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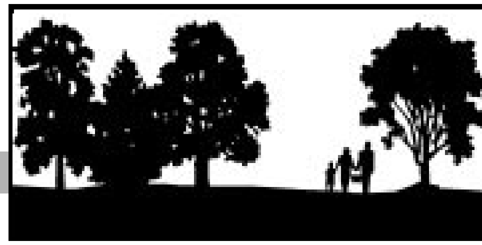

Trees for Problem Landscape Sites
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Air Pollution

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Conditions in urban environments place trees under numerous stresses including compacted soil, soil moisture extremes, and reduced soil fertility. Polluted air is another stress that contributes to the decline of urban trees. Air pollution may cause short-term (acute) damage, which is immediately visible, and long-term (chronic) damage, which can lead to gradual tree decline. Long-term damage may predispose trees to other disorders, making diagnosis difficult.

The major phytotoxic (toxic to plants) air pollutants, in decreasing order of severity, are:

- oxidants [ozone and peroxyacetyl nitrate (PAN)]
- sulfur dioxide
- particulates

Gaseous pollutants

Gaseous pollutants, such as ozone and sulfur dioxide, enter plants through natural openings, usually stomates, and react within leaf tissues to inhibit photosynthesis. Acute damage levels can be high enough to cause sudden tissue damage and death. Chronic damage occurs when small amounts of toxic gases enter leaves and do not initially cause tissue death, but inhibit leaf functions. Whether or not a pollutant causes acute or chronic damage depends upon tree species. Individual trees within a species often display varying degrees of tolerance to the same pollutant.

Acute gaseous pollutant damage to red maple leaves. All leaves on the tree are chlorotic (pale yellow).

Ozone

Ozone is the most damaging air pollutant. The action of sunlight (ultraviolet radiation) on molecular oxygen and oxides of nitrogen spontaneously generates ozone. The organic compounds in automobile exhaust enhance ozone accumulation. Ozone can move across great distances to cause tree damage far from its origin and is therefore classified as a non-point-source pollutant.

The extent of tree damage depends on the concentration of ozone, the duration of exposure, and tree sensitivity. Acute damage to deciduous trees causes marginal leaf burn and dot-like or irregularly shaped lesions or spots that

Container-grown eastern white pine with ozone damaged needles.

Ozone-caused brown bands at the same point on all needles of an eastern white pine.

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may be tan, white, or dark brown, and that may spread over entire leaves. Another common symptom is bleaching of the upper leaf surface. Acute damage to conifers causes browning at the same point on all needles in a bundle (needle cluster).

Chronic damage occurs with repeated ozone absorption in amounts not high enough to cause sudden tissue death. Chronic symptoms include chlorosis (general yellowing), premature leaf drop, reduced growth, and progressive decline of tree health and vigor. Ozone damage also increases a tree's susceptibility to insect damage. As ozone restricts carbohydrate movement in leaves, the resulting higher sugar concentration makes the leaves more susceptible to insect attacks.

PAN is produced through the interaction of sunlight and power plant and/or automobile emissions. High levels of PAN and ozone are toxic to trees, but ozone is more abundant and injurious.

Sulfur dioxide

Sulfur dioxide is primarily a result of fossil fuel burning for electricity generation, and to a lesser degree, the processing of steel and other ores. Sulfur dioxide is classified as a point-source pollutant.

Acute sulfur dioxide damage causes severe leaf scorch, usually on upper interveinal leaf surfaces. Younger leaves are generally more sensitive. Moisture in the air or on leaf surfaces may combine with sulfur dioxide to form sulfuric acid. Sulfuric acid causes leaf scorch, spotting and defoliation, and can also cause tree death over a large geographic area with many affected species. Chronic sulfur dioxide damage results in leaf chlorosis (colors of the chlorosis ranging from white to red) and tree decline.

Particulates

Particulates (dusts), classified as point-source pollutants, are generated by major industrial processes as well as by quarries, rock-crushing plants, cement plants, soil erosion, and auto exhaust emissions. Particulates are not extremely damaging, but can inhibit or reduce photosynthesis by plugging stomates. Particulates are usually washed from leaves by rain or irrigation, and are therefore more harmful during dry periods.

Weather and pollutants

Air currents carry all air pollutants. Air movements and geographic features influence pollutant concentration, chemical structure, and the duration of tree exposure to pollutants.

Air temperature determines vertical movement of air pollutants. Under normal conditions, warm air near the soil surface causes pollutants to rise vertically. Pollutants rapidly become diluted and blown away by upper level winds before contacting many trees. However, thermal inversions (cool air at the surface beneath warmer air above) restrict movement and dispersal of pollutants, resulting in increasing phytotoxic levels and prolonged exposure. These inversions usually occur in narrow valleys close to mountain ranges, and near large bodies of water.

Temperature also influences a pollutant's chemical reaction rate. When the temperature is high, more photochemical oxidants are produced. These oxidants cause more severe damage during sunny hot weather and less damage during cool cloudy weather. Atmospheric moisture causes pollutants to become solutions, increasing their toxic potential.

Diagnosing air pollution damage

Proper diagnosis of air pollution damage is difficult because other causes of tree damage, including environment, insects and diseases, can cause similar (mimicking) symptoms. Obtaining the following information will help in making a proper diagnosis:

1. Pollutant origin (point-of-source or non-point-of-source?)
2. Chemical and physical nature of the pollutant.
3. Geographic and topographic influences.
4. Weather conditions (air temperature and wind direction).
5. Length of exposure and concentration.
6. Types of symptoms.
7. Possible mimicking symptoms.
8. Size of affected area.
9. Date of suspected exposure.
10. Affected tree and other species.
11. History of previous exposure.

Trees with a range of ozone tolerance and sensitivity

Tolerant	**Intermediate**	**Sensitive**
Arborvitae (*Thuja* spp.)	Boxelder (*Acer negundo*)	Ash, white (*Fraxinus americana)*
Birch, European white (*Betula pendula*)	Elm, lacebark (*Ulmus parvifolia*)	Ash, green (*Fraxinus pennsylvanica*)
Dogwood, white (*Cornus florida*)	Gum, sweet (*Liquidambar styraciflua*)	Catalpa (*Catalpa* spp.)
Fir, balsam (*Abies balsamea*)	Lilac (*Syringa* spp.)	Crabapple (*Malus* spp.)
Fir, Douglas (*Pseudotsuga menziesii*)	Oak, black (*Quercus velutina*)	Honeylocust (*Gleditsia triacanthos*)
Fir, white (*Abies concolor*)	Oak, scarlet (*Quercus coccinea*)	Mountain ash, European (*Sorbus aucuparia*)
Ginkgo (*Ginkgo biloba*)	Pine, eastern white (*Pinus strobus*)	Oak, white (*Quercus alba*)
Gum, black (*Nyssa sylvatica*)	Pine, Scotch (*Pinus sylvestris*)	Oak, pin (*Quercus palustris*)
Holly (*Ilex* spp.)	Pine, shortleaf (*Pinus echinata*)	Pine, Austrian (*Pinus nigra*)
Linden, American (*Tilia americana*)	Redbud, eastern (*Cercis canadensis*)	Pine, Loblolly (*Pinus taeda*)
Linden, little-leaf (*Tilia cordata*)	—	Pine, Virginia (*Pinus virginiana*)
Maple, Norway (*Acer platanoides*)	—	Poplar, tulip (*Liriodendron tulipifera*)
Maple, sugar (*Acer saccharum*)	—	Sycamore, American (*Platanus occidentalis*)
Oak, English (*Quercus robur*)	—	Walnut, English (*Juglans regia*)
Oak, red (*Quercus rubra*)	—	Willow, weeping (*Salix babylonica*)
Pine, red (*Pinus resinosa*)	—	Zelkova, Japanese (*Zelkova serrata*)
Spruce, blue (*Picea pungens*)	—	—
Spruce, Norway (*Picea abies*)	—	—
Walnut, black (*Juglans nigra*)	—	—
Yew (*Taxus* spp.)	—	—

Trees with a range of sulfur dioxide tolerance and sensitivity

Tolerant	**Intermediate**	**Sensitive**
Arborvitae (*Thuja* spp.)	Linden, American (*Tilia americana*)	Ash, green (*Fraxinus pennsylvanica*)
Ginkgo (*Ginkgo biloba*)	Boxelder (*Acer negundo*)	Birch (*Betula* spp.)
Juniper (*Juniperus* spp.)	Cottonwood (*Populus deltoides*)	Elm, lacebark (*Ulmus parvifolia)*
Linden, littleleaf (*Tilia cordata*)	Elm, American (*Ulmus americana*)	Pine, eastern white (*Pinus strobus*)
Maple, silver (*Acer saccharinum*)	Lilac (*Syringa* spp.)	Poplar, lombardy (*Populus nigra* 'Italica')
Maple, sugar (*Acer saccharum*)	Maple, red (*Acer rubrum*)	Serviceberry (*Amelanchier* spp.)
Oak, pin (*Quercus palustris*)	Mountain ash, European (*Sorbus aucuparia*)	Willow, black (*Salix nigra*)
Oak, red (*Quercus rubra*)	Oak, white (*Quercus alba*)	—
Spruce, blue (*Picea pungens*)	Pine, Austrian (*Pinus nigra*)	—