Basic Principles for Managing Mold

>> by Michael A. Berry, Ph.D.

Mold is everywhere on Earth and has been evolving for nearly three billion years. Hundreds of thousands of mold species along with yeasts dominate a unique kingdom of living organisms called fungi that are neither plant nor animal. In recent years, mold found indoors has become a concern that needs to be discussed as part of general public health education.

Mold is a decomposer. Mold has an affinity for substances derived from photosynthesis. A primary role of mold in the web of life is to consume organic materials and return carbon, which is found in all living matter, along with other elements and compounds, back to the ecosystem. Water and organic matter are absolutely essential for the existence of mold. Mold does not usually degrade matter by itself but often degrades matter in collaboration with bacteria and insects that are fully compatible with environments in which molds live and die.

By understanding how microorganisms live, we can successfully manage molds indoors with constant attention to the environmental conditions that prevent mold colonies from decomposing materials and growing. We can control mold growth and mold spore levels in indoor environments by keeping interiors and the materials in them clean and dry.

Excessive amounts of a dominant species of mold indoors is a good indication of environmental system malfunction or mismanagement. Abnormally high levels of mold spores are virtually always associated with water damage, water intrusion, failed HVAC systems, or nonexistent or ineffective cleaning programs. Water, when combined with an organic nutrient (a substance that contains carbon), usually in the form of cellulose material or natural soils and debris, for extended time periods, at common indoor climate temperatures, can result in mold growth and excessive spore levels resulting from that growth.

The scientific literature indicates that mold spores of any species in extremely high concentration have the potential to cause health symptoms often associated with what is commonly called "sick building syndrome." The symptoms are sensory irritation of the eyes, nose and throat; skin irritation; neurotoxic symptoms; hypersensitivity reactions; and odor and taste symptoms. High concentrations of mold spores, usually at levels that are magnitudes higher than those found in surrounding outdoor air, tend to trigger or be related to allergic reactions. Fatal exposure to mold, if it occurs at all, occurs rarely, and primarily through ingestion of mold. Although there is speculation in the medical community from time to time, death has not been conclusively shown to be an expected direct health endpoint of common inhalation exposure to mold. Death can occur infrequently from a severe asthma attack that is triggered by mold. Recent reviews of the

peer-reviewed scientific literature do not substantiate the claim of frequent fatal air exposure to mold.

Mold as a Consequence of Mismanagement

Mold indoors is an indication of mismanagement. Addressing just a symptom, in the form of mold, does not solve the real problem, which is water intrusion and nutrient in the form of dirt or debris. If we analyze the mold problem realistically, we find that professional water restoration practices, and existing housing codes for clean, properly drained, and waterproofed housing, prevent mold conditions if followed or enforced (USEPA 2002).

Mold is virtually everywhere and is as essential to the natural life cycle as carbon and water. If mold did not exist, our environment would become like one giant leaf pile. We cannot completely eradicate mold, but only manage it to a sanitary extent. We keep excessive mold out of buildings by keeping them clean and dry.

Based on today's science, it is not possible to set an acceptable exposure level for fungal colonies and spores. Mold risk is many times more difficult to estimate because all routes of exposure — dermal, inhalation, and ingestion — come into play, and the mechanisms of human response are highly complex and not fully understood. There is no science that allows us to describe exposure and human response to different levels of fungal colony forming units (CFU) or spores. In the absence of credible study and data, such levels are at best professional judgments.

Indoor molds are unlikely to be life threatening. Livestock have died from eating moldy feed and contaminated food and fungal infections can be fatal to humans, although this is rare. There is no specific mold that creates a life-threatening situation by its mere presence.

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Executive Summary

Mold is everywhere on Earth and has been evolving for nearly three billion years. In recent years, mold found indoors has become a concern that needs to be discussed as part of general public health education.

A primary role for mold in the web of life is to consume organic materials and return carbon, which is found in all living matter, along with other elements and compounds, back to the ecosystem.

Excessive amounts of a dominant species of mold indoors is an indication of environmental system malfunction. Abnormally high levels of mold spores are virtually always associated with water damage, water intrusion, failed HVAC systems, or ineffective cleaning. These conditions have the potential to cause health symptoms, including sensory irritation in the eyes, nose and throat; skin irritation; neurotoxic symptoms; hypersensitivity reactions; and odor and taste symptoms.

It is important to understand how to assess the likelihood of fungi causing a health effect. We do this by means of the environmental risk assessment process: Source and hazard identification, emission and transport, exposure, concentration, dose delivered to the human receptor, and the reaction to the dose.

There are some general, commonsense means of determining if we might have harmful levels of mold indoors:

- Look for moisture or damage (leaks, standing water, water stains, condensation).
- Look for visible mold colonies. If mold growth can be seen, a mold problem exists.
- Use smell to locate sources of "musty" or "earthy" odors. Mold excretes odorous volatile organic compounds. If mold growth can be smelled, a mold problem exists.
- Measure relative humidity at cold surfaces and within wall cavities.

We should not generally assess the risk of mold by its color. Only a mycologist, or specially trained microbiologist or health scientist with advanced training and laboratory skills, is qualified to correctly identify species and make credible professional judgments about potential risks to humans.

Testing to determine the kinds and amounts of mold present is rarely necessary or helpful under normal residential situations. Instead of testing, there are more cost-effective methods for identifying environments needing intervention.

In the indoor environment, control mold reservoirs and amplification by removing their food supply through cleaning and moisture control. Three steps of a basic strategy to manage mold:

Step 1: Control the environment, especially moisture and temperature, so that the microorganism cannot grow.

Step 2: Take away any organic foods so that the microorganism will starve.

Step 3: Keep viable and nonviable organisms away from humans.

Additionally, airflow and ventilation are critical to mold management. Like water, air is a fluid. As air flows, it carries suspended materials with it, including water. Airflow is necessary to achieve drying as well as to transport airborne spores to proper disposal.

Mold removal requires a strategy to deal with the cause(s) of moisture and the mold contaminants. First, locate the moisture source and correct the problem. Next, remove mold by cleaning and disposal. Porous materials should be removed, bagged and discarded. Nonporous materials may be cleaned. Dry thoroughly.

Moisture control is the key to preventing indoor mold growth. Rapid response to moisture problems is critical. Examples include:

- Control indoor moisture by fixing plumbing leaks, drips or "sweating" pipes; limit sources of indoor humidity/dehumidify indoor air; improve air movement in poorly ventilated areas; increase fresh air ventilation when outdoor air is not humid; warm cold surfaces where condensation occurs.
- Control outdoor moisture by maintaining roof and gutter/downspout systems; direct runoff away from the foundation by grading, drain tile, landscaping, etc.; use air conditioning and keep building closed during high outdoor humidity; prevent leakage around windows, doors, flashing, etc.; waterproof foundation structure.

in Cleveland. The media labeled Stachy as a "killer" mold because some of these infants died. However, the Centers for Disease Control and Prevention (CDC) and other experts reviewed the investigations of the Cleveland cases and concluded that an association between the exposures to mold and the illnesses was not proven (MDH 2001).

Despite the focus on Stachy, many kinds of mold can affect people's health. Although healthy individuals are not likely to experience severe effects from small amounts of mold growing indoors, some people are more susceptible and hence at greater risk than most of the population. It is generally prudent to assume that some

Frequently Asked Questions About Mold in the Interest of General Public Health Education.

Q: What are molds, plants or animals?

A: Neither. Molds are members of a unique kingdom called fungi. Other common fungi are yeasts and mushrooms.

Q: Are molds only found in wet environments?

A: Mold grows everyplace on Earth (the water planet) in all climates and environmental conditions. Fungi have an absolute requirement for water but exhibit a wide range of tolerance in relation to water availability. Fungi can survive over a broad temperature range; however, optimum growth tends to be found in the range of 54–84ºF.

Q: What is the source and cause of "musty" or distinct odor associated with wet or damp environments?

A: The odorants are organic (carbon based) compounds excreted from bacteria and fungi. They are often referred to as VOCs (volatile organic compounds) but more accurately they should be identified as gas-phase organic compounds derived from biodegradation.

Q: What is the leading cause of serious deadly illness indoors?

A: Bacteria and viruses are the most "pathogenic" (disease causing) organisms commonly found indoors.

Q: What is the most likely human response to mold by way of exposure to air?

A: The most likely human response by way of air exposure is allergic reaction to mold spores when in a sufficient high concentration.

Q: Who is most at risk when exposed to mold and mold spores?

A: The very young, the very old, those with weakened immune systems, and asthmatics.

Q: Can we see mold spores indoors?

A: No. The size of mold spores is between two and 100 microns. The vast majority are under 20 microns. A micron is one millionth of a meter. We cannot see objects of less than 40 microns without optical magnification.

Q: What about the size of mold spore and bacteria, is size important?

A: Particles of all size ranges are important. They can enter the cranial cavity, be ingested, enter the upper or lower regions of the lung or come in contact with the eyes or skin. Particles smaller than 2.5 microns are especially hazardous; they are small enough to be inhaled into the alveoli region of the lung. The gas exchange portion of the respiratory system is the alveoli (air sacs). When damaged, lung function is permanently impaired.

Q: What species of mold should be of most concern?

A: *Penicillium, Aspergillus, Stachybotrys* are hazardous species in the sense that humans tend to have more of an allergic reaction to these. Hazards by themselves do not guarantee harm. But we should be very concerned when any of these three species are the source of the dominant spore concentration often found indoors.

Q: Is *Stachybotrys chartarum* a "killer" mold?

A: Much concern was raised about the mold *Stachybotrys chartarum* because it was found in homes of infants with an unusual "bleeding lung disease" in Cleveland. The media labeled it as a "killer" mold because some of these infants died. However, the Centers for Disease Control and Prevention (CDC) and other experts reviewed the investigations of the Cleveland cases and concluded that an association between the exposures to mold and the illnesses was not proven.

Q: What about the color of mold, is black mold more dangerous than other species?

A: We should not try to judge the risk potential of mold by its color. For example, there are literally thousands of species of mold, and a large number of them appear black when the mold colonies grow large enough to see.

Q: Are there any safe molds as far as allergic response goes?

A: In the face of uncertainty, it is prudent to suspect that all mold spores are allergens to some degree. In high enough concentrations and sufficiently long exposure times, regardless of species, mold spores can, in theory, trigger a reaction. Some molds trigger allergic reactions even at lower exposure levels.

Q: What are mycotoxins?

A: Mycotoxins are metabolites produced by fungi that are toxic to warm-blooded animals, primarily by way of ingestion. Only about two hundred mycotoxins have been identified and most are found harmful only in farm animals. Aflatoxin is often cited as an example of a mycotoxin that was found to cause a rare form of liver cancer in humans (in Africa) as the result of ingesting moldy food (peanuts). Only a few studies suggest possible human effects derived from air exposure. Mycotoxins should be considered hazardous.

people might experience problems when any kind of mold is allowed to grow unchecked indoors, and the likelihood of health effects increases as the amount of mold or duration of exposure increases.

Since there is no practical method for detecting and quantifying with certainty all molds that may cause health effects in an environment, it is safest to invoke the "Principle of Prudent Avoidance"[1] and to treat any indoor mold growth as a "potential health hazard" which should be corrected.

Any one fungal species can produce allergens. An allergen is a substance that causes a hypersensitive reaction. In healthy humans, allergic reactions

Q: If mold has been around for millions of years, why all of a sudden are people concerned or complaining about mold?

A: Several reasons: 1) People are more aware about environment and its relation to human health than at any time in history. People are learning that microorganisms, biopollutants, and biocontaminants, not chemicals, are the biggest health risks indoors. 2) Humans tend to react to risks that are exotic and invisible and that affect their children and those they protect, like elderly parents. Living, colorful mold, growing in a Petri dish is exotic especially in the mind of someone who has never taken a biology class. 3) Modern dwellings tend to trap dirt and moisture. Little water leaks are often unnoticed and not attended to. If we do not keep an indoor environment dry and clean, mold is going to grow, always.

Q: What are the main sources of water and moisture for mold growth?

A: Common indoor moisture sources include humidifiers, cooking and dishwashing, bathing, plumbing leaks, house plants, firewood storage indoors, improper venting of clothes dryer/indoor clothes line, and combustion appliances. Common outdoor sources of moisture include roof leaks, flooding, rain or snowmelt, seasonal high humidity, ground moisture, and wet building materials.

Q: How do we best manage mold spores from floating around indoors?

A: Mold spores are aerodynamic. Spore laden areas should be pressurized negatively and clean areas should be pressurized positively to minimize cross contamination.

Q: What is the most effective way to manage mold?

A: The most effective way to prevent mold growth is to keep materials clean and dry; if they get wet, dry them quickly before mold growth can start.

Q: Can biocides be used to effectively manage mold?

A: Biocides are useful poisons designed to kill microorganisms. Serious concerns about biocide use may include toxicity to all forms of life, they can be inactivated and be ineffective as poisons, and some may cause damage to materials. Biocides will only slow the mold problem down; it will not correct the problem. The environmental conditions that support mold growth must be changed. Remove water and the organic food source.

Q: Can ozone be used to manage mold?

A: No, ozone is totally ineffective in mold management and on top of that is toxic to humans.

Q: How do we manage fungal spores in the air?

A: Properly designed airflow across a source of mold spores carries airborne contaminants into the air filtration device where they are trapped. This principle can be applied to vacuum cleaners and air filters.

Q: Do we need a HEPA vacuum to remove mold spores from a building?

A: HEPA vacuums are useful professional tools, but they are not essential to the removal of mold spores. HEPA filters were designed in the 1940's to trap energized nuclear particles. Any vacuum that can filter particles down to one micron or less, if applied consistently, will remove large amounts of mold spore from an indoor environment.

Q: How can we best get rid of mold spores?

A: Do not let mold grow to begin with. Keep the environment clean and dry. If mold does grow, contain the growing mold along with its wet food source (i.e., wrap it in plastic and get it outside) before spores are released to the air. If spores are released, remember that they settle onto surfaces hours after activities end in the exposure area. Effective vacuuming and damp wiping of walls and hard surfaces, vacuuming of fabrics to include carpet is effective in the removal of mold spores before they can get put back into the air.

Q: How should we manage environmental quality in the face of demolition or mold-damaged material removal?

A: Demolition procedures on a restoration project should be performed in such a way as to minimize and control dust to include mold spores and other biopollutants. Controls applicable to mold management include source containment before removal, minimization of air activity prior to containment, containment and negative air pressurization of contaminated areas.

Q: Do we always need to sample for mold?

A: Generally speaking, no. Under most circumstances in residential environments damaged by water intrusion, mold testing is unnecessary in the process of correcting the problem.

are prevented by the immune system. However, after a significant exposure to a particular allergen, an individual may become sensitized to that allergen and develop an allergy. Sensitization occurs when the antibody specific for the allergen attaches to the surface of the mast cells making the individual react to future exposures. Subsequent exposures cause the release of agents that interact with surrounding tissue (Institute of Medicine, 1993).

Health effects associated with exposure to mold manifest themselves in common symptoms and complaints. These are the general health effects often associated with the so-called "sick building":

- Sensory irritation in the eyes, nose and throat are associated with pain, dryness, stinging, hoarseness, and voice problems.
- Skin irritation in the form of pain, reddening, smarting or itching, and dry skin.
- Neurotoxic symptoms in the form of headache, sluggishness, mental and physical fatigue, memory loss, difficulty concentrating, dizziness, intoxication, and vomiting.
- Hypersensitivity reactions include runny nose, teary eyes, asthma-like response, and hyper-ventilating sounds from the respiratory track.
- Odor and taste symptoms include changed sensitivity in smelling and tasting as well as impressions of unpleasant odors and tastes.

Environmental risk is the probability of an adverse effect. When health conditions such as these occur as the result of human exposure to mold allergen, they are often considered severe enough to be classified as adverse. These health effects clearly detract from an overall sense of wellbeing and often interfere with human productivity in environments such as offices and schools.

It is important to understand how to assess the likelihood of fungi causing a health effect. We can do this by means of the environmental risk assessment process: Source and hazard identification, emission and transport, exposure, concentration, dose delivered to the human receptor, and the human reaction to the dose.

Most important to a proper understanding of mold risk is the toxicology principle: "It's the dose that makes the poison." We need a sufficiently high dose of allergen spores before we can have an effect. Next, there needs to be an exposure (air, dermal, ingestion) to a specifically high concentration of an allergenic substance. In order for this to occur, there must be an effective transport of significantly high quantities of a dominant allergen from a significantly large fungal growth area.

There must be a source of allergen. There must an environmental condition under which the allergen is amplified; there must be water and an organic food supply.

In general, environmental measurements are difficult to make. Mold measurements are especially difficult and highly variable. Even when made properly, they can be difficult to interpret. For mold measurements to be of any use in the successful management of the indoor environment, we need to know where to measure (in the air or on surfaces), what to measure (species, spore count, CFUs), how to measure (proper sampling media, collection devices and techniques), and what to look for (credible identification of dominant sensitizing species, high concentration of allergen).

We should be concerned about mold exposure indoors when indoor air concentrations of mold significantly exceed typically maximum outdoor air levels (background) and are dominated by a known sensitizing or problem species of mold, particularly *Penicillium, Aspergillus,* and *Stachybotrys* (Burge 1995). These conditions almost always are caused by water intrusion indoors.

As we should never consume a mushroom of unknown species, we should never consider a species of mold to be hazard*less*. We know with certainty that elevated numbers of mold spores in air do trigger allergic reactions.

Small amounts of mold growth on indoor surfaces are not likely to pose a problem. It is only when spores are released into the air that the risk increases. As mold on an interior surface matures, it releases spores as part of normal reproduction. The longer mold is allowed to grow, the more likely it becomes that large amounts of sensitizing spores will be released into the air.

For most human receptors, health complaints from mold exposure are generally unlikely where we find a heterogeneous mix of species at an air concentration of less than 1,000 spores/cubic meter (Gots & Pirages). However, in rare instances, for some highly sensitive individuals, no level of indoor or outdoor air concentration is free of allergic reactions.

Managing Mold Indoors

In the outdoor environment we have little control over microorganisms like fungi, but indoors we can control their reservoirs and amplification by removing their food supply through cleaning and controlling moisture. Routine housekeeping and preventive maintenance are the most effective means of controlling mold in buildings. To keep microorganisms of all kinds under control, we must especially keep the environment free of wet organic matter. It is essential that we remove dirt and water to prevent the conditions that promote mold growth.

Following are the three steps of a basic strategy to manage mold:

Step 1: Control the environment so that the organism cannot grow. For example, control moisture and temperature.

Step 2: Take away any organic foods so that the microorganism will starve.

Step 3: Keep viable and nonviable organisms away from humans. Kill it, remove it, or contain it.

In Step 1 we attempt to create conditions that the organism cannot live under. A building's environment is largely controlled by how we design

and operate it. We also control it when we properly clean and restore it to a sanitary condition. If we use too much water or do not control moisture when we clean, we create conditions that allow reservoirs of fungi and bacteria to grow or amplify.

We follow Steps 2 and 3 while cleaning and restoring an environment. When we follow environmental principles of cleaning, we extract the most pollutants possible from the environment. Many organic substances feed biopollutants. If we deprive microorganisms of food, and give them an unsuitable environment such as a dry one, the organism will die or at least will be unable to flourish.

If we could fully control the foods of living organisms in an environment, they would cease to be a problem. But we cannot control their environments and food sources completely. Therefore, we must go after them directly. We can kill them, remove them, reduce their amplification or concentration, or contain them so they cannot spread throughout the environment.

Airflow and ventilation are critical to the mold management process. Like water, air is a fluid. As air flows, it carries suspended materials with it, including water. Airflow is necessary to achieve drying as well as to transport airborne spores to proper disposal. Drying occurs only when suspended moist air is displaced by dry air on, above, and through an environment that has been cleaned with a liquid solvent. Many problems occur in the process of cleaning when environments remain wet. Wet environments are breeding grounds for living organisms.

We should, as routine hygiene and housekeeping, take reasonable steps not to allow any species of mold to grow uncontrolled indoors. Killing small amounts of mold with something as available as household bleach or a registered fungicide, or containing and removing material with growing mold and keeping the environment clean and dry, will help manage and prevent harmful mold growth.

Mold excretes odorous volatile organs compounds. An effective way to identify a mold problem is by visual inspection and following odors. If mold growth (any type) can be seen or smelled, a mold problem exists. Ordinarily, resources are better used to control the moisture source(s) and remove mold contamination rather than for testing.

Check for visual signs and odors. Look for moisture or damage (leaks, standing water, water stains, and condensation). Measure relative humidity at cold surfaces and within wall cavities. Look for visible mold colonies (may appear cottony, velvety, granular, or leathery and have varied colors white, gray, brown, black, yellow, green, or other). Use smell to locate sources of "musty" or "earthy" odors.

Mold testing can be quite costly. Testing to determine the kinds and amounts of mold present is rarely necessary or helpful under normal residential situations. No single test can detect all types of mold. Results only crudely estimate the amount of mold present (and only for the time the sample was collected). Interpretation of results is difficult — numeric criteria for interpreting data are arbitrary. Findings may mislead (e.g., false negative results). Test results are not fully predictive of health effects and risks. Instead of testing, there are more cost-effective methods for identifying environments needing intervention (MDH 2001).

Testing is warranted when there is a clear objective that can only be met through obtaining sampling data. Always in mold testing, there should be a clear understanding of what specifically is to be tested for and what the results will be used for ("for what?" and "what for?") before testing is considered.

In a residential setting, a thorough visual inspection looking for mold growth or signs of water damage and wetness and locating sources of mold odors by smell are generally effective and recommended (MDH). Once mold growth has been located, appropriate actions are needed to correct the source of the moisture and remove mold contamination.

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We should not generally assess the risk of mold by its color. There are literally thousands of species of mold, and many of them appear black when the mold colonies grow large enough to see. Only a few species of mold can be identified by their color. Only a mycologist, or specially trained microbiologist or health scientist with advanced training and laboratory skills, is qualified to correctly identify species and make credible professional judgments about potential risks to humans under different exposure scenarios.

Mold removal requires a strategy to deal with the cause(s) of moisture and the mold contaminants. First, locate moisture source and correct the problem. Next, remove mold by cleaning

and disposal. Porous materials should be removed, bagged and discarded. Nonporous materials may be cleaned with non-ammonia detergent and scrubbing. Disinfect using ¼–½ cup bleach per gallon of water. Dry thoroughly.

Recommended personal protection includes respiratory protection goggles, rubber gloves, washable or disposable clothing. Ventilate the area well when using bleach. Establish containment around the work area for large or heavily contaminated areas to minimize the spread of spores.

Controlling moisture is the key to preventing indoor mold growth. Rapid response to moisture problems is critical. Examples include:

- Control indoor moisture by fixing plumbing leaks, drips or "sweating" pipes; limit sources of indoor humidity/dehumidify indoor air; improve air movement in poorly ventilated areas; increase fresh air ventilation when outdoor air is not humid; warm cold surfaces where condensation occurs.
- Control outdoor moisture by maintaining roof and gutter/downspout systems; direct runoff away from the foundation by grading, drain tile, landscaping, etc.; use air conditioning and keep building closed during high outdoor humidity; prevent leakage around windows, doors, flashing, etc.; waterproof foundation structure.

Summary

Mold is a fact of life and is, in fact, an essential component of our ecosystem. When water damage or mismanagement of the indoor environment result in mold amplification, risks to human health and damage to property are the result. We manage mold indoors by utilizing sound environmental management strategies and especially by keeping the environment clean and dry.

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>> ABOUT THE AUTHOR

MICHAEL A. BERRY, PHD is an environment and public health educator, a writer and science adviser interested in health policies and environmental management strategies.

Dr. Berry served as an Army Officer in Vietnam 1967-68 where he developed an interest in human health protection. He earned a Doctor of Philosophy in Public Health from the University of North Carolina at Chapel Hill, and a Master of Science in Management from Duke University's Fuqua School of Business. He holds both Bachelor and Master of Science degrees in Mathematics from Gonzaga University.

Dr. Berry retired from the U.S. Environmental Protection Agency in 1998 where as a senior manager and scientist he was the Deputy Director of the National Center for Environmental Assessment at Research Triangle Park, NC. During his 28-year career with EPA, he had extensive interactions with private industry, trade associations, environmental organizations, governments, the federal courts, U.S. Congress, universities worldwide, and institutions such as the National Academy of Sciences, the World Health Organization, and the North Atlantic Treaty Organization.

Between 1984 and 1991, Dr. Berry organized and managed the U.S. EPA's indoor air research program.

From 1984 until 2006, he served on the faculty of the University of North Carolina at Chapel Hill where he taught a broad range of environmental science, policy, and business and environment courses in the School of Public Health, Business School, and Environmental Studies Program.