International Journal of Environmental Sciences
Vol. 7 No. 2 (July-December, 2021)

http://www.theaspd.com/ijes.php

Air Pollution: A Threat to Biodiversity

M. Mishra* & N. C. Sahu**

**Reader in Economics, Department of Economics, Faculty of Social Science, Banaras Hindu University, Varanasi-221 005, UP, India.*
*** Coordinator, Department of Economics, Berhampur University, Berhampur-760007, Ganjam, Orissa, India.*

Received: 30th July, 2021
Revised: 29th August, 2021
Accepted: 25th September, 2021

Abstract: Biodiversity is the basic foundation of human existence which represents important opportunity for economic improvement. Apart from long range ecological security it ensures supplies of goods and services that are indispensable for human life. But in recent years the large scale urbanization, industrialization and associated environmental alteration and its impact on biodiversity pose a threat to human existence through basic necessities, recreation and the ecological functions. It is evident that pollution from various sources particularly from industries and power plants has negative impacts on biodiversity, irreversible in nature, cause extinction, resulting in loss of unique genetic resources of great use. The present paper is an attempt at identification and valuation of biodiversity loss due to air pollution in Angul-Talcher industrial area in Orissa. The study is based on a floristic study and phytosociological analysis conducted during 1992 and 1993. Herbaceous biomass pattern and production and species diversity has been considered as the important indicators of impact of pollution on biodiversity in the study area. For the purpose of analysis three sites at different locations has been chosen and it is observed that both the biomass production and species composition is much higher in the control site than the polluted sites. Though it is difficult to assign a money value to biodiversity but in recent years several attempts have been made on the basis of its option and existence values. In the present study, it is observed that the study area suffers a biodiversity damage worth about Rs. 6 millions per annum due to air pollution in the area.

BACKGROUND

Biodiversity is the basic foundation of human existence. It is important for the stability and resilience of an ecosystem. Besides ecological security, it provides many goods and services indispensable for human life. A good stock of natural biological capital ensures sustainable development. It is an important biological resource and strength of the developing countries. The most important anthropocentric reason for biodiversity conservation is, therefore, the role it plays for the human existence. Biological diversity benefits refer to all current and potential services provided by rich living environment, including a variety of species, gene pools, habitats and ecosystems. Along with the supply of several important resources including drugs and chemicals it also is basic to evolution. The history of human civilization and development of economic systems and thoughts are all inherently and inveterately interwoven with this biological resource. However, at present, an important biological challenge to the economics of natural resources utilization relates to biodiversity loss. The rate of resource depletion, the degree of environmental alteration and its impact on quantity, quality and distribution of biodiversity pose a threat to human society through food supply, medicine, recreation and other ecological functions (Pearce and Moran, 1994).

Growing economic activities like clearing of forests for mining, power plants and industries and other development projects including urbanization pressurize the ecosystem, interfere with its internal reorganization and cause loss of biodiversity, which is irreversible in nature. Pollution of different kinds, now a days has become a growing threat to natural vegetation and biodiversity. The effects of pollutants and acid rain on natural vegetation and biodiversity, therefore, are an important area of research in environmental/ ecological economics.

THE PROBLEM OF STUDY

Ecologists view the critical importance of biodiversity for a healthy ecosystem supporting human survival. But there is nothing to be surprised that the high aspirations of the human society in a world of material prosperity clash with the objectives of biodiversity conservation. Pollution has possible adverse impact on biodiversity, cause extinction, implying loss of some unique genetic material of great usefulness (Johanssen, 1993). Biodiversity loss is a meta phenomenon at the center of global environmental policy efforts. There is a broad scientific consensus that biodiversity is an important feature of life on this earth and is increasingly threatened by human activity (Reid and Miller, 1999; Heywood, 1995). Pollution leaves negative impacts on agriculture and vegetation (Seneca and Taussig, 1974). Growing plants are susceptible to pollution causing interruption in the process of photosynthesis, retarding growth and visible injury. Productivity and crop yield of many important crops have been reduced due to pollution. Pollutants affect plants adversely in several ways, and injury to plants can be acute, chronic and hidden (Woodwell, 1970). Various types of dust are emitted into the atmosphere by the industrial, mining and related activities. Around such sources a large quantity of dust cover on vegetation has been frequently observed. Highly alkaline dusts visibly injure plant leaves and also affect photosynthesis and transpiration. It is observed that plants around large dust sources are susceptible to chronic decrease in photosynthesis and consequently in growth (Hirano *et al,* 1995). Metal accumulation in soil affecting potherbs and cultivated plants in domestic gardens and agricultural field crops is accompanied by diminished crop yield and reduced growth of some seedlings (Robitsch, 1995).

It is evident from scientific research that air in industrially polluted area is composed of several hazardous pollutants that affect the plants kingdom in a complex manner. Biological studies have isolated the effects of a variety of pollutants like SO_2, NO_x, fluorides etc. on vegetation. Considerable scientific evidence exists to demonstrate the causal relationship between poor air quality and deteriorating plant growth (Seneca and Taussig, 1974). Air pollutants like sulphur dioxide and the oxides of nitrogen, ozone and the photochemical oxidants and fluorides are most damaging. Damages from SO_2 can be extensive enough to result in a total destruction of the entire crop. Recent instances support the view that SO_2 affects the trees and the forest crops, especially from the discharge of the nearby thermal power plants. SO_2, is considered as one of the main causes of forest decline world over. Since areas with extensive large-scale forest decline correlate well with the areas where sulphur dioxide concentrations are elevated. Both herbaceous and woody plants are subject to SO_2, damage. In spring it causes foliar necrosis. Long-term exposure causes visible injury, retards growth and reduces yield (Guderian, 1977). Even at low concentration SO_2 influences physiological processes, growth and yield of some sensitive plants (Black, 1982; Last, 1982). The crop like barley and other grasses are prone to SO_2 injury as such awns are aerodynamically the suitable sites for absorption of pollutants (Johnson *et al.,* 1975). The effects of sulphur dioxide can lead to visible injury, which can take the form of necrosis of plant tissue- typically the leaves die. It also causes growth retardations. Damaging effects range from chlorosis to necrosis (Barrett and Benedict, 1970) that inhibits pollen germination (Varshney and Varshney, 1981), reduces reproductive capacity, fruit setting and seed yield (Murdy, 1979). Deterioration in seed quality is seen as a common feature in case of SO_2 exposed plants (Pandey, 1978; Prasad, 1980; Agarwal, 1982). As a result, there is a decrease in crop productivity, yield and changes in plant community.

Another primary pollutant, NO_x causes soil acidification when the concentration exceeds the critical load. It suppresses and retards growth, causes leaf bleaching (Barrett and Benedict, 1970; Guderian, 1977). Fluorides cause severe damage to agriculture and vegetation. It is more sensitive to fruit plants, affecting the number and weight of fruits produced. Hydrogen fluoride even at low concentrations interrupt in the photosynthesis process, retard plant growth, causes tip burn of the leaves, (Kudesia, 1985). It has more of local than community wide effect, as it is source specific (Leone, 1979). With a mixture of pollutants several types of interactive effects like synergistic (Roberts, 1984), antagonistic, predisposition and desensitization (Runeckles, 1984) may occur.

SCOPE AND OBJECTIVES

Biodiversity loss is a widely accepted and well-documented environmental crisis world over. In spite of many positive and encouraging developments, it is observed that the approaches and responses have failed to control biodiversity loss. The fast deterioration of biological diversity occurs both at local as well as global level. Habitat loss and degradation is the most primary causes of biodiversity loss and for this the socio economic forces and institutions like market laws, political forces and social norms and requirements which promote expansion of development projects are largely held responsible. The present study intends to quantify the loss of biodiversity in economic terms caused by pollution in a development project area of Angul-Talcher in Orissa. The area has been chosen because it represents one of the 24 pollution hot spots of Indian Union and the socio-economy of the area is rural and agricultural based with more of people being poor and backward.

METHOD OF BIODIVERSITY VALUATION

The study is built upon secondary sources of information only. The impact of pollution on natural vegetation and biodiversity of the area described in the study has been derived from a scientific study conducted jointly by the Orissa University of Agriculture and Technology and the Orissa Environmental Society in 1993.The preliminary floristic survey and phytosociological analysis has taken biomass pattern and species diversity as the indicators of impact of industrial pollution on biodiversity. On the basis of polluted area and control area comparison the study found the area as ecologically degraded.

The economic valuation of biodiversity in this study is based upon the value of plant-based drugs. In this context the works of Pearce and Moran (1994) and Pearce and

Purushothaman (1996) are noteworthy. Biodiversity provides many economic and non-economic services. Their option and existence values are reported to be high. Lal (1992) has estimated the rental value of one hectare of forest as the harbourer of biodiversity at Rs.1028 (1987 – 88 prices) per annum, which we have applied to the study area of this work taking due note of price rise.

$$\text{So } B_D = Rh_a^{-1}. A$$

Where B_D = Biodiversity damage

Rh_a^{-1} : Annual rental value per hectare of forest land

A = Area of forest loss

BRIEF DESCRIPTION OF STUDY SITE

Angul-Talcher is one of the two largest industrial agglomerations of Orissa in India. Talcher, which is famous for its coal deposits, has attracted rapid industrialization being supported by other factors like cheap labour, plentiful water supply, good transport network, abundant space for construction and other locational advantages. Industrialization has taken a big leap during 1960s to 1980s (OEP, 1994) and the area has emerged as a big source of coal and thermal power in the country (SAC, 1990).

The area spreads over the revenue district of Angul in the central part of Orissa, stretching over 20^0 48' to 20^0 58' N latitude and 85° 53' to 85° 28' E longitudes (CGWB, 1993). The area is 160 kms away from the Bay of Bengal. It occurs at an altitude of about 100 mtrs above the mean sea level. The pollution impact zone covers an area of 2829 Sq. kms encompassed by 30 kms radius circle on both sides of river Brahmani inhabited by a population of 8.4 lakhs. The area has a rural agro-based economy with 83% of rural population and 65% depending on agriculture (GoO, 1993). However, there is a recent trend towards urbanisation due to phenomenal growth of industries. Since traditional and low productivity agriculture is the main occupation, majority of people are poor and backward (GoI, 1991).

There operates seven large-scale public sector undertakings in both central and state sectors. The industries produce urea and ammonia, aluminium, thermal power, chemicals and heavy water (Table 1). Extensive mining, power plants, industries and growing urbanisation has seriously damaged the environment in the area. Eco-degradation in the form of degraded and denuded forests, eroded soil, impure air and water, large-scale land conversion is observed (ORSAC, 1994). Main air pollutants in the area include SPM, SO2, NOx, CO, CO_2, urea dust, ammonia, fluoride, fly-ash, dust, soot, smoke, fume, hydrocarbons, etc. These pollutants remain suspended for a long period of time in the ambient air and cause serious damages over a large stretch of area. These air pollutants from the industries cause the biotic and abiotic components of the ecosystem degraded in the region (Das, 1990). Large quantity of water drawn from the rivers and water bodies for various processes return back with contamination and degradation. The polluted water /industrial effluents include various heavy metals, fluoride, hexavalent chromium, ammonical nitrogen, ash, suspended solids, oil and grease etc. Water in the area is so polluted that it is not fit for direct use as drinking or bathing. Besides this, huge quantities of solid waste in the form of ash, ash slurry, scrap metals etc. are generated which adds to the pollution problem of the locality. Industries release 1,42,000 kgs of SPM, 90,000 kgs of SO_2, and 70,000 kgs of NO_x on a daily basis to the ambient air in the area. Apart from the above pollutants, 1843 kgs of urea dust and 503 kgs of ammonia from FCI and 76 kgs of fluoride (gaseous and liquid) are released from NALCO smelter plant daily.

The huge quantities of air pollutants certainly cause havoc for the people, plants, animals and other living creatures as well as the assets and physical property. From the point of view of quantity, fluoride of 76 Kgs./day is small but from the point of view of its damaging effect, such small quantity is of serious concern. Equally true is the case for urea dust and ammonia. The large quantities of SPM, SO_2, NO_x, leave a greater degree of damage. Water bodies receive 1,15,389 m_3 of industrial effluent daily, containing heavy metals like lead, chromium, cadmium, cobalt, zinc, thorium, aluminium, etc., with high adverse effects on living creatures. An amount of 6,205 MTs of solid waste per day is also a matter of serious concern. All the industries found in the area come under the list of 17 highly polluting industries classified by the Central Pollution Control Board (CPCB) and the Ministry of Forest and Environment, Government of India. The extent of pollution is so high that the area has attracted attention from within and outside the state and has been branded as a problem area, one of the twenty-four important hot spots of industrial pollution of the country. Table 3 explains about the nature and extent of pollution generated by the industries. The table justifies that Angul-Talcher area of Orissa is reeling under severe environmental pollution caused by the industries. The pollution problem has become so high that the area has attracted attention from within and outside the state and has been branded as a problem area, a pollution hot spot of the country.

Table 1: Industrial Profile of the Region

Name of Industry year of establishment	Output Produced	Investment (Rs.in crores)	Employment	Annual average output (MT/MW)	Annual average value of product(in Rs. Crores)
FCI, Talcher (1980)	Urea Ammonia	225.52	1380	1,12,585	79,20
NALCO (aluminium smelter plant) Angul (1986)	Aluminium	2408	5450	1,81,365	1120,00
NALCO (captive power plant) Angul (1986)	Thermal Power			3,519	
TTPS, Talcher (1967)	Thermal Power	750	1200	12,83	91.30
ORICHEM, Talcher, (1982)	Sodium Dichromate & Basic Chrome Sulphate	08	200	2,600	7.60
H. W. Plant, Talcher	Heavy Water	NA	NA	NA	NA
TSTPP, Kaniha	Thermal Power	NA	NA	NA	NA
Total		391.52	8230		1298.10

Note: Annual Average refers to an average of 6 years,1990-91 to 1995-96.
Source: 1. OSPCB, (1990)
2. Annual Reports of concerned industries, Government of Orissa, 1992
3. Through Questionnaire cum schedule.

Table 2: Pollution Profile of the Region

Name of the Industry	SPM Kg/day	SO_2 Kg/day	NO_X Kg/day	Waste Water m^3/day	Solid Waste tones/day
FCI	53,740	5,664	3,792	4,757	459
NALCO (ASP)	200	2,208	897	12,485	18
NALCO (CPP)	8,980	33,591	19,297	71,455	3,879
TTPS	65,700	29,400	21,250	15,076	1,836
ORICHEM	154	03	NIL	NIL	13
TSTPP	13,219	19,056	23,640	11,616	NA
TOTAL	1,41,993	89,922	68,876	1,15,389	6,205

Note: Apart from the above FCI emits 530 kgs. Of ammonia (NH_3) AND 1,843 of urea dust daily and NALCO smelter release 76 Kgs of Fluoride daily.
Source: OEP, (1994)

IMPACT OF POLLUTION ON NATURAL VEGETATION AND BIODIVERSITY

As an impact of indusrtialisation, urbanization and related economic activities natural vegetation and biodiversity in the study area is expected to have undergone certain modifications. A preliminary floristic survey and phytosociological analysis conducted jointly by the Orissa University of Agriculture and Technology and Orissa Environmental Society in 1993 shows the impact of industrial pollution on natural vegetation and species diversity in the industrial area of Angul-Talcher in Orissa. The study considered herbaceous biomass production and weight and species diversity as the indicators of impact of pollution on natural vegetation and biodiversity. For the purpose three sites were taken for experiment, a) the Gadarkhai village a fallow land an immediate neighboring village of the aluminium smelter plant, b). Balaramprasad hillock, a small patch of forest situated near the ash pond of the Nalco Captive Power Plant, and c). Chandrabahal Hillock, part of a contiguous hill forest 10 kms away from the industrial agglomeration. The first two sites are in the polluted area where as the Chandrabahal Hillock is taken as the control site as it is away from the source of pollution. The results of herbaceous biomass content clearly indicate the adverse impact of pollution and pollutants on biodiversity and vegetation. Herbaceous biomass production is higher in the control site, and is very low in Balaramprasad hillock near the ash pond on NALCO captive power plant, the degradation is expected due to the interference of fly ash and other particulates in the photosynthesis processes. So also in Gadarkhai village, a fallow land in the immediate neighbour of the aluminum smelter plant biomass is small which is expected due to accumulation of pollutants including particulate matter containing fluoride on the vegetation and soil substratum (Table 3).

Table 3: Herbaceous Biomass Pattern of Experimental Sites in Angul-Talcher in Orissa

Study Site	Month	Biomass Weight (kg/hectare)
Gadarkhai (Polluted Site)	November	12.2
	December	9.58
	January	9.78
	February	6.22
	March	9.80
	April	8.00
Balaramprasad (Polluted Site)	November	7.85
	December	6.57
	January	6.52
	February	5.97
	March	3.68
	April	2.27
Chandrabahal (Control Site)	November	17.24
	December	10.32
	January	10.72
	February	10.13
	March	9.43
	April	12.40

Source: Mishra, 1999

The analysis of species diversity also shows the negative impacts of pollution on biodiversity. An analysis of the species composition and species diversity of the three sites also exhibits that the control site is more heterogeneous with high species diversity where as the other two sites are comparatively less rich in species heterogeneity. Chandrabahal hillock the clean area possesses 99 species of all kinds, trees, shrubs, climbers and herbs against 76 in Balaramprasad hillock and 66 in Gadarkhai village (Table 4).

Table 4: Species Composition and Diversity in Study Area

Study Site	Trees	Shrubs	Climbers	Herbs	Total
Gadarkhai	10	05	02	49	66
Balaramprasad	16	09	05	46	76
Chandrabahal	25	12	06	56	99

Source: OES (1993)

Low species heterogeneity in the polluted area indicates the region as ecologically degraded. Diseases like chlorosis, marginal necrosis, tip burn, bleaching and discoloration in the affected areas are prominent. Works of Mudd and Kozlowaski (1975), Fitter and Hay (1981) established the fact that industrial pollution causes the symptoms of these diseases. Also adverse ecological conditions are observed for some grasses and Euphorbia species on the banks of Nandira in NALCO ash pond and smelter plant areas.

ECONOMIC ASSESSMENT OF BIODIVERSITY LOSS

Tropical rain forests are described as pharmacies but the value of such forests is yet to be ascertained completely. Most of economic quantifications of such rain forests are based on the value of timber only though forests are the harbourer of biodiversity. Non-timber forest products (NTFPs) which account for a large number of items such as flowers, essential oils, gums, honey, fruits, dye, resins etc are not given due recognition and evaluation except through a few isolated case studies. It is now increasingly realized that the NTFPs particularly the medicinal and aromatic plants, are going to be the most important and valuable revenue yielding commodities of the tropical forestlands. The value of such plant resources is now receiving attention in international discussions. The economic estimation of biodiversity is based on the value of plant-based drugs per hectare of forestland degraded as estimated by Lal (1992). In Indian context Lal (1992) has estimated the biodiversity rental value of 64.2 million hectares of forest area at Rs. 6600 crores in 1987-88 prices with a savings linked insurance premium assumption. The value of biodiversity of forest comes Rs.1963/- per hectare per annum for the study period. For the total area of biodiversity degraded in the study area is 2985 hectares and the value of biodiversity loss is estimated at Rs.5.86 millions per annum.

References

Agrawal, M. (1982), A Study of Phytotoxicity of Ozone and Sulphur Dioxide Pollutants, Unpublished Ph.D. Thesis, Banaras Hindu University, Varanasi.

Barrett, T. W. and H. M. Benedict (1970), Sulphur Dioxide, in: J. S. Jacobson and A. C. Hill (ed), *Recognition of Air Pollution Injury to Vegetation: A Pictorial Atlas,* Pittsburgh, Air Pollution Control Association, C1-C5.

Black, V. J. (1982), Effects of Sulphur Dioxide on Physiological Processes in Plants, in: M. H. Unsworth and D. P. Ormord (ed), *Effects of Gaseous Pollutants in Agriculture and Horticulture*, Proceedings of 32nd School in agriculture Science, Butterworth, London, 67-91.

Central Ground Water Board (1993), *Study on Fluoride Pollution of Ground Water around Angul*, Ministry of Water Resources, Eastern Zone, Bhubaneswar.

Das, R. C. (1990), *Water Resources: State of Environment in Orissa, Vol. I*, Bhubaneswar, State Pollution Control Board, Orissa.

Das, R. C. (1990), *The Atmosphere: State of Environment in Orissa, Vol. II,* State Pollution Control Board, Orissa.

Fitter, A. and Hay, R.K.M (1981), *Environmental Physiology of Plants*, Academic Press, New York and London.

GoI (1991), *Census of India*, Series 19, Orissa, Provisional Population Totals, Paper 1 of 1991 Supplement, Directorate of Census Operations, Orissa, Bhubaneswar.

GoO (1993), *District Statistical Hand Book, Angul* 1993, Bhubaneswar, Directorate of Economics and Statistics, Orissa.

GoO (1993), *Annual Survey of Industries*, Bhubaneswar, Directorate of Economics and Statistics, Orissa.

Guderian, R. (1977), Air Pollution: Phytotoxicity of Acidic Gases and its Significance in Air Pollution Control, *Ecological Studies*, 22: 122.

Hirano, J., M. Kiyoto and I. Aira (1995), Physical Effects of Dust on Leaf Physiology of Cucumber and Kidney Bean Plants, *Environmental Pollution*, 89(3).

Heywood, V. H. (1995), The Mediterranean Flora in the Context of World Biodiversity, *Ecologia Mediterranea*, 21: 11-18.

Johansson, P.O. (1993), *Cost Benefit Analysis of Environmental Change*, Cambridge University Press, Cambridge.

Johnson, R. R., C. M. Willmer and D. N. Moss (1975), Role of Awns in Photosynthesis, Respiration and Transpiration of Barley Spikes, *Crop Science*, 15: 217-221.

Kudesia, V. P. (1985), *Water Pollution*, Pragati Prakashan, Meerut.

Lal, J. B. (1992), Economic Value of India's Forest Stock, in A. Agrawal (ed.), *The Price of Forests*, Centre for Science and Environment, New Delhi.

Last, F. T. (1982), Effects of Atmospheric Sulphur Compounds on Natural and Manmade Terrestrial and Aquatic Ecosystem, *Agricultural Environment*, 7: 299-387.

Leone, I. A. (1979), The Effects of Atmospheric Pollution on Vegetation, in Raychoudhury and Gupta (eds). *Environmental Pollution and Toxicity*, Proceedings of International symposium, New Delhi, 1-9.

Mishra, M. (1999), *Economics of Industrial Pollution in Angul-Talcher Industrial Area in Orissa,* Unpublished Ph.D Thesis, Berhampur University, Orissa.

Mudd, J.B. and Kozlowaski, T.T. (Eds) (1975), *Response of Plants to Air Pollution*, Academic Press, New York and London.

Murdy, W. H. (1979), Effects of SO_2 on Sexual Reproduction in *Lepidium Virginicum L*: Originating from Regions with Different SO_2 Concentrations, *Botany Gazzette*, 140 (3): 299-303.

O. U. A. T. (1993), *Impact of Industrial Pollution on Domestic Animals in Angul-Talcher Area, Bhubaneswar, OUAT.*

OEP (1994), Environmental Management Plan for Angul-Talcher in Orissa, Orissa Environment Programme, Bhubaneswar.

ORSAC (1996), *Monitoring and Assessment of Eco-degradation and Environmental Pollution of Angul-Talcher Region by Remote Sensing*, Bhubaneswar, Remote Sensing Application Centre, Orissa.

Pandey, S.N. (1978), *Effects of Coal Smoke and Sulphur Dioxide Pollution on Plants*, Ph.D. Thesis, Banaras Hindu University, Varanasi.

Prasad, D. (1991), Plants Injury Caused by Air Pollution, In I. Mohan (ed), *The Fragile Environment*, Ashish Publishing House, New Delhi.

Pearce, D. W. and D. Moran (1994), *The Economic Value of Biodiversity*, IUCN- The World Conservation Union, Earthscan, London.

Pearce, D. W. and S. Purushottaman (1996), The Economic Value of Plant Based Pharmaceutical, In T.Swanson (ed) *Intellectual Property Right and Biodiversity Conservation: An Interdisciplinary Analysis of the Value of Medicinal Plants*, Cambridge University Press, Cambridge, 127-138.

Rabitsch, W. B. (1995), Metal Accumulation in Athropods Near a Lead/Zinc Smelter in Arnoldstein, Austria I", *Environmental Pollution,* 90(2): 221.

Reid, W. V. and Miller, K. (1989), *Keeping Options Alive: The Scientific Basis for Conserving Biodiversity*, World Resources Institute, Washington.

Roberts,T. M. (1984), Long- Term Effects of Sulphur Dioxide on Crops: An Analysis of Dose –Response Relations , *Phil Trans Royal Society London, No 305.*

Runeckles, V .C. (1984), Impact of Air Pollutant Combinations on Plants, in M Treshow (ed), *Air Pollution and Plant Life*, John Wiley and Sons, Chister.

Seneca, J. J. and F. H. Taussig (1974), *Environmental Economics*, Prentice Hall, New Jersey.

Varshney, S. R. K. and C. K. Varshney (1981), Effects of Sulphur Dioxide on Pollen Germination and Pollen Tube Growth, *Environmental Pollution,* 24 (Sec A): 87-91.

Woodwell, G. M. (1970), Effects of Pollution on the Structure and Physiology of Ecosystem, *Science*, 168: 429-443.