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APPENDIX A: PLANT PATHOLOGY MONITORING

Appendix A. Plant Pathology Monitoring

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A. Plant Diseases Caused by Biotic Agents.

Plant diseases caused by biotic agents are a natural part of any environmental setting. The diseases may be endemic (always present) or introduced, and can play an important part in the change of plant communities and even in plant evolution (Bingham et al., 1971; Harlan, 1976). The monitoring of plant diseases caused by biotic agents (fungi, bacteria, viruses and nematodes) is an important component in preoperational and operational studies. The primary rationale for monitoring such plant diseases is to be able to distinguish them, and their impact, from injury caused by the actual construction and operational phases of man-created processes like mining and ore processing. Although such studies have been rarely if ever recorded in the literature, many plant pathologists have been involved in studies where plant diseases caused by biotic agents have been confused with vegetation damage caused by man-created sources. In most cases preoperational diagnosis and assessment of plant diseases in the area, coupled with adequate mapping (to establish the geographical boundaries of the diseases(s)) and archive sampling for future reference, would have prevented much of this costly confusion.

Diagnosis of plant diseases is an area separate from assessment of disease. Diagnosis of most common diseases is based upon identification of the pathogen(s) and/or symptoms exhibited by the plant, using methods that are universally known and accepted by plant pathologists (James, 1974). Once the diagnosis of a disease is made, assessment of the disease can be divided into two parts, "disease incidence" (defined as the number of plant units infected, usually expressed as a percentage of the total number of plant units observed in a delimited area or plot), and "disease severity" (defined as the area of plant tissue affected by disease, expressed as a percentage of the total tissue area). In practice, only "disease incidence" is used in most disease assessment methods because measurement of "disease severity" is a difficult and time consuming effort. Disease severity readings are only attempted with annual agricultural crops where the application of chemical control methods may be used early in the development of epidemics, or for experimental purposes where yield loss is to be correlated with "disease severity" (James, 1974; Van Der Plank, 1963).

In the Copper-Nickel Study Area the future assessment of plant diseases caused by biotic agents should largely be restricted to dominant forest tree species in forest communities or other dominant plant species in non-forest community types. Because the region is largely an area of native vegetation, measurable changes in plant communities are not likely to take place unless the dominant species are affected. Dominant species exert a powerful influence on understory vegetation and on community succession. Therefore diseases of dominant species are of primary importance to document any later changes in plant communities.

In any preoperational or environmental-setting study two types of plant-disease evaluation are necessary. The first type can be termed a diagnostic study in which the total area to be impacted would be systematically surveyed (grids or points to be surveyed can only be determined by using vegetation maps of the region and by preliminary reconnaissance) for plant diseases caused by biotic agents. For reference, known diseases of the dominant plant species in the general area, such as those listed in Table 1, section   of this report, should be diagnosed, recorded, mapped, and archive specimens collected, prepared and stored for future reference. During the diagnostic survey the location of major diseases of dominant vegetation should be mapped and notes taken on geographic ̄ .reas that may be used for disease assessment. The second type of disease study is the disease assessment study, and, as previously mentioned, it involves quantitation of "disease incidence" (defined as the number of plant units infected, usually expressed as a percentage of the total number of plant units observed in a delimited area or plot). There are no standardized techniques for measuring disease incidence; it is usually left to the judgment of the pathologist(s) involved to use whatever technique(s) seem appropriate for a given disease in a given area. For example, a stand of white pine suffering from white pine blister rust may cover several square miles. To examine each tree in such an area would be clearly impossible. Therefore, such an area may be subdivided into smaller areas (perhaps 500 x 50 meter plots) and a random assortment of these smaller plots may be used for the actual counting for disease incidence. Alternatively a patholgist may simply run a number of transects through the large area and observe only those trees that fall on or within a prescribed distance of the transect. When a large number of areas are to be examined in a short amount of time an alternative to actual counting of infected and non-infected plant units (semi-quantitative disease incidence) may be used. More than one pathologist may traverse a given plot or stand area and give an estimated percentage of disease incidence. Estimates are then combined and averaged for a given plot or area. There are many variations in disease measuring techniques that experienced pathologists may employ. The only rule is that the same technique be applied to the same disease in all areas to be mapped and recorded. Where large land areas are being mapped for disease incidence and distribution (geophytopathology), semi-quantitative methods are often utilized and are sufficient to give geographical boundaries to infected areas (Weltzien, 1972). In small areas or in permanent study plots strict quantitative procedures are used, and in the case of diseases of epidemic proportions many other quantitative procedures can be employed should measurement of the progress of the epidemic be of concern (Zadoks, 1972).

In terms of techniques used for disease assessment there are only generalized techniques to work from; in general when a technique is employed it should be adequately described and the study areas adequately mapped and sited so that the technique can be accurately reproduced at a later date on the same site. When the two types of disease studies (i.e., diagnostic and incidence studies) are combined an adequate preoperational evaluation of plant health status can be determined. These base-line data can then be used to set up permanent study plots that are necessary during operational studies. The establishment of the numbers and locations of permanent plot sites is usually dictated by the nature of the operational plan (mining, smelting, coal-fired power station, etc.) and the estimated land area to be influenced by the operation. Permanent study plots for plant disease assessment should, when possible, be located near or within other vegetational study plots utilized for ecological, botanical, entomological, wildlife, or phytotoxicology studies, so that a more complete understanding and integrated study of the area is accomplished.

B. Plant Diseases Caused by Abiotic Agents.

Plant diseases are caused by the interactions of the host, the environment, and various pathogenic agents. A pathogenic agent or pathogen is any agent whose presence can cause disease symptoms on a plant(s). As previously described plant pathogenic agents may be either "biotic" (parasitic or pathogenic agents of a biological nature; fungi, bacteria, viruses, or nematodes) or "abiotic" (pathogenic or phytotoxic agents such as sulfur dioxide, oxides of nitrogen, fluorides, ozone, peroxyacetyl nitrates, particulates, etc.). For clarity, single environmental factors such as lack of water (drought) or excesses of water are considered "stresses" and not plant diseases; similarly insect damage to vegetation is not considered as plant disease.

Air pollutants are, in terms of plant health, by far the most common agents of abiotic plant disease and are of immediate concern in regions of native vegetation, such as the Copper Nickel Study Area, where industrialization is being contemplated. The procedures used for surveying, assessing, and mapping abiotic plant diseases are essentially the same as for diseases caused by biotic agents, however, the procedures used for diagnosing abiotic disease and for linking cause and effect are different. Symptoms of foliar injury to sensitive vegetation caused by air pollutants are only one of many diagnostic criteria used for determination of plant disease caused by these abiotic agents. Although air pollutants such as sulfur dioxide and ozone, in phytotoxic concentrations, result in characteristic symptoms on sensitive vegetation (Jacobson and Hill, 1970; Davis and Wilhour, 1976); symptomotology alone is not always considered sufficient evidence for positive identification of air pollution damage (Taylor, 1973). This is especially true when a single species of a pollutant-sensitive plant (an indicator plant) is used for diagnostic purposes, because drought and wind, normal senescence and biotic disease agents may incite the same symptoms (van Raay, 1968). The strongest evidence that can be gathered for air pollution damage by symptomology on sensitive plant species is obtained when several species of plants in the same locality show characteristic symptoms of a particular pollutant (Jacobson and Hill, 1970; MPCA, 1977). Thus, should industrialization take place in a region like the Copper Nickel Study Area, symptoms on indicator plant species (pollution sensitive higher plant species) would be but one diagnositic criteria for judging pollution damage to plants. An example of how native plant species in Minnesota can be utilized to indicate sulfur dioxide pollution damage was shown in the 1977 Environmental Impact Study at the Clay Boswell Coal Fired Power Station near Grand Rapids, Minnesota (MPCA, 1977).

Air pollution injury to plants may also occur when plants are exposed for prolonged periods to levels of pollutants below the recognized threshold levels at which visible symptoms occur. For example, subthreshold levels of sulfur dioxide may result in altered growth rates, reduction in plant size, and alterations in reproductive capacities, all of which are measurable only if the plants can be compared with others of the same variety growing under nonpolluted conditions (Feder, 1973).

Because evidence is accumulating for plant health damage by subthreshold levels of air pollutants, and because plants may vary in symptom expression when exposed to above threshold levels for injury, it is advisable to couple plant pathological studies with air quality monitoring and chemical analysis of plant tissues. Photochemical oxidants like ozone, peroxycetyl nitrate, and oxides of nitrogen are truly transitory, have short half-lives, and are not traceable or measurable in tissue samples once they enter plants. For these types of phytotoxic air pollutants air quality monitoring should be coupled, in the field, with symptom expression of sensitive plants in order to demonstrate cause and effect relationships for plant damage. The combination of air quality monitoring with symptom expression is the best field method of determining plant injury due to photochemical oxidants and oxides of nitrogen (Feder, 1973). Air quality monitoring under field conditions also allows for the correlation of experimental evidence obtained from chamber studies (either with open-top field chambers or controlled environmental chambers) with actual field conditions and observations. The technology involved with air-quality monitors and data loggers has advanced rapidly, and when it is combined with the data summarization powers and speed of computer analysis of data it is possible and feasible to do air quality monitoring along with symptomotology of indicator plant species in the field.

Sampling of pollutant damaged plant tissues for chemical analysis to determine toxic accumulations of air pollutants has been used with damage caused by fluorides. The accumulation of fluoride in plants is similar to heavy-metal accumulation. The levels of fluoride can be measued quantitatively in tissues and the levels can be related to the intensity of symptom expression in plants (Feder, 1973). Accumulation of sulfur in plant tissues due to exposure to sulfur dioxide can be demonstrated although, to date, there is no agreement among researchers as to whether such data can be strongly correlated with symptom expression (Feder, 1973; van Raay, 1968). Most studies that attempt to correlate measurable sulfur accumulation in tissue with symptoms of sulfur dioxide damage on tissue do show trends that link sulfur dioxide damage with increased sulfur content in tissues (MPCA, 1977), however, the correlation is not as good as it is with fluorides or with heavy metals. For field studies involving sulfur dioxide sources it is advisable to use symptom expression in sensitive plants, air quality monitoring for sulfur dioxide, and tissue analysis for total sulfur content whenever possible.

Because certain air pollutants and heavy metals can be quantitatively measured in soils and plant tissues, archive sampling is one method of obtaining baseline data during both preoperational and operational studies of vegetation and plant communities. Archive sampling of plant tissues from species to be used as pollution indicators may be extremely useful, especially where time and expense do not allow for complete analysis prior to the initiation of any industrial activity (MPCA, 1977). When properly treated and stored, plant tissues and soil samples can yield important data on preoperational conditions even if they are analyzed many years later. Archive samples from permanent plots are one means used to monitor accumulation, over time, of phytotoxic substances, especially when there are observed, after an operational phase has begun, plant health problems that were not previously noted. Any proposed scheme for preoperational and operational studies in the Copper Nickel Study Area should include archive sampling of permanent study plots. Another reason for archive sampling is that methods of detection of pollutants are constantly being improved. Thus, what is considered undetectable or unimportant today may become detectable and important in the future, when new technologies and methods are developed (Rowland, 1976).

C. Recommendations for Plant Pathology Monitoring.

1. In the case of any contemplated industrialization in the Copper Nickel Study Area, both diagnostic surveys and disease assessment studies for plant diseases caused by biotic agents should be done in the preoperational phase. The results of such studies should be used for both environmental setting data and for the placement and siting of permanent study plots to be used during operational phase work.

2. If the contemplated industrialization could result in soil or plant accumulation of phytotoxic substances, the preoperational studies should at least include archive sampling of soils and plant tissues so that base-line data on potential pollutants can be quantitatively obtained at later dates. Archive samples should also be maintained so that they are available as new technologies and methods of detecting pollutants are developed.

3. If the contemplated industrialization includes point sources of air pollution, (i.e., smelters) preoperational studies should include air quality monitoring for at least three growing seasons prior to any operational activity.

Plant pathology study plots for point sources of air pollution should be located with the assistance of air quality modeling data for any proposed point source but should also be located symmetrically about such a source, for air quality modeling is often not sufficient for predicting episodes of air pollution damage to vegetation.

Whenever possible, native pollution-sensitive (indicator) species should be used in study plots concentrically arranged around the point source of air pollution.

Native plant species are often more abundant and can be used as pollution indicators in areas outside of study plots, should future situations dictate such usage. The use of air pollution sensitive species and permanent study plots should be augmented with air quality monitoring during the growing season. The number and types of air pollution monitors will of course be dictated by the size and type of emissions of the point source, air quality modeling, and by geographical features of the study area. In addition to housing air pollution monitors on selected plant pathology study plots, there should be at least one mobile air pollution monitoring laboratory for each point source of air pollution. Such a mobile laboratory should be used in a systematic pattern about the pollution source to check the air quality modeling data and to determine if permanent study plots are placed in the most strategic locations. Prior to using air quality monitors in study plots, a rapid system for handling and analysing air quality data should be operational. Air quality data should be available from each monitoring station, in usable form, at the end of each month of the growing season so that rapid correlations between suspected air pollution damage in vegetation can be made in the same time span in which the damage occurs.

4. Should a state plant toxicology laboratory be established, it should, in addition to the equipment mentioned in the other portions of the proposal, be equipped with fully analytical equipment and staff for determining elemental composition in plant and soil samples. The laboratory should also have data handling, processing, and analysis capabilities for air quality monitoring.

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