The Role of Plants in Removal of Air Pollutants

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Farm Crops

A substantial amount of research has been reported concerning the effect of air pollutants on plant growth and crop production; however, information describing the capacity of plants for removal of pollutants from the atmosphere is much more restricted. Several articles can be found in the literature suggesting that plants may be of significant value as filters for air pollutants (Bulgakov, 1964; Doolittle, 1969; Popov, 1965; Rich, 1970; Smith, 1970; Spilhaus, 1969). Quantitative information, however, is very limited.

An exception is an article published by Hill (1971) who evaluated the capability of an alfalfa canopy to remove gaseous air pollutants. His results showed that an alfalfa canopy removed gases from the atmosphere in the following order of uptake: hydrogen fluoride (HF) > sulfur dioxide (SO_2) > chlorine (CL_2) > nitrogen dioxide (NO_2) > ozone (O_3) > peroxyacetil nitrate (PAN) > nitric oxide (NO) > carbon monoxide (CO). The absorption rate of NO was low and no absorption of CO was noted by alfalfa with the methods used.

Hill points to the rather rapid removal of most gaseous air pollutants from the atmosphere and suggests that since vegetation covers 90 percent of the land area in the United States, it would seem logical to consider vegetation as a significant sink for pollutants. This would be particularly true since the leaf surface area of plants is usually many times the corresponding land surface area and the cell surface area surrounding the inner cellular air spaces within a leaf is considerably higher than the leaf surface area. As noted by Hill, the stomatal apertures must be considered an important mechanism for plant uptake when we are dealing with gaseous pollutants. The solubility of various air pollutants in cellular constituents was also found to be an important factor determining the amount and rate of uptake of pollutants into the plant. Hill also noted that the removal of submicron size suspended particulates by vegetation appears to be relatively slow in comparison to removal of most of the gaseous pollutants.

Smith (1970) in discussing removal of air pollutants by plants, cited indirect evidence supporting the effectiveness of trees as filters for particulates and aerosols. A case in point was the reduction in pollen count provided by a canopy in a Pennsylvania forest. Evidence of materials that are found in high concentrations by plant tissue analysis but are not found within cells of the plant suggest primarily a surface filtering effectiveness of plants for particulate and aerosols. Radioactive fallout measurements also demonstrate the importance of plants in trapping particulate material.

In order to evaluate the role of plants for air pollution abatement, it would be desirable to consider the uptake, movement, and possible interaction of specific kinds of pollutants in and on vegetation.

Lead

Lead content in vegetation has been widely studied. Keller (1970) has noted that crops and trees accumulate lead in and on their leaves. Concentrations were a function of traffic density, season, age of vegetation,, and the vertical and horizontal distance from the highway. Much of the lead was found on the plant's surface and this lead washed off only to a limited extent. Unwashed crops 100 meters from roads ranged from 0.3 to 0.5 ppm (parts per million) for cereals to 2 to 8 ppm for hay. Conifers were specifically noted as having excellent air filtering capacity. Dedolph (1970) noted that air and soil deposition of lead on plants was the significant source of lead found in plants. Francis (1968) reported that root uptake of lead is essentially nonexistant. Deposition of lead on leaves by rainfall was considered a primary mode of entry into plants. The general trend of research tends to confirm that lead absorption is minimal either by the leaves or roots. Schuck strongly suggests that most lead exists on the plant in dust form. Support for this position is provided by Maeno (1969) who found that lead dust on several plants averaged around 932 ppm, while plant absorbed lead was only in the range of 25 ppm.

Sulfur Dioxide

Leaf absorption of sulfur dioxide is well documented (Materna, 1963; DeCormis, 1969; Guderian, 1970a). Leaf margins and tips are a prime site for absorption (Kohout, 1966). High periods of photosynthesis tend to favor sulfur dioxide absorption; Guderian (1970a, 1970b) also reports that sulfur accumulation in plants is increased with lower sulfur dioxide concentrations and increased exposure time. SO_2 is absorbed at night at about one-third the daylight rate. Metabolic utilization by the plant and ease of translocation of organic sulfur accounts for the relatively high rate of absorption.

Fluorine

Papers published by Hill (1960), Garber (1962), and McCune (1970) indicate that fluorine is readily taken up by plants. Fluoride in the plant is directly related to exposure time and concentration with the leaf as the prime absorption area. Tree bark, especially that facing the source, has been shown to absorb significant amounts of fluorine (Garber, 1962, 1966). As with other pollutants, plant necrosis increases with higher concentrations.

Carbon Monoxide and Carbon Dioxide

Research has been reported indicating plant uptake of carbon monoxide. Delwiche (1970) found significant uptake as well as emission of CO by plants. However, Hill (1971) found no CO uptake in alfalfa canopies. Carbon dioxide fixation by plants has been studied widely from the standpoint of a plant nutrient. Fixation of CO_2 increases at higher atmospheric concentrations, and thus this response may prevent dramatic atmospheric CO_2 concentration increases (Peterson, 1969).

Particulate Material

The filtering of dust by plants is commonly assumed. However, the efficiency of such filtering has not received much attention. Further investigation is needed in this regard. Voloshin (1962) and Sitnikova (1964) have substantiated that dust on plants reduces photosynthesis and increases plant temperatures. Differential resistance to smoke and dust accumulation was noted in the species of plants investigated.

Other Pollutants

Plant absorption of other pollutants such as chlorine, ozone, peroxyacetyl nitrate, and nitrogen oxide should be investigated further; particularly since some are unstable and form reaction products with other atmospheric components or pollutants. Hill (1971) has shown alfalfa foliage to be a sink for the aforementioned pollutants. The relative uptake of pollutants such as NO and PAN appears low, but some of the reaction products (e.g., NO_2) may be taken in more readily. Rich (1970) noted that ozone was taken up primarily through stomata. Uptake was similar to water vapor and was proportional to leaf area.

New developments in the area of plant breeding must be considered in order to evaluate plants in terms of their capacity to remove air pollutants. Recent work by Howell (1971) with alfalfa and Johnson (1971) with sweet corn, demonstrated the possibility of selecting plants for resistance to air pollution damage. If the basis for resistance is related to the capacity for a plant to remove and detoxify air pollutants, then perhaps even more effective cleansing of the atmosphere by plants could be anticipated. Further studies are obviously necessary to describe the basis for resistance in plants.

In considering plants in the role of sinks for air pollutants, it must be recognized that there are important seasonal and species differences. Conifers would of course have a leaf surface area throughout the year whereas deciduous trees are restricted in surface area to only twigs and bark during the winter season. The effect of specific nutrient application and general soil fertility level would be important in determining crop surface area and metabolic activity.

Other organisms, such as lichens, may also warrant attention (Skye, 1968) although extreme sensitivity to pollutants may lessen their value. It has become increasingly evident that the soil and particularly the microflora play an important role in the removal of certain air pollutants (Abeles, 1971; Inman, 1971).

Basic studies are necessary to further describe the methods by which plants are able to absorb and translocate exogenous substances. For example, Franke (1960) showed the importance of the ecdodesmata in the assimilation of materials through the leaf. Studies with specific emphasis on the air pollutants seems warranted.

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