13.7: Environmental Impacts of Industrial Ecosystems

The practice of industrial ecology in the anthrosphere certainly has profound potential effects upon the atmosphere, hydrosphere, geosphere, and biosphere. Anthrospheric influences may range from highly localized effects to global effects, such as greenhouse warming or stratospheric ozone depletion. The magnitude of the effects may be minor, or they may be catastrophic. Until relatively recently, the effects of human activities on the surrounding environment were of relatively little concern, resulting in neglect that is the cause of many of the environmental problems that exist even today. However, the proper practice of industrial ecology requires that consideration be given to the various influences that anthrospheric activities have upon the surrounding environment.

Consider the kinds of effects that industrial activities may have upon the natural environmental spheres. One of the most obvious influences is upon the atmosphere because of the emission to the atmosphere of pollutant gases, vapors from volatile compounds, and particles. Released carbon dioxide and vapors such as those of fluorinated hydrocarbons have a high potential to cause greenhouse warming. Particles obscure visibility and cause adverse health effects in people who must breathe the air in which they are contained. Chlorofluorocarbons lead to stratospheric ozone depletion and hydrocarbons and nitrogen oxides released to the atmosphere can cause formation of photochemical smog. Industrial activities often utilize large quantities of water for cooling and other purposes. Water may become polluted or warmed excessively when used for cooling (thermal pollution).

Many industries require large quantities of materials that are taken from the Earth by the extractive industries. This may result in disruption of the geosphere from mining, dredging, and pumping of petroleum. The other major effect upon the geosphere results from the need to dispose of wastes. Scarce land may be required for waste disposal dumps and the geosphere may become contaminated with pollutants from disposal of wastes.

The biosphere is most affected by industrial activity when toxic substances are released. Other effects upon the biosphere may be indirect as the result of adverse effects upon the atmosphere, hydrosphere, or geosphere.

Industrial systems are largely dependent upon the utilization of fossil fuels, so many environmental effects are due to fossil fuel extraction and combustion. Greenhouse-warming carbon dioxide emissions, acid gas emissions, smog-forming hydrocarbons and nitrogen oxides, and deterioration of atmospheric quality from particles released from fossil fuel combustion are all atmospheric effects associated with fossil fuel combustion. Coal mining activities have the potential to release acid mine water to the hydrosphere, petroleum production can release brines or result in ocean oil spills, acid precipitation may acidify isolated lakes, and water used as cooling water in power plants may become thermally polluted. The geosphere may be disrupted by fossil fuel extraction, especially in the surface mining of coal. Coal is extracted from some areas of West Virginia by cutting off entire mountain tops overlying coal seams and dumping the overburden into valleys below in order to get to the coal. Effects upon the biosphere from fossil fuel utilization may be direct (birds coated with tar from oil spills come to mind), but are more commonly indirect, such as acidified bodies of water from acid rain resulting from sulfur dioxide emissions from coal combustion.

Agricultural activities certainly have to be considered as parts of the anthrosphere, and modern agricultural practices are part of vast agriculturally based industrial systems. Large quantities of greenhouse-warming methane are released to the atmosphere from the action of anoxic bacteria in rice paddies and in the intestines of ruminant animals. “Slash and burn” agricultural techniques practiced in some tropical countries release greenhouse gas carbon dioxide to the atmosphere and destroy the capacity of forests to sequester atmospheric carbon dioxide by photosynthesis. Enormous quantities of water are run through irrigation systems. Some of this water is evaporated and lost from the hydrosphere. The water that returns to the hydrosphere from irrigated fields picks up significant amounts of salt from the land and fertilizers applied to the land, so water salinity can become a problem. Underground aquifers become severely depleted by pumping large quantities of water for irrigation. The production of protein from livestock requires much more water overall than does the production of an equivalent amount of protein from grain. Animal wastes from huge livestock feedlots are notorious water polluters, adding oxygen-depleting biochemical oxygen demand (BOD, see Chapter 9, Section 9.3) and potentially toxic inorganic nitrogen compounds to water. The disturbance of the geosphere from crop cultivation is enormous. Raising livestock for food entails a much greater degree of land cultivation than does the cultivation of cereal grains. Agricultural production replaces entire, diverse biological ecosystems with artificial ecosystems, which causes a severe disturbance in the natural state of the biosphere. Another agricultural activity that affects the biosphere is the loss of species diversity in the raising of crops and livestock. In addition to the loss of entire species of organisms, the number of strains of organisms grown within species tends to become severely diminished in modern agricultural practice. Obviously, those varieties of crops and livestock that are mostproductive are the ones that will be used to produce grain, meat, and dairy products. However, if something happens, such as a particular variety becoming susceptible to a newly mutated virus, alternative resistant varieties may no longer be available. Finally, the raising of transgenic crops and livestock (see Section 12.12, “Agricultural Applications of Genetically Modified Organisms”)promises profound and potentially unforeseen effects upon the biosphere.

Design of Industrial Ecosystems to Minimize Environmental Impact

From the discussion above it is obvious that industrial activity, broadly defined to include agriculture as well, has a high potential to adversely affect the atmosphere, hydrosphere, biosphere and geosphere. Inherent to the nature of industrial ecosystems, however, are measures and systems designed to minimize such impacts.

Several measures may be taken to minimize the effects of industrial ecosystems upon the geosphere. Since most of the raw materials required for manufacturing originally have to be extracted from the geosphere, the recycling of materials inherent to well designed industrial ecosystems minimizes impact upon the geosphere. The selection of materials can also be important. As an example, the mining of copper to make copper wire once widely used to carry communications signals involves digging large holes in the ground and exposing minerals that tend to release metals and acidic pollutants. The silica used in the fiber optic cables that now largely substitute for copper is simply obtained from sand. The impacts of disturbing the geosphere for food and fiber production can be minimized by some of the conservation methods and agricultural practices discussed in Chapter 11.

Well designed industrial ecosystems emit much less harmful material to the atmosphere than do conventional industrial systems. Industrial atmospheric emissions have been decreasing markedly in recent years as the result of improved technology, more stringent regulation, and requirements to release information about atmospheric emissions. One of the main classes of industrial atmospheric pollutants has consisted of the vapors of volatile organic compounds (VOCs). These have been significantly reduced by modifying the conditions under which they are used to lower emissions and by measures such as activated carbon filters to trap the vapors. The practice of industrial ecology goes beyond these kinds of measures and attempts to find substitutes, such as water-based formulations, so that volatile organic compounds need not even be used.

Years of regulation have resulted in much lowered releases of water pollutants from industrial operations. These lowered levels have been due largely to sophisticated water treatment operations that are applied to water before it is released from a plant. Desirable as these “end-of-pipe” measures are, the practice of industrial ecology goes beyond such pollution control, minimizing the use of water and preventing its pollution in the first place. One way to ensure that water pollutants are not released from an industrial operation is to completely recycle water in the system—no water out, no water pollutants.

In past years, many hazardous solid and liquid wastes have been improperly disposed to sites in the geosphere, giving rise to a large number of “hazardous waste sites,” the subject of Superfund activity in the United States. The practice of industrial ecology seeks to totally eliminate any such wastes that would require disposal. Ideally, such wastes simply represent material resources that are not properly utilized, a fact that can serve as a guideline for the prevention of such wastes.

The expenditure of energy entails the potential to cause environmental harm to the various spheres of the environment. A prime goal in the proper practice of industrial ecology is the most efficient use of the least polluting sources of energy possible. More efficient electric motors in industrial operations can significantly reduce electricity consumption. The proper design of buildings to reduce heating and cooling costs can also reduce energy consumption. Many industrial operations require heat (process heat in industrial parlance) and steam. Rather than generating these separately, they can be produced in combined power cycles along with the generation of electricity, thereby greatly increasing the overall efficiency of energy utilization.