerous when honeybees land on them. How do honeybees distinguish nectar-bearing from non-nectar-bearing flowers and safe from dangerous flowers?

With "photographic images," says biologist James Gould at Princeton (N.J.) University. Gould's experiments, reported in the March 22 SCIENCE, show that honeybees can store flower patterns as low-resolution images, contradicting earlier studies that suggested bees remember only isolated features of flowers, such as prominent line angles or the ratio of edge to area.

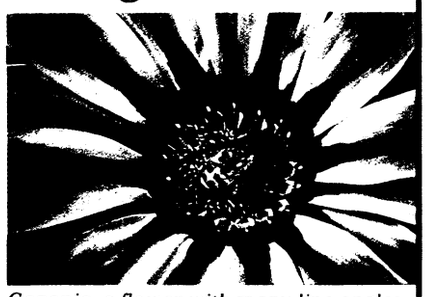
"The old idea," Gould says, "is that they remember a checklist of characteristics — much like a description of a murder suspect whose hair and eye color are known, but with no photograph." Gould's data indicated that honeybees can remember how flower parts are arranged in relation to each other, a feat possible only when photographic images, not isolated features, are remembered.

Photos: Kenneth Lorenzen

Honeybee "drinks" nectar from orchard maid flower.

In his experiments, honeybees were given a choice between two similar patterns that differed only in the spatial relationship between their parts. One of the patterns provided a sugar reward, the other did not. After being reinforced on the pattern providing the sugar, the bees were offered the same patterns in another trial. This time the patterns' positions were reversed, and neither provided a reward. Yet in most cases bees chose the pattern on which they had been reinforced in the previous trial, suggesting that they had remembered the spatial relationships of the elements in the pattern.

Honeybees' ability to distinguish different flowers and flower parts can help them avoid dangerous situations. For example, alfalfa blossoms' unusual arrangement of petals and stamen can be fatal to honeybees. The pollen-bearing stamen of an alfalfa blossom is covered by a central petal. When an insect lands on the flower, the petal releases the stamen and sweeps pollen upward to facilitate pollination. The mechanism is adaptive for large insects, but honeybees trying to pollinate unopened flowers will be jolted off or trapped inside the central petal. In a separate experiment, Gould showed that honeybees quickly learn to distinguish opened from unopened flowers, "showing that they have good pictorial memory."



Gazania, a flower with many line angles.

The studies show that many scientists' "presumptive vertebrate-invertebrate dichotomy is false," Gould says. But in order to truly bring vertebrate bias down to size, Gould will have to show that honeybees have size constancy — the ability to remember something they first saw close up when they later see it from farther away. —*D.D. Bennett*

happen here."

Meanwhile, Union Carbide has taken steps to reduce the risk of problems at its recently closed plant in Institute, W. Va., in preparation for reopening the plant as early as next week. These steps include installation of a computerized chemical vapor warning system, the use of chloroform instead of salt water for storage tank cooling, the reduction of methyl isocyanate inventories and louder sirens to warn the community.

However, some U.S. critics are not satisfied that the Union Carbide scenario accounts for the Bhopal leak. If a different sequence of reactions had taken place, as the Indian scientists suggest, then it still isn't clear that a similar problem can't occur in the United States.

"Union Carbide doesn't really have a basis for making the kind of judgments as to what exactly happened," says A. Karim Ahmed of the Natural Resources Defense Council, an environmental group based in New York. "We need an independent assessment of whether the plant in West Virginia is, in fact, as safe as Union Carbide officials are claiming it to be."

The Bhopal tragedy has also prompted the U.S. chemical industry to look more closely at its safety practices. This week, the Washington, D.C.-based Chemical Manufacturers Association announced a program that focuses on integrating chemical plant emergency procedures with a community's emergency-response plans. At the same time, the program is designed to increase public access to information about hazardous chemicals.

In response to the Bhopal disaster, Congress is collecting information from the chemical industry on the hazards that various chemicals present to communities where plants are located.

— I. Peterson

Penn State heart gets nod

There is now more than one U.S. government-approved replacement for the human heart. On March 14, the Food and Drug Administration okayed six trials of the "Penn State heart."

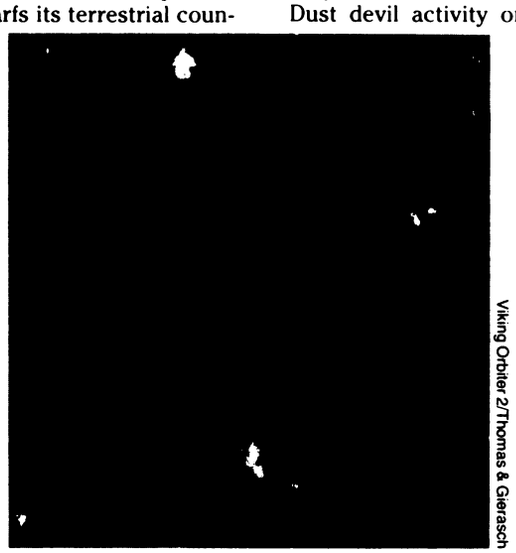
The newly approved model differs from the Jarvik-7, which has federal approval for four more implants. According to a Pennsylvania State University spokesperson, the sack through which the blood passes is seamless to help prevent blood stagnation and clotting; disks within the device are made of plastic rather than more brittle carbon; and blood flow controls are incorporated into the device rather than requiring manual adjustment.

William S. Pierce of the university's Hershey Medical Center has been developing the Penn State heart since 1970, not as a permanent implant but as a holding measure to allow a person with a severely damaged heart to survive until a human heart is available for transplantation. □

Towering dust devils discovered on Mars

The most drought-ridden wastes of sub-Saharan Africa are almost verdant compared with the planet Mars, which was completely hidden from view by a global dust storm when the U.S. Mariner 9 spacecraft arrived there in 1971. Decades before that, astronomers had noted surface changes — so vast as to be visible all the way from earth — that have since been attributed to redistribution of dust by the Martian winds.

Now two researchers report yet another Martian dust spectacular. Not unexpected, it nonetheless dwarfs its terrestrial counterpart: "dust devils," swirling, tornado-like columns of dust that on earth may range from mere centimeters to hundreds of meters in height. But the dust devils of Mars, according to Peter Thomas and Peter Gierasch of Cornell University in Ithaca, N.Y., sometimes loom as much as 6 kilometers — more than 3½ miles — above the parched terrain.



Viking Orbiter 2/Thomas & Gierasch

"Dust devils" loom over the Martian plains.

Thomas and Gierasch spotted the devils while looking through photos taken by the two orbiting Viking spacecraft, which got to Mars in the summer of 1976 and together took more than 51,000 images of the planet below. Only a small fraction of the photos were made from low enough altitudes to reveal such features, the scientists say, "but the storms appear not to be rare in those [photos] taken near midday and at low latitudes, where the sun is high in the sky and surface heating is intense." In all, says Thomas, the 99 dust devils so far identified, along with other "tentatives" that need further study, range in height from 0.5 to 6.0 km (most are 2 to 3 km). And if everything suspected of being a dust devil turns out to be one, the vast majority of them are clustered in an area where there is one such feature, on the average, for every 30-by-30-km patch of ground.

Since the orbiters were looking down on the features from above, the photos do not show the dust devils as the towering columns that would be visible to an observer on the surface. The key to determining their heights is to measure their shadows. In the photo shown, taken by Viking Orbiter 2 of a spot at about 41° north latitude by 143° longitude in the Arcadia Planitia region of the Martian northern hemisphere, the sun is shining down at about a 45° angle, so that the shadows are about the same heights as the dust devils themselves.

Among the Viking images that are sharp enough, most of the dust devils are concentrated in a region from about 33°N to 43°N and 142°W to 155°W in Arcadia, with a few others at about 37°N by 192°W in Utopia Planitia. All were spotted in the mid-afternoon during the northern hemisphere's summer, and they seem to occur mostly in areas that are relatively smooth.

Dust devil activity on Mars was predicted in 1964 by Jack A. Ryan, now with California State University in Fullerton. Ryan has studied Martian meteorology at length with the aid of data from the Viking orbiters and landers. It is not absolutely certain that the features in the images represent true, rotating dust devils, but, says Ryan, "they certainly have all the appearance we would expect to see." The possibility is also consistent with Ryan's finding that a number of vortices — the same kind of swirling winds that can sometimes pick up loose particles to form dust devils — have crossed over the wind speed and direction sensors of the Viking landers.

As for whether such spinning winds actually pick up enough surface material to form visible dust devils, he notes, that depends on such factors as temperature, the amount of available loose surface grains, the size of the grains and the cohesion between them. Could the photographed features be volcanic plumes, which would be a momentous and unexpected finding? They cannot be ruled out, admits Gierasch, but he says there is no evidence from other Viking instruments (such as the spectrometers aboard the orbiters) of the trace gases that would accompany such activity, and the surface around the features appears undisturbed.

Furthermore, the Cornell researchers noted at the recent Lunar and Planetary Science Conference in Houston, Mars lacks the bountiful water that is constantly modifying the surface of the earth. On Mars, according to the researchers, wind transport of dust is "the major process that changes the face of the planet."

— J. Eberhart