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Introduction to Environmental Risk

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Introduction to Environmental Risk

A Primer on Environmental Risks to the Insurance Industry

AUTHORS

Margaret Conroy, Ph.D, FCAS, MAAA
Natalie Howe, Ph.D
Therese Klodnicki, ACAS, MAAA
Alexandra Baig, MBA, CFP
Kimberley Ward, FCAS, MAAA, CPCU, ARM

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Introduction to Environmental Risk

A Primer on Environmental Risks to the Insurance Industry

Introduction

When we hear “environmental risk” applied to insurance, we may immediately think of commercial general liability (CGL) coverage. Traditionally, “environmental claims” were either legacy pollution claims that were incurred before the “sudden and accidental” and “absolute pollution” exclusions became widely used, or the alleged “unexpected and unintended” pollution exposures of the past. In actuality, "environmental risk” generates financial risk for most lines of insurance business and all types of insureds. Both public and private interests, locally and globally, stand to lose from environmental risk. This article will endeavor to introduce the reader to some of the known and developing environmental risks that impact the business of insurance, with a specific focus on North American risks.

History

Historically, environmental risks were covered, often by general liability policies, simply because they were not excluded from the policy. Since they were generally not recognized as identifiable, insurable risks they were not considered in pricing. As the number and amount of pollution claims increased, insurers began to directly address the liability by excluding coverage for it in CGL policies. General liability policies that were issued prior to exclusions for environmental risks are still subject to claims arising from environmental problems whose resulting harm can take many years to identify. Because mediation and litigation of these claims is a lengthy process, general liability insurers may still be incurring substantial loss from this business, and their experiences can serve as a valuable reference for producers currently pricing business lines that are likely to cover any of the ever-expanding categories of environmental risk.

Environmental degradation in the early part of the twentieth century was not seen as a problem for society in general. Liability could arise, but out of common-law doctrines of trespass and nuisance, which required proof of proximate causation before providing retrospective compensation of property loss.

Attitudes began to change after World War II as industries began to employ more and more synthetic chemicals that had not been tested for safety. The expansion of chemical use on top of general industrial growth led to an increased frequency of environmental disasters. For example, burning rivers—the most famous being the Cuyahoga River in Ohio—were not uncommon. Rachel Carson’s seminal book *Silent Spring* popularized the issue and educated the general public on the risk of environmental pollution. Rising public awareness of the dangers of environmental destruction and pollution culminated in a constitutional amendment, proposed in 1968 “Inalienable right to a decent environment”, which failed. However, there

were the successful creation of the Environmental Protection Agency in 1970, the passage of the Clean Air Act of 1970, and the passage of the Clean Water Act of 1972. These acts introduced clean air and water standards and assigned liability to those who did not comply. Other acts followed, including the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and Toxic Substances Control Act (TSCA), which regulate manufacture, distribution, and use of commercial chemicals and the Resource Conservation, and the Recovery Act (RCRA) of 1976, which regulates cradle-to-grave tracking of hazardous materials. The Love Canal case helped to catalyze public concern about environmental risk. At the Love Canal site in upstate New York, tons of known toxic chemical wastes had been dumped in an abandoned canal since the 1940s. Subsequently, an elementary school and homes were later built above the dump. The resulting health impacts to the residents exposed the gap in hazardous waste regulation. In response, Congress passed the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA aka Superfund) in 1980. CERCLA dealt with hazardous wastes or products, manufactured or disposed of before RCRA, FIFRA, and TSCA went into effect (Salzman and Thompson, 2014). These acts and other similar laws created liability for manufacturers and other polluters. Liable companies then turned to their insurers to cover the resulting costs, even though the policies had not been issued or priced with the intent to cover environmental risk.

The insurance industry response to the liability being foisted upon them by the courts in the wake of CERCLA, was to introduce exclusions into the standard general liability policy language to limit coverage in future policies. The first change was in 1973 to the Insurance Services Office, Inc. (ISO) commercial general liability (CGL) policies to exclude coverage for contamination and pollution with the exception of "sudden and accidental" pollution. The courts rendered this exclusion moot by taking an exceedingly broad view of "sudden and accidental" which had not been contemplated in the pricing of the policies. Thus, the ISO 1986 policy introduced what is known as the "absolute" pollution exclusion (though it is not actually absolute), which states that there is no coverage for bodily injury or property damage (BI/PD) "arising out of the actual, alleged or threatened discharge, dispersal, seepage, migration, release or escape of pollutants". This policy language removes coverage for most pollution events but preserves coverage for some significant exposure (including for hostile fire damages, products and completed operations, and certain off-premises work by contractors). This too was not a strong enough policy language and was replaced by the total pollution exclusion endorsements, which eliminate virtually all coverage for pollution incidents. These endorsements remove coverage for products/completed operations and do not cover defense costs.

Around the time the exclusions went into place, environmental impairment liability policies (EIL) and environmental protection liability policies (EPLI) became more readily available to cover risks that had been excluded out of general liability policies. For risks that have the potential to cause environmental accidents in the future, insureds need to purchase a separate EIL or EPLI policy, usually on a claims made basis, to provide coverage for bodily injury and property damage, as well as for covering clean-up, business interruption, and legal expenses.

The list below provides some examples of perils traditionally associated with environmental risk. Note the variety of insurance lines of business affected by environmental pollution in these examples.

1. Pollution costs associated with past pollution, particularly involving Superfund sites
2. Asbestos claims from casualty policies, written primarily before 1990
3. Claims from operation of typical businesses, such as dry cleaners or pesticide applications
4. Workers' compensation claims for exposure to hazardous materials
5. Radon or "sick building" claims on Homeowners or Commercial building owners
6. Health concerns and liability from medical devices, particularly implants

7. Health claims and liability suits from exposure to lead paint
8. Accidents involving the transportation of hazardous material
9. Claims from agricultural operations, particularly chemical overspray or noxious smells
10. Errors or omissions by environmental consultants for errors in identifying or planning mitigation operations, environmental contractors for liability arising from their operations remediating property, and environmental testing laboratories for liability arising out of laboratory errors
11. Coverage in connection with properties that lenders and real estate agents buy, sell, or finance
12. Coverage for oil spills and leakage of other toxic substances for owners and operators of ships/vessels
13. Coverage for liability due to leaks of underground storage tanks for property owners

The history of traditional pollution claims and the unintended coverage described above provides a strong lesson for insurers today and demonstrates a framework for which actuaries can contemplate the development and handling of new environmental risks related to their products. The focus of this paper is on risks that are not necessarily explicitly recognized and categorized as "environmental" and risks that are not covered in explicit environmental insurance coverages. As an introduction to environmental risk written for actuaries, the focus is on the potential insurance implications due to risks that environmental experts have long recognized, but for which the general public is only recently becoming slowly aware.

Perhaps the largest emerging risk to the environment is climate change. Although fairly well known to the general public, the ways in which climate change is affecting our environment are numerous and varied. However, in this paper, we are not addressing the risks to our environment due to climate change directly. Rather, we discuss the lesser-known risks to our environment, some of which are exacerbated by climate change.

Industry history has shown that a risk, which was never contemplated when a policy was designed and priced, could subsequently generate enormous, unexpected catastrophic level claims. It is, therefore, key for actuaries to be aware of the many types of environmental risk, any of which could be the next catalyst for catastrophic claims and understand how these risks can potentially impact policy liability and associated price. Could one of these be the "next big thing" in insurance?

Globalization

Most invasions of species and diseases are shaped by trends in human transport. Global trade and travel, including long-distance pressurized transport, are increasing the transport frequency of animal and plant species and the diseases that they carry (Ascunce et al. 2011). Often, items being transported (plants, animals, materials, etc.) can be an unintended transmitter of disease or pollution, or a vector thereof.

GLOBALIZATION OF DISEASE

Infectious diseases can spread at the speed of an airplane. Diseases, stemming from environmental risks in other countries, can easily spread to North America. For example, live wild-animal markets with animals for consumption and for use in traditional medicine are common in Asia and some other parts of the world. These markets are known to transmit diseases and parasites, which can spread to the rest of the world. Disease outbreaks, propagated by wildlife trade, have caused hundreds of billions of dollars of economic damage globally (Karesh et al., 2005).

Over 35 new infectious diseases have emerged in humans since 1980. In a list of 1,415 human pathogens, 61% are known to be zoonotic including HIV (from the human consumption of non-human primates); Ebola (from great apes hunted for food), and SARS-associated coronavirus (from small non-domestic carnivores). Diseases can also be transmitted from wild to domestic animals, causing economic damage and sometimes leading to human health problems. Examples of such diseases include bovine spongiform encephalopathy, foot-and-mouth disease, avian influenza, and swine fever (Karesh et al. 2005). Most recently, we see wild-animal-to-human transmission with SARS-CoV and COVID-19, which are both thought to have jumped to humans from wild animal markets in China. As we all know too well due to our experience in 2020, pandemics, such as COVID-19, cause massive and rapid changes in the macroeconomic, financial, and regulatory environments. These changes, in turn, can generate unexpectedly high losses in multiple lines of insurance as well as claims from unusual or new sources.

Many diseases either have recent origin in the natural environment, are transmitted by a wildlife vector, or both. There is risk of new diseases emerging, and of the spreading of already familiar diseases into new geographic areas. As climate change intensifies, tropical diseases may spread away from the equator into larger areas of North America, affecting health insurance, workers' compensation, and perhaps life insurance, depending on the severity of the diseases.

INVASIVE SPECIES

Invasive species - organisms that cause ecological and/or economic harm in a new environment where they are not native (NOAA 2020)- can harm infrastructure, property values, agricultural productivity, public utility operations, native fisheries, tourism, outdoor recreation, and the health of an ecosystem (USF&WS, 2012). Much of this damage is to forests, crops, land, ecosystems, and ecosystem services, the majority of which are not insured. However, many invasive species cause insured or insurable loss to property, business, and health. About 80% of the costs associated with invasive species in the U.S. are attributable to a few groups of alien invaders: pests and pathogens of crop plants, crop weeds, non-native rats, feral cats, and non-native diseases that infect livestock and humans (Levin 2009).

Black and Norway rats consume or destroy stored grains and property, valued over $19 billion annually in the U.S. (USF&W 2012). The nutria (***Myocastor coypus***) is a very destructive but lesser-known invasive rodent, currently affecting the U.S. Nutria, which can grow to over 20 pounds, feed on the roots of plants that support marsh soils leading to the destruction of marshes and loss of wetlands that provide storm surge protection. For every mile of coastal wetlands lost, storm surges increase on average by about a foot. Nutria also breach and undermine water-retention and flood-control levees; weaken the foundations of reservoir dams, buildings, and roadbeds; damage vegetation and crops; destroy banks of ditches, lakes, other water bodies; and spread diseases (USF&W, 2012). Nutria populations are currently heaviest in the South along the Gulf Coast, along the Chesapeake Bay, and in the Pacific Northwest and California. The diseases and parasites from Nutria may increase health costs in a large area of the U.S. in addition to the agricultural, infrastructure, and ecosystem services damage they cause.

Invasive insects take a large human and financial toll through agricultural damage and/or injury to humans or animals. Red fire ants (***Solenopsis invicta***), for example, damage young citrus trees, potatoes, dry crop seed, and other crops and also attack humans and domestic and wild animals in large numbers causing injury by stinging simultaneously (Fox 2014). In the U.S., current cost estimates for control, medical treatment, and property damage due to the fire ant alone top $6 billion annually (Ascunce et al. 2011). Another similar example is the Africanized honeybee (a hybrid ***Apis*** species) which disrupts the traditional pollination service industry, causing enormous agricultural losses, but with its aggressive tendency to swarm and sting, is also a potential life, health and casualty risk for farm workers (USDA 2020). A relatively new agricultural threat is the spotted lanternfly (***Lycorma delicatula***) which is causing severe damage to

grapes, apples, hops, hardwood, and other crops along the mid-Atlantic states. Insecticide costs because of the lantern fly have trebled, and some growers are losing entire vineyards (USDA 2020).

Mosquitoes can cause indirect harm to humans and animals as vectors for disease. Although native mosquitoes can also spread disease, many mosquito vectors responsible for transmitting diseases are invasive species (Wilke et al. 2020). There have been increasing cases of mosquito borne diseases such as Saint Louis encephalitis, West Nile virus, chikungunya, dengue, Zika, and yellow fever (for which there is a vaccine) in the United States. Costs have been estimated for certain mosquito-borne diseases in contained geographic areas, such as counties, which if added or multiplied would indicate costs in the billions.

The invasive feral swine (***Sus scrofa***) cause an estimated $1.5 billion in damage and control costs in the United States each year. They cause major damage to agriculture, transmit diseases to livestock and wildlife, damage residential and commercial property, destroy cultural and historic resources, and involve themselves in wildlife-vehicle collisions (WVCs). Feral swine have become widespread throughout much of the United states where they are present in 38 states, primarily in the South and in California (USDA 2016).

Aquatic invasives are not as well known but are a potentially costly environmental risk. The bivalve mollusks, Zebra mussels (***Dreissena polymorpha***) and the related Quagga mussels (***Dreissena rostriformis bugensis***), cost the U.S. economy $1 billion in 2002 (Quinn et al. 2013) and have spread far wider since. Zebra mussels can occur in densities as high as 750,000 individuals per square meter (McLaughlan et al. 2014), driving ecosystem-level change and becoming a costly biofouler to industry. Mussels foul submerged substrates including canal and dock walls as well as watercraft outdrives. Mussels clog water intake pipes and associated installations, severely impairing water delivery to hydroelectric, municipal, and industrial users which incur enormous cleaning costs (often over $1 million per cleaning per facility) and business interruption (Rosaen et al. 2016). Shutdown of power generating facilities results in lack of power to the surrounding areas causing additional damage to their customers. In the Great Lakes area, where the industrial base relies heavily on water, the losses can be severe.

Mussel increase water clarity, and light transmittance which cause an increased growth of benthic plants creating conditions that promote blue-green algae blooms, which can clog water intakes and pipes; contaminate water so that it is toxic to drink and harmful to touch or if airborne droplets are inhaled; and increase the cost of water treatment. The consumption of fish caught in contaminated areas, can cause illness. A further negative health effect is biomagnification of contaminants and cut feet, which can become infected from the toxic algae. The mussel contributes to the formation of disinfection by-products, reducing water quality (Chakraborti et al 2016) and concentrates organic pesticides and polychlorinated biphenyl compounds, which then enter the food chain (MacIsaac 1996). Private companies that do not comply with the ballast water management regulations (put in place to stop further spread) face fines and fees of hundreds of thousands of dollars or higher. Any company that ships in freshwater is at risk, especially those in the Great Lakes (Rosaen et al. 2016).

The Asian carp is a huge fish that has infiltrated most of the Mississippi, Ohio, Missouri, and Illinois River Systems, where it now makes up more than 95% of the biomass. It can jump at least 10 feet out of the water and grow to 110 pounds. Asian carp (several species) not only wreak ecological havoc and threaten fisheries—including the over $7 billion Great Lakes fisheries—but also cause injury and property damage. Collisions between boaters and jumping silver carp have the potential to cause human fatalities (USF&W 2004).

Invasive plants can also be problematic. The highest losses stem from management and removal costs or agricultural losses. However, invasive plants can also cause infrastructure damage, which, in turn, can increase the frequency and magnitude of natural risks such as fire and flood.

Salt cedar (of many species of ***Tamarix***) causes high non-crop damage, including water, municipal, agricultural, hydropower, as well as cause flood-control issues and increased fire risk. The quickly spreading ***Tamarix*** thrive in dry areas, hogging precious water, causing areas to become dryer and secreting salt into the soil. This leads to hydrological impacts, increase of fire frequency, displacement of native flora and fauna, and increased soil salinity. The plants cause economic damage through water loss within irrigation and municipal water systems, flooding from impeded water channels, reduction in hydropower capacity, and loss of wildlife habitat and recreational opportunities. Cost is forecast to be between $7 and $16 million in lost ecosystem functions over the next 55 years (Zavaleta 2000) (Lindgren et al. 2010). With wildfires increasing in intensity and costs, and ***Tamarix*** present in many of the highest fire-risk areas, the increased fire frequency in the presence of salt cedar may end up being the costliest type of loss caused by this species for insurers.

Other notable invasives include hydrilla (***Hydrilla verticilata***) and watermilfoil (many species of ***Myriophyllum***), which impede irrigation and boating, clog intakes at power generation and water supply facilities, and hinder recreation (swimming, boating, fishing, waterfowl hunting) (USF&W 2012); sudden oak death (***Phytophthora ramorum***), which is estimated to incur a costs of $7.5 million to treat, remove, and replace more than 10 thousand oak trees in addition to the potential losses from increased fire and safety risks, attributable to the dead trees and the loss of ecosystem services (Kovacs et al 2010); and the . emerald ash borer (***Agrilus planipennis***) pest, which incurred mean discounted costs for treatment and removal of trees, estimated at $10.7 billion for the 10-year period within 2009-2018 (Kovacs et al 2010). Potential insured losses related to sudden oak death and the emerald ash borer arise from damage to homes or commercial buildings or passersby by falling dead trees and increased fire risk.

EMERGING ENVIRONMENTAL RISKS FROM PRODUCTS – NANO- AND MICROPLASTICS

Globalization has led not just to the spread of infectious diseases and invasive species, but also to the proliferation of plastics for packaging and transportation of goods over long distances. When plastics degrade, they break down into smaller particles, referred to as micro- (0.1-1000microm) and nano- (<=0.1microm) particles (henceforth referred to as microplastics). There is a growing concern over the health risk of these particles in the environment. These risks affect health and workers' compensation insurance and could trigger products claims.

The sources of microplastic risk are broad and varied. Tires are acknowledged as a key source of microplastics (Wright and Kelly, 2017). Discarded plastic in the marine environment degrade to microplastics. Synthetic clothing leaches microplastics into the water supply when it is washed. Agricultural products are affected when wastewater treatment plant sludge is used as fertilizer. Dust from these fields can kick up microplastics into the atmosphere. Workers in manufacturing facilities could potentially suffer occupational diseases and injury from inhalation of microplastics. It is possible that as the health effects of microplastics become more well-known, there may be products claims against the most egregious of the products that shed microplastics.

Humans are exposed through ingestion and/or inhalation, negatively affecting health, in turn leading to increased health and workers' compensation insurance costs. Microplastics have been found in fish and shellfish, honey, sugar, beer, and sea salt. Microplastics, whether inhaled or ingested, can cause inflammation and compromised immune responses and can impact the lymphatic and/or circulatory systems, the health of cells and the immune system, and can accumulate in secondary organs. (Wright and Kelly, 2017). Microplastic particles have been found in cerebrospinal fluid, liver, spleen, bone marrow and blood of test subjects. (Wright and Kelly, 2017)

Energy and Manufacturing

Extraction, whether for energy (coal, natural gas, oil, uranium, etc.) or other purposes (bauxite, copper, feldspar, lithium, silver, gold, iron ore, lead, nickel, phosphate rock, gypsum, molybdenum, clay, gravel, etc.) causes environmental damage and leads to air and water pollution. Much of the damage is to uninsured land, or to the workers. Such risk has traditionally been assessed by actuaries and has been included in analysis of insurance, but researchers are beginning to document the increased health costs for those living in the vicinity. These additional risks cannot be ignored. The increase of mining near population centers broadens the risk. (Stewart 2019) Not only are the air and water contaminants a potential source of risk for neighboring communities, but also vibrations and noises from blasting, drilling, and crushing have adverse physical effects, such as raised blood pressure (ibid).Mining activities generate contaminated atmospheric dust and aerosol as well as metal and metalloid contaminants. Coarse particles may be dispersed via mining activities, water, and wind up to 4 km (study in Iran) from mine sites. Fine particles travel further, often in association with aerosols, and penetrate more deeply throughout the respiratory system, resulting in adverse health effects. Particles can also be ingested, and mining delivers harmful elements into the food chain. (Stewart 2019). The recycling of electrical and electronic equipment also adds contaminants to the environment, similar to mining, including metalliferous dusts. These can mix with organics and plastics, creating exposures to contaminant mixtures (Stewart 2019).

The mining of certain specific elements introduces more particular environmental risks to those who live in the vicinity or downstream. Uranium mining greatly increases mortality from radon-related lung cancer and arsenic exposure. Uranium mining in the Navajo Nation territory has led to autoimmune disfunction, high blood pressure, kidney disease, reproductive problems, bone cancer, and lung cancer in inhabitants in the vicinity of the mine, not just in miners. (EPA 2020).

Many chemicals used in U.S. natural gas operations were found to be potentially mutagenic or carcinogenic and have the potential to cause numerous biological effects. 65% of the chemicals in fracturing fluids or wastewater for which data was available, were potentially toxic. Anywhere between 9 and 80% of the contaminated fracking fluid could resurface. Naturally occurring radioactive materials (that had been deep in the ground but are brought to surface by mining) represent another hazard (Saunders et al. 2018).

Well venting, flaring, and burning gas on release during the fracking process are an additional risk accounting for one of the largest sources of air emissions. Diesel emissions from equipment, including trucks, adds to the air pollution (Finkel and Hays 2016). The fracking fluid (each fracking episode can inject 2-8 million gallons of fracturing fluid (Saunders et al. 2018)) also contributes to water pollution. Other risks are stray gas contamination of shallow aquifers; spills, leaks and/or disposal of inadequately treated wastewater; accumulation of toxic and radioactive elements in soil or stream sediments near disposal or spill sites; and over extraction of water resources (Saunders et al. 2018).

Fluid injection for hydraulic fracturing of shale formations or coal seams to extract gas and oil; disposal of wastewater from these gas and oil activities by injection into deep aquifers; and the development of enhanced geothermal systems by injecting water into hot low-permeability rock, may induce earthquake sequences. Wastewater disposal is associated with the largest earthquakes, with maximum magnitudes sometimes exceeding 5 on the Richter Scale (McGarr 2014). These can have effects on property insurance for any buildings that have earthquake as a covered peril and may generate professional liability, corporate management liability, general liability, contractor liability, or pollution policy claims.

Pipelines, tankers, trucks, and storage tanks of fossil fuels all have been shown to have negative environmental effects. Pipelines and underground storage tanks have risk of leakage or vandalism (including cyberattack). Energy leakage into the air occurs with methane, and flaring of natural gas from

crude oil wells, gas wells, and landfills, including sour gas (which includes hydrogen sulfide, a highly toxic substance).

Coverages most affected by environmental risks of mining include workers' compensation, health, liability lines such as professional liability, management liability, and general liability.

Energy use creates environmental risk. Power companies have been implicated for triggering wildfires, causing large amounts of property and casualty damage. It has been estimated that 10 percent of California wildfires are triggered by power lines. (Atkinson, 2018). There is high insured risk, whether the homeowners, property, and life insurers cover claims, or whether the power company is held liable and its insurance company pays.

Emissions from energy use are another source of environmental harm, which is beginning to be regulated, and which may lead to more liability payments. As a result of ***Massachusetts v. EPA*** (2007), the EPA has begun to regulate carbon dioxide as a pollutant under the Clean Air Act. Other emissions could be added to those regulated by the EPA. There is a potential for liability to purveyors or users of energy for emissions that pollute including those that accelerate climate change.

Though Alternative Energy is healthier in many respects, there are still environmental risks from non-fossil-fuel energy.

Wind power is increasing greatly both onshore and offshore. Much of the accident risk is associated with the fact that turbines are built in high risk locations – offshore or at high elevations. The high wind, potential barometric pressure changes, and high electric voltage associated with wind turbines add risk for workers. The high winds may contribute to tipping of heavy equipment, such as cranes. Wind turbine construction causes environmental destruction and can lead to deforestation and landslides (Dai et al. 2014), which could impact errors and omissions or professional liability policies of those professionals, siting or directing construction of the wind turbines. Building and maintenance activities such as parts replacement or lubrication can cause oil or waste to pollute surrounding areas, which may be particularly relevant for offshore wind farms due to the difficulty of servicing. As a relatively new but growing technology, many employees lack experience which could lead to more workers compensation accidents. Particularly hazardous are construction and maintenance activities offshore. (Transportation Research Board, 2013)

Risks to those living near wind farms are mainly due to noise which has been found to induce sleep disturbance and hearing loss in humans and trigger headaches, irritability, and fatigue as well as constrict arteries and weaken immune systems. The sleep deprivation due to wind turbine noise can cause serious health problems and the infrasound from the wind turbines may directly impact the vestibular system (Dai et al. 2014). All this would either impact health insurance costs or liability insurance if the turbine owners or operators are found liable.

A further risk from wind turbines is electromagnetic interferences, which can cause errors in navigational systems and disrupt the modulation in typical microwaves (Dai et al. 2014), both of which could cause insured accidents. Turbines are also a source of risk for birds and bats, which could have an impact on pest control.

Large-scale solar generating facilities impact land use. Workers' compensation risks for installation and maintenance of solar panels include the typical construction risks plus some additional hazards, stemming from the fact that the solar array continues to produce power, even when the building or array's main breaker is shut off, and even in low-light conditions which can cause thermal burns; muscle, nerve and tissues damage; falls from surprise shock; and death from electric shock, burns, or falls (OSHA 2020),

(Graphic Products 2020). Photovoltaic panels sometimes contain toxic substances which could lead to pollution claims. In addition, the batteries to store the energy for use when the sun is not visible, can contain lead and sulfuric acid, leading to the typical hazardous materials risks (Lee 2020). Siting in sensitive areas could trigger errors and omissions for professional liability policies. The increased use of rooftop solar panels creates a new threat to firefighters. Solar panels make it more difficult for firefighters to maneuver on the rooftop and may add risk if they cannot be turned off during the fire as the light from the fire keeps them energized which can cause electric shock or burns (Lee 2020).

Hydropower carries high risks. Dam failure, due to complete collapse or drainage pump or other equipment failures, is both not unlikely and expensive (Geiger, 2020). Along with significant property risk, insurers may face liability claims associated with the inability to provide contracted power during drought or if water is promised to upstream users and for damages to fisheries by impeding movement including spawning. Of course, building new hydropower dams carries all sorts of construction and destruction risks, including pollution. The health of those living downstream from hydropower dams can be affected by exposure to methylmercury in untreated water and locally caught food. Microbes convert naturally occurring mercury in soils into methylmercury when land is flooded. Methylmercury can increase up to 10 times pre-dam levels when a dam is installed (Calder et al. 2016). Increase in exposure to methylmercury is associated with increased risks of cardiovascular disease and neurodevelopmental delays in children. (Burrows, 2016)

Carbon Capture and Storage (CCS), in which waste carbon dioxide is transferred as high-pressure liquid carbon dioxide to underground geologic formations is an enormous undertaking requiring construction of massive infrastructure of facilities, pipes, and pumps dedicated to capturing, pressurizing, transporting, and injecting the carbon dioxide underground. Leakage of CO_2, either gradual or catastrophic, would negate the initial environmental benefits of capturing and storing the CO_2 and be dangerous for those nearby. When an abrupt leakage occurred naturally from Lake Nyos, a volcanic lake in Cameroon, in 1986, the CO_2 released was equivalent to approximately 1 week of carbon dioxide emissions from a single coal-fired power plant yet caused severe damage (Fogarty and McCally, 2010). High concentrations of carbon dioxide interfere with cellular metabolism in humans, livestock and other animals. A release from intentional CCS could adversely affect both life and health insurance; Farm and BOP policies; and could trigger liability associated with not safely storing the dangerous waste and with failure to fulfill the contract.

Injecting CO_2 into or near underground aquifers leads to the formation of carbonic acid, which can increase the leaching of contaminants such as arsenic, lead, mercury, and organic compounds. The injected CO_2 may be contaminated with pollutants from coal plant emission, increasing the water pollution (Fogarty and McCally, 2010). Human or animal health problems from the contaminated waters could lead to pollution liability claims to the CCS company and perhaps to the power company, which produced the CO_2. Regardless of payer, there would be increased health care costs.

Pressure built up by injected CO_2 could trigger small seismic events (Australian House of Representatives Report), which may be covered under earthquake coverage. Since CCS is done underground, with some in old mines and others in other geologic formations, it is unclear who owns the rights to carbon capture and storage, which may affect title insurance.

The extraction and use of traditional fossil fuels as well as the production and use of alternative energy generate air and water pollution as well as environmental changes, all of which can cause increased risk to human health, as well as environmental.

Human Health Effects of Air Pollution

Recent medical science has increasingly found links between air pollution and disease. Aside from toxic air pollutants (such as vinyl chloride) and small particulates, air pollution alone generally does not produce fatalities; instead it aggravates health problems through chronic exposure, increasing the incidence and severity of respiratory diseases (such as bronchitis, pneumonia, and asthma) (Salzman and Thompson, 2014). Over 35 million Americans suffer chronic lung disease. Lung troubles can also lead to coronary heart disease and can increase risk of death from other diseases. Air pollution is the leading environmental cause of early death, contributing to the equivalent of 5% of all deaths globally and is responsible for a substantial amount of morbidity (Pimpin et al. 2018). A RAND study estimates that failing to meet federal air quality standards led to nearly 300,000 hospital admissions and emergency room visits between 2005 and 2007 in California alone, resulting in $193 million in cost. A team of biostatistics researchers at Harvard found a correlation between long-term exposure to fine particulate matter and county-level death rates from COVID-19; an increase of one microgram of particulate matter per cubic meter is associated with a 15% increase in COVID-19 fatalities (Economist 2020).

Hazardous air pollutants mainly come from incinerators and industrial sources, but also from motor vehicles. Vehicle emissions are responsible for over half of total CO_2 emissions, about half of NO_X and over one-quarter of volatile organic compounds (VOCs). Power plants are key emitters of SO_2 and NO_X. (Salzman and Thompson 2014) All these effect health insurance and life insurance. The Clean Air Act reduced health and mortality costs from air pollution, but whenever it is weakened, these costs increase (Salzman and Thompson, 2014).

The Montreal Protocol (ratified by 197 countries as of 2013) reduced the dangers of ozone depletion. Ozone in the stratosphere absorbs certain frequencies of harmful ultraviolet radiation, emitted by the sun (UV-B). A reduction in ozone brought about by CHCs, chlorine, bromine, and others, impact human health, causing greater incidence of skin cancers, cataracts, and sunburns and leading to immunosuppression. Ozone depletion also reduces the photosynthesis and growth of certain plants, including commercially valuable plants. (Salzman and Thompson 2014) Thus, ozone depletion increases health/life insurance costs as well as crop insurance costs.

Increases to UV-B also damage the base of the marine and freshwater food chains by reducing the growth of marine phytoplankton and damaging midge larvae, resulting (among other things) in loss of protein available for human consumption (Salzman and Thompson 2014). This could lead to increased health insurance costs and possibly to increased property or workers' compensation claims from the fisheries sector.

Human Health Effects of Water Pollution

Thanks to the Clean Water Act, point source polluters are no longer major contributors to water pollution in rivers and lakes. Industrial facilities are not among the top ten sources of water pollution in lakes and rivers, and municipal sewage is not in the top five. Sewage and industrial waste, however, are still a major source of estuarine pollution. Much pollution is from run-off, which picks up pollution from farms, mines, construction sites, parking lots, and air pollution. Agriculture is the primary source of water pollution in rivers and streams and third for lakes. (Salzman and Thompson, 2014) Because nonpoint source pollution is nonpoint, it may be difficult to trace back to polluters, making assigning liability unlikely. However, as the costs of water pollution damage grow, lawsuits from affected parties may lead to more stringent regulations, fines, and more vigorous attribution attempts. Much of the costs of human health effects of water pollution will be borne by insurers whether as liability or simply under health coverages.

Bacteria and viruses that are typically in water bodies can pose a threat to human health if they multiply in drinking water. The leading cause of disease outbreaks due to drinking water is the respiratory pathogen ***Legionella pneumophila*** which naturally occurs in fresh surface water; prior to now it was gastrointestinal microbes. Waterborne diseases in the United States generate over $1 billion in annual hospitalization expenses, with additional costs of outpatient treatments, lost productivity, and death. (Zahran et al. 2018) Five primarily waterborne diseases, giardiasis, cryptosporidiosis, Legionnaires' disease, otitis externa, and non-tuberculous mycobacterial infection cost over $970 million per year with over 40,000 hospitalizations (Collier et al. 2012).

Agriculture/Husbandry/Silviculture

Agricultural crops face risks from the environment, from human acts, from insects and wildlife, and from bacterial and fungal pathogens. There are first-party risks to the crops or to properties themselves and third-party risks to surrounding properties, resources, and population. Nitrogenous wastes (agricultural fertilizer or animal-waste runoff), a main nonpoint source of pollution, can lead to eutrophication, a process by which a body of water is nutrient enriched stimulating the growth of aquatic plants resulting in depletion of dissolved oxygen. Eutrophication-driven declines in fish populations and biodiversity can lead to business risks to fishing-related tourism business, as well as to fishing businesses; algal blooms also can lead to health risks as many species are toxic to humans (reviewed by Selman, Greenhalgh, Diaz, & Sugg, 2008).

Environmental stressors include drought, which may generate profitability losses due to the increased expense of irrigation, or crop productivity losses associated with underwatering (Simelton et al. 2009). Similarly, cold spells may decrease insurable farm productivity, as ~10% of annual crop losses in the U.S. are associated with cold (USDA-ERS 2019). Herbaceous invasive insects decrease plant production (Oerke 2006). Invasive seeds or plant parts can contaminate crops, decreasing their value (USDA-APHIS 2018).

Herbicides and pesticides can cause damage to neighboring crops through drifting (US-EPA 2017) and contaminating water. It is unclear whether the manufacturer of an herbicide or pesticide could be liable for crop losses. Chemically damaged water can cause health problems and lead to agricultural losses and companies that produced or released those chemicals could be held liable for the losses. When sewage added to fields is contaminated by industrial compounds, some of the contaminants could accumulate in tissues of animals grazing there (Fernandez et al. 2019), potentially leading to human health risks. Workers' compensation risks include heat stress from inadequate shade for workers, such as those on sugar farms (Crowe, de Joode, and Wesseling 2009), and lack of suitable protective equipment for workers tasked with herbicide or pesticide application (Feola and Binder 2010).

Insects cause crop (Deutsch et al. 2018) (Ramsfield et al. 2016) and livestock (Mastrangelo and Welch 2012) damage. Rodents bring pathogens into livestock-rearing areas. Although granivorous (Kross et al. 2019) and frugivorous birds (Anderson et al. 2013) are documented to cause yield losses for some crops, overall, insectivorous birds are important in preventing yield losses to insects (Maas, Clough, and Tscharntke 2013).

The fungus causing white-nosed syndrome attacking bats in natural ecosystems leads to agricultural damage as bats provide $22.9 billion worth of pest suppression services. Additionally, as bats are important regulators of insects that are disease vectors (such as mosquitoes), decreased bat populations may also result in increased human health risks from insect-transmitted diseases.

Genetically engineered (GE) products both mitigate and create risks. Plants may be engineered to survive climate extremes and stressors (reviewed by Raza et al. 2018 and Parmar et al. 2017); require fewer resources (reviewed by Lopez-Arredondo et al. 2014); and increase production. Biotechnology can also be used to alter animal populations to reduce the spread of human disease (reviewed by Esvelt et al. 2014). GE organisms can generate environmental risks to the crops which are modified, and also to neighboring plants. GE plants can be engineered to be resistant to certain insect pests and herbicides. These traits can harm beneficial insects and increase pest suppression costs. In addition, the increased use of herbicides with herbicide-resistant GE, crops may have human health risk (Europe has banned some because of studies in France). Bacteria can be engineered to degrade pollutants or to produce valuable compounds, a mitigating factor of GE organisms that may reduce the cost of environmental clean-up claims. Production of pharmaceuticals in plants could have adverse health consequences if regulation is not maintained (Drake et al. 2017). Companies performing GE and promulgating GE products could be held liable for negative effects. Up to this point, the courts have not upheld National Environmental Policy Act (NEPA)-based cases against GE manufacturers, but it continues to be tested in the courts (Nelson, 2010).

Weeds can also be a serious environmental risk in agriculture. Many countries careful consider the consequences of allowing entry of foreign plants. These efforts are often aimed at preventing agricultural losses, land management costs, or degradation of natural habitats. Some of the financial consequences of weeds include: decreased agricultural output (row crops, rangelands), increased management costs (golf courses, residential areas), and decreased function of natural ecosystems (clogging intakes to nuclear power plants, making recreational use waterways impassible, contributing to shore erosion).

Native Non-Agricultural Pest Species

Environmental risks from native non-agricultural pest species, include damage caused by large animals, native arachnids and native insects.

Wildlife vehicle collisions (WVC) are on the rise. A comprehensive report to congress, last updated in 2008, finds that WVCs are a major problem for wildlife and humans. The study estimates between one and two million collisions between vehicles and large animals (such as moose or deer) in the United States each year, costing over $8 billion. More recent but less comprehensive studies find an increase in WVCs due to an increase in vehicle traffic, increase in regional wildlife densities, and shifts in resource distribution.

Though damage caused by pets, birds, rodents, insects, or vermin isn't typically covered by homeowners, damage to the building from other wild animals could be covered and comprehensive auto coverage will cover most wildlife damage to a covered auto. Human-wildlife conflict insurance is a growing field, worldwide. Most compensation for lost or damaged inventory in the U.S. is through the government.

Native arachnids are disease vectors. In the United States, ticks (comprising numerous species) transmit pathogens that cause at least 16 different human illnesses. Climate change has been linked to increasing tick populations (Junker 2020). Tick-borne diseases also threaten livestock, pets, and wildlife. Some ticks are even considered high-consequence bioterrorism agents threatening livestock enterprises and food security. It is estimated that any one potential new disease entering the U.S. could cause losses exceeding $760 million annually if it became established in indigenous tick populations (Junker 2020). Tick-borne diseases are on the increase because of natural resource degradation. Forest destruction and fragmentation are leading to an elevated risk of exposure due to three interrelated reasons: lower diversity of mammals, increased densities of white-footed mice, and increased density of tick nymphs. Forest patches that are less than 2 hectares in area present an elevated risk of Lyme disease (Allan et al. 2003).

Climate Change and Exacerbation of Environmental Risk

Models of actual events indicate an increase in extreme wind and precipitation events, such as heavy rain, thunderstorms, tornadoes, hurricanes, and extreme drought. As invasive species and further human development destroy natural barriers to storm surge, coastal losses will likely cause the increased activity to be even more damaging. Extreme events will likely increase storm- and wildfire-related insured losses and these will likely be the most costly insured losses due to climate change. Storm damage to capped or otherwise remediated superfund sites which will require additional cleanup could also lead to expensive claims. Direct casualty and mortality losses due to extreme heat will likely rise, as well.

The effects of climate change on water resources, including the likelihood of drought increases the liability risk to hydropower.

Natural disasters often increase the spread of invasive species as enclosures are destroyed and floodwaters and winds move organisms into new areas. Climate change, with its attendant increase in extreme events and natural disasters (Actuaries Climate Index; Rahmstorf et al. 2011; Stott 2016) will likely accelerate the spread of invasive species. At the same time, climate change could change the ranges of many species as warmer weather spreads away from the equator. North America may offer a larger home to subtropical and even tropical species, including pest species and disease vectors. Property, casualty, and health losses are likely to rise from these changes.

Conclusion

Environmental risks touch almost all lines of business for insurers. It is important that actuaries recognize and try to quantify environmental risks for each line of business. Environmental risks are changing rapidly with the shift of energy from fossil fuel to alternative, climate change, habitat loss, population increase, and globalization. Understanding the potential impact of these changes is key to more accurately project risks for future policies.

Environmental risks have the potential to become catastrophic. It is difficult to estimate and impossible to know which risks could become the next Superfund or the next asbestos. However, the more actuaries know about the risks, the better predictions we can make. Whether microplastics suddenly become the next big products claim or fertilizer-makers are held responsible for water pollution, insurers will want their actuaries to be cognizant of the risks.

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Project Oversight Group members:

Priya Rohatgi, ASA, Chair of Project Oversight Group

Rachit Agarwal, FSA, CERA, FCIA

Mark Alberts, FSA, MAAA

Jessica Chen, ACAS

Robert Erhardt, PhD, ACAS

Alexander Hoffman, ASA MAAA

Eric Holley, PhD

Petar Jevtic, PhD

Joe Kennedy, FSAI, FIA, MSc, Dip Man

Jiani (Maggie) Ma, FSA, FCIA

Max Rudolph, FSA, CFA, CERA, MAAA

Robert Zhan, FSA, CERA

Ruobing Zhang, ASA, ACIA, CERA

At the Society of Actuaries:

R. Dale Hall, FSA, CERA, MAAA, Director of Research

Scott Lennox, FSA, FCAS, FCIA, Staff Actuary

Rob Montgomery, ASA, MAAA, Consultant and Research Project Manager

Erika Schulty, Research Associate

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Society of Actuaries
475 N. Martingale Road, Suite 600
Schaumburg, Illinois 60173
www.SOA.org