ENVIRONMENTAL MONITORING

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Keywords: point and nonpoint sources, mobile source pollution**,** soil, water, and air monitoring

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Summary

Since World War II, agricultural production has shifted from labor-intensive to machine-driven and chemical-intensive methods. The use of the latest technology in farm mechanization, plant and animal breeding, and in the production of new chemicals for insect and weed control has resulted in an abundant supply of food and fiber at a relatively low cost. During the last quarter of the twentieth century, a serious public concern has emerged about the fate of agrochemicals and their impacts on humankind and the environment (particularly in relation to water quality). This concern was further intensified with the detection of many agricultural pollutants in the world's major water

bodies by several environmental monitoring programs worldwide. A number of environmental monitoring programs were initiated in the United States to better understand the movement and degradation of agricultural pollutants in the soil–water–air system. The results of these studies indicate that behavior of agrochemicals in the soil and water system is a complex process influenced by hydrologic and geologic conditions of the region, chemical properties, and agricultural production practices. Many technologies are now available to increase the efficiency of machines, nutrients, pesticides, and irrigation water use by adopting appropriate farming systems. Review of some of these studies indicate that better agricultural management practices can minimize the impacts on soil and water quality and make our ecosystem much better. Development of sustainable agricultural production systems will be necessary to safeguard the world's already damaged ecosystem and sound principles of science and technology can be applied to minimize environmental degradation.

1. Introduction

Ecology and economy are twin elements of global stability. About twenty-five years ago, it was a popular belief that the goals of economic development and environmental protection were mutually exclusive. Today, this view has largely given way to a belief that we need a better understanding between economic development and the global environment. The first and foremost component of a comprehensive environmental-assessment policy is that economic development be environmentally sound and sustainable. Nothing illustrates better how ecological sustainability challenges us all than the link between population and development.

Although population growth rates have been declining recently, by 2050 the planet could have 10 billion people, almost double the population at the turn of the twenty-first century. If we look at the global picture on resources, we see a frightening outlook. The impact of this increased population on the environment will be severe. As much as 95% of world population growth is projected for developing countries which, by 2050, will have 87% of world population. This will add enormous stress on the available soil, water, mineral, and energy resources for domestic, industrial, and agricultural use while simultaneously increasing the pressure to maintain environmental quality and preserve our ecosystems.

Maintaining a good standard of living for this growing population will require a renewable water resources capacity of 1000 m^3 per person per year. China and India are developing future water resources management plans on renewable water supplies of 500 and 250 m^3 per person per year, respectively, to sustain their economics. Many other countries have less renewable water resources for their economic growth. In contrast with population growth, water resources are finite. An increasing population will require more food and in many areas will mean more depletion and pollution of water resources. This might result in less water available for industrial and municipal demands. In 1900, 90% of all water used in the world was for irrigation; in 2000 it has fallen to about 60%. These data indicate that we must grow more food with less water, using more intensive agriculture and fertilizers and pesticides. Farmers use pesticides to keep grasses and insects at bay and fertilizers to help crops grow better. For years it was believed that these chemicals would either remain on the ground surface of agricultural fields or would degrade before they could reach the groundwater and/or surface water. However, drinking water supplies have been found to contain nitrates, nearly all of which may have come from fertilizers. Many of these water supplies contained nitrate–nitrogen (NO_3-N) concentrations greater than 10 mg L^{-1}, a drinking water standard set by the U.S. Environmental Protection Agency (USEPA). Besides NO_3-N, some common pesticides have also been found in ground and surface water. Since the first discovery of a pesticide in groundwater in 1979, 46 pesticides have been found to contaminate groundwater as a result of normal agricultural use.

More recent experiments in developed countries have shown clearly that modern agricultural activities are contaminating the soil water sources through increased use of chemicals which are then found in surface and groundwater sources. Groundwater is a major water resource. There is about 67 times as much water stored underground (within drillable distance) than there is water in all the rivers and lakes of the world. The increased use of agricultural chemicals has contributed significantly to the agricultural productivity but has been the source of much controversy recently because of the perceived health risks posed by the presence of nitrates, pesticides, and other compounds in drinking water. This has resulted in the introduction of groundwater-quality legislation by several states in the USA. High concentrations of nitrate–nitrogen (NO_3-N) in well water was first recognized as a health problem in 1945 when two cases of infant methemoglobinemia (blue baby syndrome: a temporary blood disorder that reduces the ability of an infant's blood stream to carry oxygen through the body) were reported in Iowa, and recently in South Dakota. Some evidence exists that high NO_3-N ingestion is involved in the etiology of human cancer. The negative impacts of the use of pesticides on human health and on the environment have been a source of concern. In addition to concern about the acute and chronic toxicity of pesticides, their potential as carcinogens and their presence in groundwater sources have raised questions about their continued use in agriculture. The phosphate–phosphorous concentrations in water bodies at levels as low as 0.05 mg L^{-1} can promote the growth of algae and speed up eutrophication in lakes and reservoirs. Other forms of nitrogen and phosphorous can reduce dissolved oxygen in surface-water resources and further enrich the supply of nutrients causing nuisance plant growth. This can happen in any individual water body or on as large a scale as the Gulf of Mexico or the Black Sea, where "hypoxia zones" are drawing international attention. Another water-quality issue is the potential of pathogenic bacteria being introduced into the drinking-water supply from land receiving animal manure and other municipal and industrial wastes. Therefore, basic and applied methodologies are needed to control, retain, and monitor agricultural, municipal, and industrial pollutants in rivers, reservoirs, lakes, and groundwater resources. A better understanding of the environmental pollution mechanism is needed to develop simple and rapid monitoring technologies to identify the extent of pollution from current production systems and show how better management practices can further improve the environment. The purpose of this topic contribution is to present summaries of various environmental monitoring technologies that could be used to monitor the effects of best management practices to minimize the impacts of agricultural and water management systems on water quality and to recommend better monitoring systems to help in protecting the environment.

2. Loss of Ecology due to Agricultural Development

Human activities in the twentieth century have proved they can upset the overall balance of various processes that maintain Earth. Human activities have affected various elements of the natural environment and the resulting changes have clearly indicated that human survival on this planet may be in jeopardy. Several ecological studies have clearly indicated that the growth in human population on this planet has forced many plant and animal species into extinction. The 1995 UN Conference on Biodiversity in Indonesia found that human population growth and economic development are depleting biological resources around the globe. This conference further stated that although environmental awareness is growing, the damage to global biodiversity continues on daily basis. Several thousand plants and animal species are becoming extinct every day from the surface of this planet. This kind of information is becoming available through the monitoring efforts of various groups on "eco-monitoring networks."

A recent study conducted in Iowa on the effects of agricultural development on biodiversity showed that trends in biodiversity, population, and development are quite similar to those observed on a global scale. It has been reported that in 1780, about 1 200 American Indians lived in Iowa. Iowa's population increased from 10 500 in 1836 to 97 000 in 1846 and to 2.8 million in 1995. This dramatic increase in human population in some 150 years has destroyed some of the most preserved and productive ecosystems of the world. Destruction of natural habitat from the introduction of intensive agricultural production systems has been the greatest factor in Iowa's loss of biodiversity. Although agricultural activities have been the main causes for biodiversity destruction, other human activities such as highway construction, railroad development, expansion of urban communities, river straightening, and construction of dams and reservoirs have contributed significantly to the decline of natural habitat. Many plant and animal species simply disappeared because they were part of the natural habitat of the ecosystem.

It has been reported that the removal of prairie marshes and wetlands from the landscape of Iowa in the early 1900s changed natural habitat. In order to bring more and more land under intensive agriculture, a large proportion of wetlands and marshes were artificially drained in northwest and north–central Iowa and about 3.08 million hectares of prairie–marsh habitat was reduced to about 10 525 hectares in about 100 years. The drainage of wetlands and their subsequent degradation because of sediment and nutrients in agricultural runoff (the major source of water for many of the remaining wetlands) has resulted in a number of direct and indirect changes to Iowa's fauna and flora. Many other plants and animals adapted to wetlands suffered significant reduction because of habitat destruction. The study further illustrates the value of environmental monitoring to collect information on various environmental indicators.

3. Environmental Monitoring

Present-day agricultural production systems have been successful in increasing agricultural and livestock production to meet the growing needs of population for food and fiber through intensification. The intensification of agriculture has occurred because of increased biological inputs (crop varieties), mechanical inputs (farm mechanization), water inputs (irrigation systems), and chemical inputs (fertilizers and pesticides). The use of agrochemicals such as fertilizers, herbicides, and insecticides has not only increased crop yields but also has started deterioration of the very base of global food production system, i.e., soil and water resources. The development of a hypoxia zone in the Gulf of Mexico is linked to the production agriculture in the US Midwest. Water drained from agricultural lands in the Midwest has been reported to be a potential source of nitrate–nitrogen (NO_3-N) contamination of water bodies. The National Water Quality Assessment Program of the US Geological Survey showed several herbicides such as atrazine, metolachlor, prometon, and simazine were detected most frequently across the United States. Through extensive water-monitoring programs, this survey analyzed 2200 samples from 1992 to 1995 from sites that represent 37 diverse agricultural basins, 11 urban basins, and 10 mixed land-use basins. Nationally, 11 herbicides, one herbicide degradation product, and three insecticides were detected in more than 10% of the samples. Also, row-crop production system on steeper slopes has been found to be increasing soil erosion unless conservation tillage systems are practiced. To continue to obtain these kinds of data sets for developing environmentally effective watershed-management policies and programs, extensive networks on watershed/basin monitoring need to be developed to create baseline data sets for all the major river watersheds in the world.

Many of the current agricultural-production systems are more or less unsustainable and will be unable to continue production on a long-term basis because of the continued deterioration of natural resources which directly or indirectly support agriculture. Agriculture cannot become sustainable unless the degradation processes causing negative impacts on soil, air, and water resources are changed drastically to conserve renewable and nonrenewable natural resources. Therefore, environmental monitoring systems for water, soil, and air need to be developed to determine the ongoing effects of agricultural and animal production systems on the environment so that production systems can be sustainable for future generations. Also, one in every five people in the world live in poverty; 1.2 billion people are struggling to live on less than US$1 per day. This poverty has deprived people from access to clean drinking water, proper sanitation facilities, and decent shelter. These living conditions for the poorest of the poor in the world will lead to social and geopolitical difficulties such as the spread of conflicts over finite resources, diseases, and further degradation of the already polluted environment. Given the resources, capital, and technology available, it is quite possible that every poor person on this planet has a chance for a decent life and could thereby help to improve the environment by becoming a more productive member of society.

Environmental quality can be characterized by the physical, chemical, and biological properties of a given environment (soil, water, and air). A complete assessment in the changes of these salient features of an environment by human actions will require a well-established monitoring program. Environmental monitoring refers to those repeated observations which are the outcome of complex human actions on this planet and their related effects on degradation or improvement of the environment. The purpose of environmental monitoring is to identify and change those human activities that are responsible for soil, air, and water degradation, in order to protect human health and the wellbeing of ecological systems. Environmental monitoring should include both source monitoring and ambient monitoring to provide information to establish a cause–effect relationship. Assessment of environmental monitoring programs requires reporting and interpretation of data, and recommendation for further actions to correct any environmental damage.

Sources of environmental pollution can be grouped into three categories: (a) point sources, (b) nonpoint sources, and (c) mobile sources. The point sources refer to fixed bases or points such as industrial stacks, discharge pipes, and other stationary sources. Nonpoint sources are large areas such as agricultural lands or forests, whereas mobile sources of pollution include motor vehicle emissions or spills of toxic and hazardous substances during transportation. Source monitoring refers to monitoring the causes of environmental pollution at or near the source. Ambient monitoring refers to measurements of intensity and concentrations of pollutants in the environment, i.e., water, soil, and air. This paper will briefly mention the equipment and procedures needed for environmental monitoring of each environmental attribute.

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