AIR QUALITY CRITERIA FOR OXIDES OF NITROGEN
SUMMARY OF VEGETATION IMPACTS

GENERAL CONCLUSIONS

- Foliar injury from NO_2 is rarely found in the field. When found, the injury is usually associated with and confined to areas near specific industrial sources. For example, NO_2-induced vegetation injury has been observed near HNO_3 (nitric acid) factories and arsenals. There is growing concern that HNO_3 may impact vegetation.

- Sensitivity of plants to NO_2 varies with species, time of day, light, stage of maturity, type of injury assayed, soil moisture, and nitrogen nutrition.

- Wet and dry deposition of NO_x are important processes in the redistribution of nitrogen throughout the environment. Increasing the soil nitrogen tends to decrease NO_2 induced foliar injury.

- Sensitivity of plants to NO_x decreases as water becomes less available in the soil.

- The majority of plant damage occurs at night. Daytime light tends to accelerate existing plant damage.

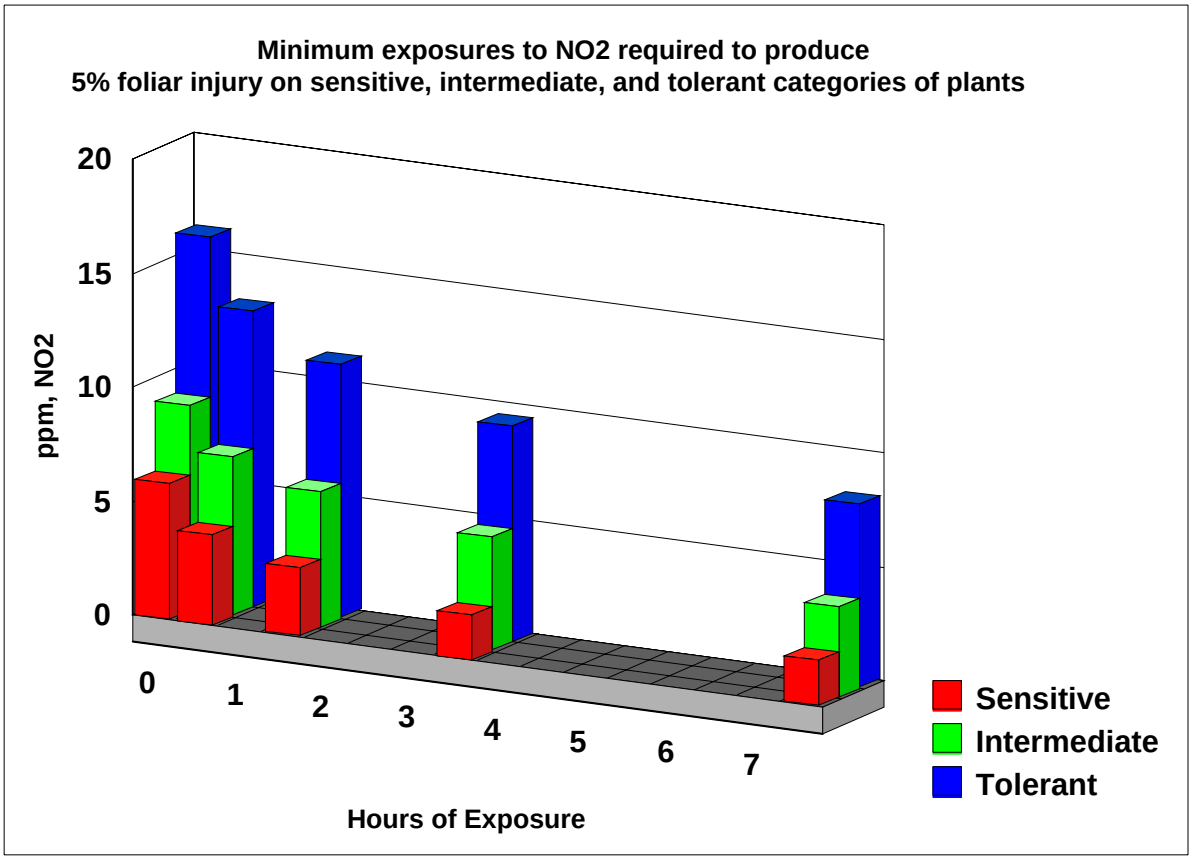
- NO_2 in combination with other ambient gases may behave synergistically.

- When exposures to NO_2 alone are considered, the ambient concentrations that produce measurable injury are higher than those that normally occur in the United States.

- Localized sources of NH_3, such as animal stockyards and ammonium nitrate fertilizer plants may have adverse effects of crops and conifers. Other emissions from livestock, such as higher amines or hydrogen sulfide can add to the effect.

- In contrast to the studies cited on the effects of NO_2 alone, a number of studies on mixtures of NO_2 with SO_2 showed that the NO_2 injury threshold was significantly decreased and that the effects of the two gases in combination were at least additive and usually greater than additive. Concentrations at which observable injury occurred were well within the ambient concentrations of NO_2 and SO_2 occurring in some areas of the United States.

TABLE 1. SHORT TERM NO_2 CONCENTRATIONS WHICH RESULT IN 5% FOLIAR INJURY						
Time (hr)	Susceptible		Intermediate		Tolerant	
	ppm	mg/m^3	ppm	mg/m^3	ppm	mg/m^3
0.5	6 - 10	11.28 - 18.8	9 - 17	16.92 - 31.96	16	30.08
1.0	4 - 8	7.52 - 15.04	7 - 14	13.16 - 26.32	13	24.44
2.0	3 - 7	5.64 - 13.16	6 - 12	11.18 - 22.56	11	20.68
4.0	2 - 6	3.76 - 11.28	5 - 10	9.4 - 18.8	9	16.92
8.0	2 - 5	3.76 - 9.4	4 - 9	7.52 - 16.92	8	15.04



RELATIVE SENSITIVITIES OF PLANTS TO NITROGEN DIOXIDE

SENSITIVE	INTERMEDIATE	TOLERANT
CONIFERS		
European larch	Colorado blue spruce Nikko fir White fir White spruce	Austrian pine English yew Hinoki cypress Japanese black pine Loblolly pine Pitch pine Virginia pine
TREES AND SHRUBS		
European white birch	Japanese maple Japanese zelkova Little-leaf linden Norway maple	Beech Black locust Black poplar Elder English oak European hornbeam Ginkgo (Maidenhair tree) Green ash Scotch elm Sweetgum White ash White oak
FIELD CROP AND GRASSES		
Alfalfa (lucerne) Barley Oats Red clover Spring clover Spring vetch Tobacco	Annual bluegrass Potato Rye Sweet Corn Wheat	Kentucky bluegrass
FRUIT TREES AND SHRUBS		
Apple (wild) Pear (wild)	Crabapple Grapefruit Japanese pear Orange Tangelo	

Table 9-6, “Air Quality Criteria for Oxides of Nitrogen”, Volume II of III, EPA/600/8-91/049bF, August, 1993.

RELATIVE SENSITIVITIES OF PLANTS TO NITROGEN DIOXIDE

SENSITIVE	INTERMEDIATE	TOLERANT
GARDEN CROPS		
Carrot Celery Leek Lettuce Parsley Pea Pinto bean Rhubarb	Bush bean Celery Tomato	Asparagus Bush bean Cabbage Carrot Kohlrabi Onion
ORNAMENTAL SHRUBS AND FLOWERS		
Azalea Bougainvillea Chinese hibiscus Common petunia Oleander Pyracantha Rose Snapdragon Sweet Pea Tuberous begonia	Cape jasmine Catawba rhododendron Common zinnia Dahlia Flossflower Fuchsia Gardenia Ixora Japanese pittosporum Ligustrum Oleander Paperbark tree Petunia	Carissa Croton Daisy Gladiolus Japanese morning glory Lily-of-the-valley Plantain lily Rose Shore juniper Spring heath
WEEDS		
Common mugwort Common plantain Horseweed Mustard Sunflower	Cheeseweed Chickweed Common chickweed Dandelion	Lamb's-quarters Nettle-leaved goosefoot Pigweed Red root
DESERT SPECIES		
Creosote bush	Brittle bush Desert willow	Alfilaria Burro weed Chaenactis (CN) Desert marigold Four-wing saltbush Scorpion weed

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RESEARCH OBSERVATIONS

- Experimental investigations have not provided a clear demarcation between exposure to NO_x that adversely affect the growth, development, or reproduction of plants and those that do not.

- High NO_2 concentrations for short periods of time seem to be much more destructive than low concentrations for long periods of time. The dose of NO_2 is not always representative of plant damage. Exposure is said to be acute if [NO_2] is 3-5 mg/m3 (1.6 - 2.7 ppm) for up to 48 hours. At lower NO_2 concentrations and longer exposure times, exposure is chronic.

- Single exposures of 24 hours or less that could produce adverse effects are at concentrations of NO_2 greater than what have been shown to occur in ambient exposures in the United States.

- Wheat, oats, and beans exposed to 30 ppm NO_2 (56.4 mg/m^3) for one hour showed little or no injury. Alfalfa showed slight signs of injury.

- In periods of two weeks or greater duration with intermittent exposures of several hours per day, adverse effects on growth and yield start to appear when the concentration of NO_x reaches the range of 0.1 - 0.5 ppm, depending on the species of plant, nature of effect, and conditions of exposure.

- Wheat, exposed to [NO_2] = 2mg/m^3 (1 ppm) for 334 hours showed no effect on grain yield. Straw yield, however, decreased 12 percent.

- Atmospheric NH_3 reduces the severity of foliar symptoms produced by NO_2, but this effect depends on light intensity and species of plant.

- [NO_2] between 0.188 mg/m^3 (0.1 ppm) to 0.47 mg/m^3 (0.25 ppm) can cause direct effects on vegetation in combination with certain pollutants. For instance... [NO_2] = 0.21 mg/m^3 (0.11 ppm) + [SO_2] = 0.29 mg/m^3 (0.11 ppm) for 103.5 hours per week (20 weeks) showed significant reductions in yield parameters ranging from 30-90 percent. Concentrations of these two gases occurring simultaneously can have major deleterious effects on plant growth.

- A survey of the sensitivity of six species to SO_2/NO_x mixtures in 4-hour exposures found that neither 2.0 ppm NO_2 nor 0.5 ppm SO_2 alone caused foliar injury. However a mixture of 0.10 ppm NO_x and 0.10 ppm SO_2 administered for 4 hours caused foliar injury to pinto beans, radish, soybean, tomato, oat, and tobacco. Exposure to 0.15 ppm NO_2 in combination with 0.1 ppm SO_2 for 4 hours caused greater foliar damage than did lower concentrations.

- Traces of foliar damage observed at 0.05 ppm NO_2 and 0.05 ppm SO_2. Co-occurrence of [NO_x] and [SO_2] at these concentrations occurs in the United States less than one (1) percent of the total hours monitored.

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