Cleaning up ou

BY EMILY J. SMITH

PHOTO BY DR. KENNETH SEXTON

Kim de Bruijne, a master's student in environmental sciences and engineering, places lung cells into an incubator where they are grown for later use in smog chamber research.

ur air

Building on three decades of smog chamber research: Human lung cells are being used to test the toxicity of the air we breathe

Cells lining the human lung know a toxic air pollutant when they see one. When a toxin is in their midst, the cells call out to one another via chemical signals in an effort to get other cells to come to their aid.

Sometimes, however, the pollutant is too overpowering, and the cells die

This innate lung cell behavior is proving useful to researchers at the University of North Carolina at Chapel Hill (UNC) where scientists are using human cells in air quality research to test the toxicity of gases and particulate matter breathed daily by humans.

These investigations are part of the "One Atmosphere Research Program" – a joint venture of the UNC Schools of Public Health and Medicine begun in 2002 and funded by the Environmental Protection Agency (EPA).

"An estimated 60,000 deaths occur in the United States each year due to urban exposure to fine particles, but the particles themselves may not be what's most dangerous," says Dr. Harvey Jeffries, professor of atmospheric chemistry in the UNC School of Public Health's Department of Environmental Sciences and Engineering and a principal investigator for the One Atmosphere Research Program.

"Instead, it may be the toxic gases that adhere to them," Jeffries says. "Particles can penetrate deep into human lungs, and those with sorbed toxic gases can become 'toxic delivery systems to human lungs."

The nation's largest smog chamber

The lung cell research is an extension of more than three-decades of air quality research designed and implemented by faculty of the UNC School of Public Health's Department of Environmental Sciences and Engineering.

The School began its smog chamber work with the 1970 construction of the UNC Ambient Air Research Facility – a double smog chamber used to study the chemistry of gaseous air pollutants. Framed in wood, the structure is lined with transparent Teflon film walls through which ultraviolet, infra-red and natural light can pass.

Located on a lush landscape in Chatham County three miles east of Pittsboro, N.C., the structure (which was rebuilt in the 1980s and again in the 1990s after its wood frame deteriorated) is the nation's largest and the world's second largest outdoor smog chamber. Each of the two side-by-side chambers measures 150 cubic meters — or the length of about 200 twenty-five-cubic-foot refrigerators.

Human lung cells, which are used to represent the lining of the respiratory tract, have been incorporated into the research conducted there by connecting the chambers to incubators in the adjacent lab via air-carrying glass and Teflon tubes. In these incubators, the cells are cradled in a liquid of nutrients and stabilized at 98.6 degrees Fahrenheit the temperatue of ▸▸

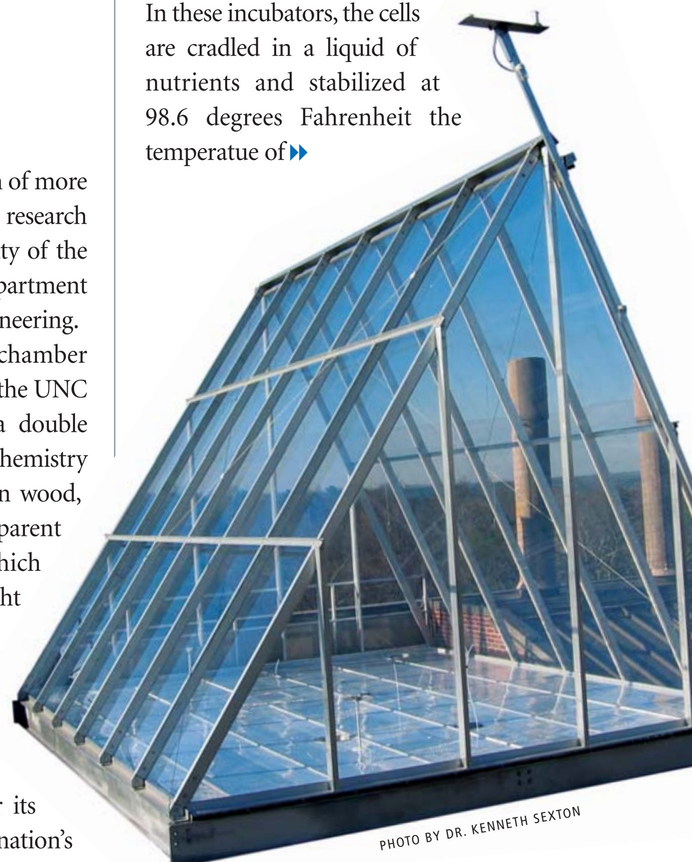


PHOTO BY DR. KENNETH SEXTON

The School's newest smog chamber, perched atop McGavran-Greenberg Hall on the UNC campus, is used to test the toxicity of gases, particulate matter, smoke and aerosols.

the human body — and are exposed to either clean air or pollutant mixture at a rate of one liter per minute.

"We use exposure to these cells to model what could potentially occur in the human lung upon inhalation of air pollutants," explains Dr. Ilona Jaspers assistant professor in the UNC School of Medicine's Department of Pediatrics and a principal investigator for the One Atmosphere Research Program. "Epithelial cells line the respiratory tract and are therefore one of the first targets for any inhaled material including air pollutants."

Inflammatory and cell viability changes in the lung cells help identify which chemicals and/or particles can cause health problems, Jaspers says.

One common finding from air pollution chamber studies has been that exposure to sunlight often converts non-toxic gases into toxic substances, and converts toxic gases into other gases with even higher toxicity.

Methanol, for example, is the second-most common toxic solvent pollutant emitted by U.S. factories. In its original form, it is fairly non-toxic. When it is exposed to sunlight, it breaks down into formaldehyde, a carcinogen; and carbon monoxide, a colorless, odorless gas that is one of the six major pollutants regulated by the EPA. Formaldehyde's toxicity is much higher than methanol's.

Additionally, one recent chamber investigation of an "urban mix" based on air samples from 40 U.S. cities found that the mix exposed to sunlight was two to three times more toxic than the same mix when it had not been exposed to sunlight.

New Directions

The One Atmosphere Research Program recently expanded its research capabilities with the construction of a 120-cubic meter chamber on the Carolina campus that allows UNC researchers to use lung cells to explore the toxicity of not just gases, but also particulate matter, smoke, and aerosols.

Perched atop McGavran-Greenberg Hall, the School's newest chamber is framed in aluminum and lined with transparent Teflon film. Air ducts connect the chamber to a laboratory immediately below it on the building's fourth floor. Construction was completed in summer 2004. (The School has two other chambers — both in the Chatham County location — but lung cells are not used with these. One is for studying wood smoke and the other to research aerosols.)

"We introduce amounts of hydrocarbons into chambers representing the way that hydrocarbons are emitted into the atmosphere in the real world by automobiles and industry," says Dr. Donald Fox, professor and interim chair of the Department of Environmental Sciences and Engineering. "With the new McGavran-Greenberg chamber, the air is re-circulated through filters and purified before any experiments are conducted so we're not taking whatever Chapel Hill offers up on any given day."

The School's smog chamber experiments are conducted on sunny days from spring through late fall.

"In developing good public health policy, it is crucial to understand how various pollutants and photochemical transformations ultimately affect human health."

"We know we only get so many sunny days each year so we try to be prepared for them," says Dr. Kenneth Sexton, research associate of analytical atmospheric chemistry in the School's Department of Environmental Sciences and Engineering. "If we get eight good experiment days a month, we're doing well."

Being prepared for those sunny days means making sure that chambers are filled with pure air and ready to use, and that adequate numbers of cells are available.

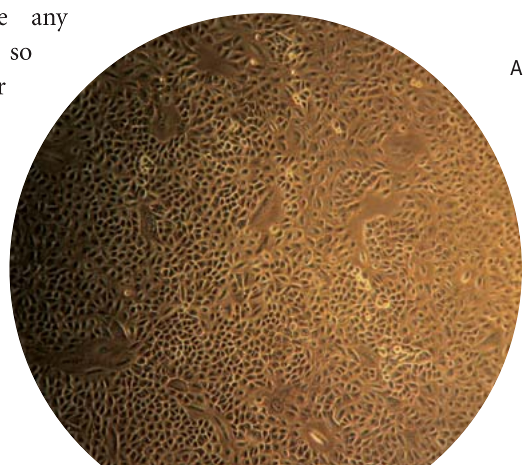
In most experiments, a small amount of the substance being studied (i.e. methanol, "urban mix," etc.) is introduced into a clean chamber just before sunrise and exposed to sunlight all day. Every two minutes throughout the day, lab instruments sample chamber air and record the amount of ozone, nitrous oxide and other chemicals produced. At sunset, the lung cells are introduced to the chamber air and exposed for five hours. Later, Enzyme Linked Immunosorbent Assays, or "ELISA" tests, are conducted on the products released by the cells to map their biochemical changes.

"Lung cells are able to produce and release mediators that recruit and/or activate other cells into the lung," Jaspers says. "In particular, we examine the effects of photochemical transformation of air pollutants on the release of pro-inflammatory mediators that are known to play an important role in inflammation of the airways."

Policing our air

Throughout the last three decades, the School's contributions to clean air have been substantial.

"Our early studies involved helping the EPA demonstrate how



A view of lung cells under a microscope.
PHOTO BY DR. KENNETH SEXTON

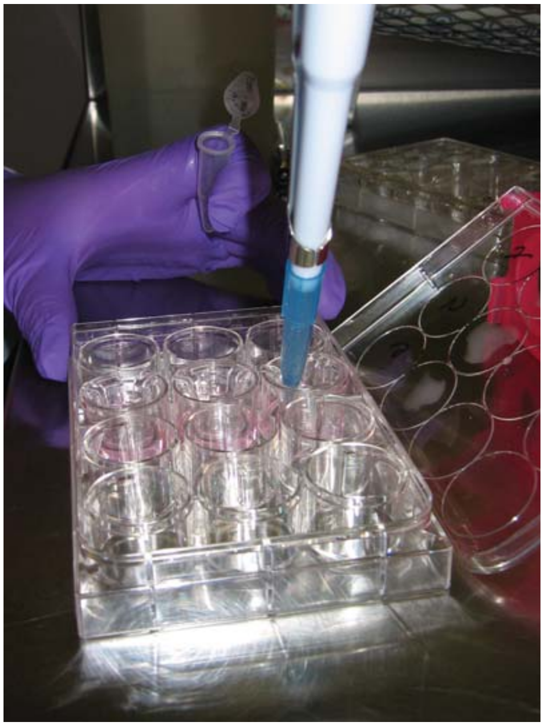


PHOTO: (left) Human lung cells are placed into vials. They will later be exposed to air toxins from the smog chambers. (Right) UNC professor Dr. Ilona Jaspers prepares to examine lung cells through a microscope.

control of hydrocarbon gases might affect ozone and nitrogen dioxide levels in urban areas," says Jeffries, who has served as an advisor to the EPA for more than 30 years.

Hydrocarbon gases are generated by various industrial processes as well as by cars, trucks, buses, earth-moving equipment, power tools, trains, airplanes and other vehicles powered by hydrocarbon-based fuels such as gasoline and diesel. Hydrocarbons also react with nitrogen oxides in the presence of sunlight to form ozone.

Since 1975, the School's researchers have also provided the EPA with data to test mathematical computer models that help the EPA regulate ozone levels throughout the country.

"Any city that exceeds the national standard for ozone is required to run these computer models to help them figure out how to lower the ozone levels in their city," Jeffries says. "Basically, every EPA model for ozone has been tested with data from our chambers."

Controlling ozone levels is crucial. In addition to attacking human lung cells and causing a variety of human health problems, ozone is able to crack rubber by attacking the natural bonds in the organic polymer. It attacks plant surfaces and burns holes in the surfaces of leaves. Even when ozone does not leave visible damage on leaves, it still causes plant damage — reducing growth of commercial crops after even moderate levels of exposure. Furthermore, the chemistry that forms ozone also forms the toxic organic gases and the organic material that sticks to particles that are then breathed by humans.

"We definitely want to reduce ozone to protect human health and to protect sensitive agricultural and natural ecosystems," Jeffries says.

Controlling ozone is tricky business. That's because ozone is a secondary pollutant formed by the photochemical reactions of other directly-emitted pollutants (such as hydrocarbons and nitrogen oxides). It can't be reduced by any direct means. Instead, one has to reduce these primary precursor pollutants.

Unfortunately, there is no direct relationship between the amount of ozone formed and the amount of primary pollutants emitted into the air. In fact, it is possible to reduce one of the ozone precursors and have ozone levels increase.

"Because of this, it has been very important to the EPA to have a scientific explanation for ozone formation — one capable of making accurate predictions of the effects of various control strategies so that effective regulatory policies can be made," Jeffries says

Jeffries expects that UNC's new research direction will be able to provide equally valuable information for the EPA.

"The use of lung cells in air quality research allows for direct observation and documentation of pollutant-induced effects that can be correlated with pollutant dose — important for risk assessment and later public policy formation," Jeffries says.

Additionally, the environment and nutrients of the cells can be manipulated to mimic disease states and nutrient deficiencies.

"This allows us to identify how specific compounds affect various parts of the human population including the healthy, those with pre-existing disease, and the elderly," Jeffries says. "In developing good public health policy, it is crucial to understand how various pollutants and photochemical transformations ultimately affect human health."