# FINAL PROGRESS REPORT
## FOREST SERVICE GRANT NO. 0897-50-G-43
Period covered by this report: July 24, 1997 through Feb 20, 2000

***NOTE: Please review the following information and revise/complete as necessary.***

**Issued to:** Southern University and A&M College

**Address:** P.O. Box 10771, SUBR, Baton Rouge, LA 70813

**Project Name:** Quantifying the Relative Ability of Tree Species in Intercepting and Removing Particle Pollution

**Contact Person/Principal Investigator:**
**Name:** Dr. Kamran K. Abdollahi
**Mailing Address:** P.O. Box 10771
Southern University and A&M College
Baton Rouge, LA 70813

**Phone Number:** (504) .771-6291
**Fax Number:** (504) 771-6293
**E-Mail Address:** Kamrana664@c s.com

**Web Site Address (if applicable):**

**Date of Award:** July 24, 1997

**Grant Modification:** Mod 1- No-cost time extension from July 1, 1999 to December 1, 1999. Mod 2- No-cost time extension from December 1, 1999 to December 30, 1999. Mod 3- No-cost time extension from December 30, 1999 to February 29, 2000.

**Date of Expiration:** February 29, 2000

**Funding: Federal Share:** $42,000 **Grantee Share:** $50,800 = **Total Project: $** 92,80.00

**FS Grant Manager:** Ed Macie
**Address:** USDA Forest Service, 1720 Peachtree Road, N W., Atlanta, GA 30367
**Phone Number:** (404) 347-7203
**Fax Number:** (404) 347-2776

---

**Project abstract (as defined by initial proposal and contract):**

According to the findings by the Natural Resources Defense Council, dust, soot, and many particles in polluted air over the nation's 239 major cities cause 64,000 of premature heart and lung-related deaths each year. In light of the new reports, the Environmental Protection Agency (EPA) has announced the plan to impose tougher restrictions to include fine particulates less than 2.5 microns (PM2.5). The new regulations could cost more than $2.5 billion a year to implement in a city like Chicago alone. Previous studies have indicated that trees in Chicago removed 234 tons of particulate matter less than 10 microns (PM10) annually. To the extend that trees can control particulate pollution there is potential for improved air quality and substantial cost savings. The proposed project will quantify the relative ability of individual tree species in removing PM2.5. Therefore, urban trees can be evaluated by decision makers in terms of dollars saved associated with avoided investment in new control strategies. Quantification of PM2.5 removal is important for integration into the UFORE model being developed.

Statistical analysis indicated that there were significant differences among different tree species in intercepting particulate matter (PM2.5). Duncan Multiple Range Test indicated the relative comparisons of the experimental species in terms of their ability to remove PM2.5 (Table 1). Trees can act as efficient biological filters, removing significant amounts of particulate pollution from urban atmospheres.Live Oaks *(Quercus virginiana)* , River Birch ( *Betula Nigra),* and Sugar hackberry *(Celtis occidentalis)* seems to be statistically more efficient at capturing pollutant particles of less than 2.5 microns than species trees such as Red Maple *(Acer Rubrum),* Southern Magnolia *(Magnolia grandiflora),* and Sycamore *(Platanus occidentalis).* It should be noted that even some species indicate better efficiency in removing particle pollution, the total contribution to pollution removal is based on the canopy size as well as age and other plant and environmental factors. Therefore, it is possible that a mature Sycamore tree would contribute more to particle removal than a River Birch tree due to the larger canopy size. There appears to be no significant differences among some species. There appears to be a negative correlation between the species with high total leaf area and their efficiency in removing particles. Species with smaller total leaf areas seems to do a better task of removing particles. However, it should be noted that the leaf morphology of these trees are different. Stomatal conductance and net-photosynthetic capability of trees were affected by the exposure to PM2.5. This was expected as it has been reported by many investigators. Electron microscopy examinations revealed possible morphological characteristics which may play an important role in particle removal.

**Table 1.** Species mean particulate removal rate based on leaf surface area (□g/ cm$^2$ /hr)

| Scientific Name | | |
|---|---|---|
| Genus | | Particle Removal rate (□g/ hr/ cm$^2$) |
| *Quercus* | *virginiana* | *0.0542 a* |
| *Betula* | *nigra* | *0.0372 b* |
| *Celtis* | *laevigata* | *0.0355 c* |
| *Fagus* | *grandifolia* | *0.0197 d* |
| *Cornus* | *florida* | *0.0169 e* |
| *Morus* | *rubra* | *0.0167 e* |
| *Morus* | *alba* | *0.0161 e* |
| *Quercus* | *nigra* | *0.014 f* |
| *Ulmus* | *rubra* | *0.0138 f* |
| *Ulmus* | *americana* | *0.0131 gf* |
| *Castanea* | *pumila* | *0.0124 gh* |
| *Sapium* | *sebiferum* | *0.0103 I* |
| *Sassafras* | *albidum* | *0.0094 j* |
| *Liquidambar* | *styraciflua* | *0.0052 k* |
| *Quercus* | *falcata* | *0.0052 k* |
| *Acer* | *Rubrum* | *0.005 k* |
| *Magnolia* | *Grandiflora* | *0.0029 I* |
| *Platanus* | *occidentalis* | *0.0022 I* |

Note: sharing the same letters ( a, b, c, d, e, f, and etc) indicate no significant difference at a = 0.05.

**Project Objectives:**

The main objectives of this project are:

1) To quantify the relative ability of selected urban tree species to remove particulate pollution of less than 2.5 microns (PM2.5)

2) To quantify the detrimental effect of the particulate pollution on the tree species

3) To use modeling techniques for projecting the findings toward mature tree species

4) To develop a management guideline for practical application of the findings

**Objectives met successfully to date:**

All the objectives have been successfully met for 18 tree species . Tree- Air Pollution laboratory work has been completed according to the plan of work. Electron Microscopy Work has been completed. Two M.S. thesis have been developed from the results. Two presentations and two articles have been published. Two newspaper article were published by the Associated Press on the project and its impact.

**Objectives not yet met:**

All objectives have been successfully completed.

**How will this project increase the knowledge we have about urban forestry? How will the public benefit?**

To the extend that trees can control particulate pollution there is potential for improved air quality and substantial cost savings. The project has successfully quantified the relative ability of individual tree species in removing PM2.5. Therefore, urban trees can be evaluated by decision makers in terms of dollars saved associated with avoided investment in new control strategies. Quantification of PM2.5 removal is important for integration into the UFORE model which was developed by the USDA-FS. In addition, species removal rate can be used to expand the GIS-based software programs like "Citygreen" .

**What specific quantifiable results will be produced?**

The final products include a report on individual urban tree species ability to remove PM2.5. In addition, data from this study would be used in conjunction with the USDA-NEFES field data and UFORE model to better assess the role of Urban trees in removing particulate pollution. Some data are being used by Dr. David Nowak (USDA-FS) for inclusion in a compendium. Two MS thesis have been completed by urban forestry graduate students. (Please see attached copies)

**How will the results be disseminated to the public?**

The report from this project are made available free of any charges to public ( Southern University will pay for the publication and distribution). The results have also been published in proceedings of the Association of Research Directors Conference (ARD) and the publications of American Meteorological Society , Third Symposium on the Urban Environment. In addition, a paper has been published in special issue of Microscopy & Microanalysis, 2000. Other manuscripts are under preparation for inclusion in technical reports of the USDA-FS (Southern Region) and in the *Journals of Arboriculture and/or phytoremediation. (please see attached publication list)*

**If no-cost time extension has been requested for this project, why is (was) it needed?**

No-cost extensions have been requested due to personnel change and new significant findings.

**List the active partners (key individuals or organizations) involved in the project to-date:**

Dr. David Nowak, Project Leader
USDA-FS ,NEFES, Syracuse, NY.

Dr. Zhu Hua Ning, Associate Professor
Urban Forestry/Anatomy&Microscopy
SUBR, Baton Rouge, LA.

Dr. William Henk: Professor and Director of the Microscopy Center, Department of Anatomy and Cell Biology at Louisiana State University, School of Veterinary Medicine.

Dr. Michael Stubblefield, Director, Center for Energy and Environmental studies (CEES), SUBR, Baton Rouge, Louisiana.

**Comments considered of importance but not covered above:**

Many visits have been made by the USDA and EPA scientist to the lab and this project has been reviewed by many peer scientists in the field of physiology, urban forestry and plant anatomy. Two MS. thesis has been developed as a result of this project. Newspaper article has been written in relation to this project. Many students, staff and faculty have been trained by this project. Dr. Darold Ward, a new USDA-FS partner and collaborator has been identified and future plans are underway to expand this project. A field project has been completed in collaboration with the City of Chattanooga Urban Forestry Department to test the mature tress in the urban forest setting.

**Publications:**


Abdollahi, K.K. and Z.H. Ning. 2000. Urban Vegetation and their Relative Ability in Intercepting Particle Pollution (PM2.5). Urban Environment, published by American Meteorology Society (AMS) University of California, Davis, California. (In Press).

Abdollahi, K.K. Azali Muhammad, Z.H. Ning, and Asebe Negatu. 2000. In: Proceedings of Association of Research Directors Conference, Washington D.C. (ARD). P45.

Abdollahi, K.K. and Zhu Hua Ning. 2000. Tree Species Leaf Surface Morphology and Particle Pollution Removal. Microscopy & Microanalysis. (in press)


**This report was prepared by:**


**Name:** Kamran K. Abdollahi
**Title:** Associate Professor, Urban Forestry/Ecophysiology
**Phone** Number: 504-771-6291

**Date:** Feb 20, 2000

## Summary of Results

Table 1. Average particle pollution removal rate of each tree species is expressed in(Og/$m^3$/24hrs/$cm^2$). The rates were calculated by dividing the particle removal measurements from the analyzer (Ogim$^3$/24hrs) by the average total surface area of the tree.

| Scientific Name | | | |
|---|---|---|---|
| Genus | | Common Name | Average Particle Removal rate (□g/$m^3$/24hrs/ $cm^2$) |
| *Magnolia* | *Grandiflora* | Southern Magnolia | 0.0029 |
| *Sassafras* | *Albidum* | Sassafras | 0.0094 |
| *Platanus* | *Occidentalis* | Sycamore | 0.0022 |
| *Liquidambar* | *Styraciflua* | Sweetgum | 0.0052 |
| *Ulmus* | *Americana* | American elm | 0.0131 |
| *Ulmus* | *Rubra* | Slippery elm | 0.0138 |
| *Celtis* | *Laevigata* | Sugar Hackberry | 0.0355 |
| *Morus* | *Rubra* | Red Mulberry | 0.0167 |
| *Morus* | *Alba* | White Mulberry | 0.0161 |
| *Fagus* | *Grandifolia* | American Beech | 0.0197 |
| *Castanea* | *Pumila* | Chinkapin | 0.0124 |
| *Quercus* | *Virginiana* | Live Oak | 0.0542 |
| *Quercus* | *Falcata* | Southern Red Oak | 0.0052 |
| *Quercus* | *Nigra* | Water Oak | 0.014 |
| *Betula* | *Nigra* | River Birch | 0.0372 |
| *Cornus* | *Florida* | Flowering Dogwood | 0.0169 |
| *Acer* | *Rubrum* | Red Maple | 0.005 |
| *Sapium* | *Sebiferum* | Tallow Tree | 0.0103 |

Table 2. Species were ranked according to the rate of removal. Duncan Multiple Range Test was performed (SAS, Inc) to determine if there are significant differences among the Means. This ranking does not indicate total contribution of species toward particle pollution removal.. However, it shows the efficiency of each species in removing or intercepting particles. Average particle pollution removal rate of each tree species is expressed in(Og/m $^3$/24hrs/cm$^2$). The rates were calculated by dividing the particle removal measurements from the analyzer (0g/m $^3$/24hrs) by the average total surface area of the tree.

| Rank | Scientific Name<br>Genus | | Common Name | Mean<br>Particle Removal rate<br>(□g/m$^3$/24hrs/ cm$^2$) |
|---|---|---|---|---|
| *1* | *Quercus* | *virginiana* | Live Oak | *0.0542***a** |
| *2* | *Betula* | *nigra* | River Birch | *0.0372* **b** |
| *3* | *Celtis* | *laevigata* | Sugar Hackberry | *0.0355***b** |
| *4* | *Fagus* | *grandifolia* | American Beech | *0.0197***c** |
| *5* | *Cornus* | *florida* | Flowering Dogwood | *0.0169***c** |
| *6* | *Morus* | *rubra* | Red Mulberry | *0.0167***c** |
| *7* | *Morus* | *alba* | White Mulberry | *0.0161***c** |
| *8* | *Quercus* | *nigra* | Water Oak | *0.014***d** |
| *9* | *Ulmus* | *rubra* | Slippery elm | *0.0138***d** |
| *10* | *Ulmus* | *americana* | American elm | *0.0131***d** |
| *11* | *Castanea* | *pumila* | Chinkapin | *0.0124***d** |
| *12* | *Sapium* | *sebiferum* | Tallow Tree | *0.0103***e** |
| *13* | *Sassafras* | *albidum* | Sassafras | *0.0094***e** |
| *14* | *Liquidambar* | *styraciflua* | Sweetgum | *0.0052***f** |
| *15* | *Quercus* | *falcata* | Southern Red Oak | *0.0052***f** |
| *15* | *Acer* | *Rubrum* | Red Maple | *0.005***f** |
| *17* | *Magnolia* | *Grandiflora* | Southern Magnolia | *0.0029***f** |
| *18* | *Platanus* | *occidentalis* | Sycamore | *0.0022***f** |

Note: sharing the same letters ( a, b, c, d, e, and f) denote no significant difference at a = 0.05 between or among the means.

Table 3. Average of the total leaf area/tree for each species is expressed in $cm^2$. Average is calculated based on total leaf areas of 5 individual trees per species. Total leaf area for each tree was obtained using a LI-Cor Automatic Leaf Area meter.

| **Scientific Name** | | | | |
|---|---|---|---|---|
| **Genus** | | **Common Name** | **Average Total Leaf Area/Tree ( $cm^2$)** | **Standard Deviation ( $cm^2$)** |
| *Magnolia* | *Grandiflora* | Southern Magnolia | 6980 | 626 |
| *Sassafras* | *albidum* | Sassafras | 2080 | 396 |
| *Platanus* | *Occidentalis* | Sycamore | 18000 | 4949 |
| *Liquidambar* | *Styraciflua* | Sweetgum | 5180 | 228 |
| *Ulmus* | *Americana* | American elm | 1558 | 67 |
| *Ulmus* | *Rubra* | Slippery elm | 1595 | 202 |
| *Celtis* | *Laevigata* | Sugar Hackberry | 890 | 211 |
| *Morus* | *Rubra* | Red Mulberry | 2470 | 54 |
| *Morus* | *Alba* | White Mulberry | 2990 | 134 |
| *Fagus* | *Grandifolia* | American Beech | 1293 | 43 |
| *Castanea* | *Pumila* | Chinkapin | 2012 | 109 |
| *Quercus* | *Virginiana* | Live Oak | 384 | 64 |
| *Quercus* | *falcata* | Southern Red Oak | 3953 | 526 |
| *Quercus* | *nigra* | Water Oak | 2700 | 268 |
| *Betula* | *nigra* | River Birch | 544 | 59 |
| *Cornus* | *florida* | Flowering Dogwood | 1574 | 294 |
| *Acer* | *Rubrum* | Red Maple | 3036 | 624 |
| *Sapium* | *sebiferum* | Tallow Tree | 1093 | 177 |

Table 4. Species were ranked according to their average total leaf area. This ranking is only valid for the same age and size trees of the same species. Average of the total leaf area/tree for each species is expressed in $cm^2$. Average is calculated based on total leaf areas of 5 individual trees per species. Total leaf area for each tree was obtained using a LI-Cor Automatic Leaf Area meter.

| Scientific Name | | | | | |
|---|---|---|---|---|---|
| **Genus** | **Rank** | | **Common Name** | **Average Total Leaf Area/Tree ($cm^2$)** | **Standard Deviation ($cm^2$)** |
| *Platanus* | *1* | *Occidentalis* | Sycamore | 18000 | 4949 |
| *Magnolia* | *2* | *Grandiflora* | Southern Magnolia | 6980 | 626 |
| *Liquidambar* | *3* | *Styraciflua* | Sweetgum | 5180 | 228 |
| *Quercus* | *4* | *falcata* | Southern Red Oak | 3953 | 526 |
| *Acer* | *5* | *Rubrum* | Red Maple | 3036 | 624 |
| *Morus* | *6* | *Alba* | White Mulberry | 2990 | 134 |
| *Quercus* | *7* | *nigra* | Water Oak | 2700 | 268 |
| *Morus* | *8* | *Rubra* | Red Mulberry | 2470 | 54 |
| *Sassafras* | *9* | *albidum* | Sassafras | 2080 | 396 |
| *Castanea* | *10* | *Pumila* | Chinkapin | 2012 | 109 |
| *Ulmus* | *11* | *Rubra* | Slippery elm | 1595 | 202 |
| *Cornus* | *12* | *florida* | Flowering Dogwood | 1574 | 294 |
| *Ulmus* | *13* | *Americana* | American elm | 1558 | 67 |
| *Fagus* | *14* | *Grandifolia* | American Beech | 1293 | 43 |
| *Sapium* | *15* | *sebiferum* | Tallow Tree | 1093 | 177 |
| *Celtis* | *16* | *Laevigata* | Sugar/ Hackberry | 890 | 211 |
| *Betula* | *17* | *nigra* | River Birch | 544 | 59 |
| *Quercus* | *18* | *Virginiana* | Live Oak | 384 | 64 |

# CONCLUSION

## Manangement Recommendation:

- Trees can act as efficient biological filters, removing significant amounts of particulate pollution from urban atmospheres.
- Live Oaks *(Quercus virginiana)* , River Birch *( Betula Nigra),* and Sugar hackberry *(Celtis occidentalis)* seems to be statistically more efficient at capturing pollutant particles of less than 2.5 microns than species trees such as Red Maple *(Ater Rubrum),* Southern Magnolia *(Magnolia grandiflora),* and Sycamore *(Platanus occidentalis).*
- It should be noted that even some species indicate better efficiency in removing particle pollution, the total contribution to pollution removal is based on the canopy size as well as age and other plant and environmental factors. Therefore, it is possible that a mature Sycamore tree would contribute more to particle removal than a River Birch tree due to the larger canopy size.
- There appears to be no significant differences among some species.
- There appears to be a negative correlation between the species with high total leaf area and their efficiency in removing particles. Species with smaller total leaf ares seems to do a better task of removing particles. However, it should be noted that the leaf morphology of these trees are different.
- Stomatal conductance and net-photosynthetic capability of trees were affected by the exposure to PM2.5. This was expected as it has been reported by many investigators.