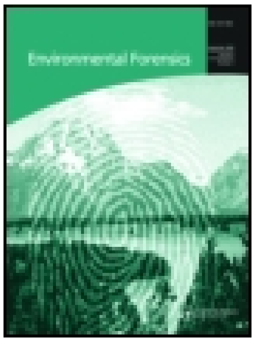


Environmental Forensics

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uenf20

Dendrochemical forensics as material evidence in courts: *How could trees lie?*

Chris Balouet, Joel Burken, Jacques Martelain, Jonathan Lageard, Frank Karg & David Megson

ENVIRONMENTAL FORENSICS
https://doi.org/10.1080/15275922.2021.1940381

Taylor & Francis
Taylor & Francis Group

OPEN ACCESS Check for updates

Dendrochemical forensics as material evidence in courts: *How could trees lie?*

Chris Balouet[a], Joel Burken[b], Jacques Martelain[c], Jonathan Lageard[d], Frank Karg[e], and David Megson[d,f]

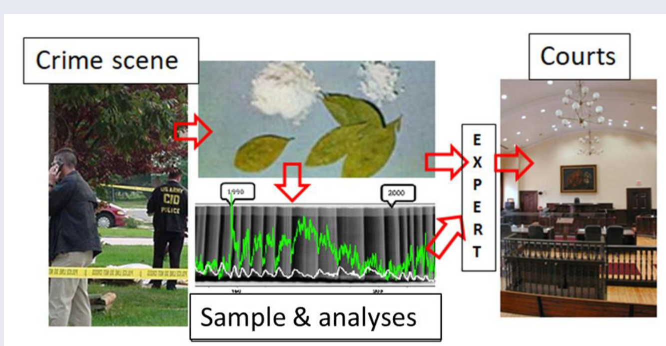
[a]Environment International, Orrouy, France; [b]Missouri University of Science & Technology, Rolla, Missouri, USA; [c]Terraquatron, Saint Cyr au Mont d'Or, France; [d]Ecology & Environment Research Centre, Manchester Metropolitan University, Manchester, UK; [e]HPC INTERNATIONAL, Hôtel de Recherche, Centre Perharidy, Roscoff/France and Atlantis Developpement, Roscoff, France; [f]Chemistry Matters Inc, Alberta, Canada

ABSTRACT

The legal admissibility of scientific tools, such as dendrochemistry providing forensic evidence for criminal or civil cases, critically relies on the quality of fundamental and applied scientific research. The "Daubert" and "Frye" criteria that federal courts in the U.S.A use for determining legal admissibility requires publication of the scientific basis for the tool, and general acceptance by the scientific community. The field of dendro-forensics is rapidly evolving, with new methods constantly being developed. In this manuscript we investigate how this dendrochemical evidence has been used successfully in the courtroom. The study of tree rings using physical anatomical and dendrochronological methods has been used as evidence in courts for over 150 years. From these beginnings in dendroecology dendrochemical and biological methods have matured enough to allow it to be used in forensic investigations, finding applications as a new independent line of evidence around the world, supporting cases involving murder, trafficking of protected species, and pollution crimes. We summarize some of the key applications of dendrochemistry in forensic cases and illustrate them with courtroom examples. The basic analytical methods discussed (e.g., PCR, GC-MS, LIBS, LA/ICP-MS, EDXRF) are all conventional. However, for findings to be relevant to judicial cases, the data is normally applied with additional lines of evidence gathered such as tree physiology and relevant statistics. This can allow us to gain more powerful data to help age date a specific event or to spatially identify a source material. The purpose of this article is to show how recent research has paved the way for the use of dendrochemical evidence in courts. It shows how dendrochemistry can be useful for forensic investigations including: murder cases, trafficking of protected species, and pollution crimes. The applications are illustrated by several summarized legal cases, but due to the confidential nature of some of these cases it was not always possible to provide full details or references.

KEYWORDS
Tree; dendrology; dendrochemistry; environmental forensics; judicial expertise; legal

GRAPHICAL ABSTRACT



CONTACT D. Megson david.megson@mmu.ac.uk Manchester Metropolitan University, Manchester, UK

Highlights

Dendrochemical evidence is used successfully in criminal and civil cases worldwide.

Chemical, biological and physical evidence can be gained from trees.

Tree evidence has supported cases involving murder, trafficking and environmental pollution.

Trees can provide excellent temporal and spatial information when used correctly.

1. Introduction

Edmond Locard, one of the early 20th century experts in forensics, developed in 1934 his "exchange" principles of investigating trace evidence left or exchanged at crime scenes. He stated that: « … *It is factual evidence. Physical evidence cannot be wrong, it cannot perjure itself, it cannot be wholly absent. Only human failure to find it, study and understand it, can diminish its value* ». His statement remains valid today and can be applied to dendroecology examples in which tree rings can act as recorders of past events or trends. Dendroecology techniques have evolved over recent decades to now include biological methods (such as DNA barcoding) and dendrochemistry methods that involve some form of chemical analysis. Trees are intimately connected to their surroundings, impacted by their environmental settings and contain chemical and physical records of their surroundings. Recent research developments continue to attest to the capacity of trees to record nearby environmental events as well as remote ones, such as century old volcanic eruptions (Hevia et al., 2018) or past cosmogenic carbon events (Büntgen et al., 2018).

Trees have been used as judicial evidence in dozens of cases, both civil and criminal (Graham, 1997; Balouet et al., 2009, 2012, 2014, 2015). The earliest cases, starting in the mid-1800s were primarily based on dendrochronology and wood anatomy and have thrown light on the theft of Christmas trees and of trees from protected forests, the age of hedges in boundary disputes and the authenticity of reputedly aged musical instruments (Jozsa, 1985; Winchester, 2003; Wolodarsky-Franke and Lara, 2005; Yaman and Akkemik, 2009; Bernabei et al., 2010; Grissino-Mayer et al., 2010; Dormontt et al., 2015; Köse et al., 2018). Additionally, pollen from distinctive vegetation types, including from trees, has been preserved on/within murder victims, on their clothing and on associated artifacts, providing strong but often circumstantial evidence in several high-profile trials (Wiltshire 2006; Wiltshire and Black 2006). Arthur Koehler, of the US Forest Products Laboratory, proved in two famous US criminal cases that evidence gained from wood could be critical (Graham, 1997). In 1918, he connected a bomb packed in a box made of elm wood to the workshop of a suspect, where shavings of the same species were identified. In the famous 1932 Lindbergh court case, he was able to use tree rings to prove that the ladder used for the kidnapping was repaired with a lath that had been cut from the attic floorboard of Richard Hauptmann. This occurred after Mr. Hauptmann's arrest on September 19, 1934 for possession of gold certificates that were part of a ransom.

Dendrochemistry (*sensu lato*) appeared in courts in the early 1980s, starting with a missing persons case in Clark County, Illinois 1982, (**Ex 1**.) Since then, dendrochemical evidence has covered a broad range of issues and methods involving generation of data from DNA to organic analytes and trace elements (i.e., EDXRF, ICP/MS, or LIBS). These have been used to identify current exposure status, or combined with the dendrochemical record to identify and age-date past events. In recent decades trees have been used in a wider range of forensic investigations. This is evidenced through this manuscript which highlights some specific cases where trees have provided pivotal evidence to help solve murder cases, trafficking and environmental pollution cases.

2. Murder cases

Murder cases can be some of the most high-profile cases to pass through the courts and often gain significant interest in the public eye. In these cases, questions to the judge vary significantly between individual cases. Trees have been used as evidence in several cases over the last century; however, as methodological developments and fundamental research into dendroforensics have developed, so has the evidence presented, along with the questions and challenges raised. Where once we relied on dendrology/dendrochronology, we now also have the added lines of evidence from chemistry and genetic analysis.

2.1. Chemistry

The developments in the field of dendrochemistry have allowed scientists to understand past levels of chemical pollutants through records that are laid down in tree rings. These are not only used from a chemical pollution perspective but can provide key evidence to assist in murder cases, as is evidenced through **Ex 1.** and **Ex 2**.

Ex 1: *Chicago area/Clark County, July 24, 1981. Mrs. Charlotte Grabbe, age 39, is reported missing. Her body was never found. In 1984, her daughter offered a bounty of $25,000 USD to anyone helping with the case; Vickie Mac Allister, the recent girlfriend of Mr. Grabbe, then affirmed that Mrs. Grabbe was shot by her husband on July 26 morning. She stated that he placed her body in a drum on his truck to burn it by a nearby river under one tree, using diesel for an ignition source. Investigators went to the mentioned location and found the exact tree in question. Burned branches were sampled and analyzed, with the conclusion that a fire had indeed occurred at this exact place at the incriminated time, (early summer, 3 years before sampling). Investigators further checked on the use of diesel fuel by sampling tree wood samples next to where the drum was reported to have been placed, and on the opposite side of the tree. The samples were analyzed by Gas Chromatography Mass Spectrometry (GC-MS) and showed evidence of diesel fuel from samples taken from where the drum was placed.*

Ex 2: *Texas, March 2004: The charred body of a young woman is found in the desert, in association with partly burnt logs. Further investigation showed that the victim had spent the past evening at a party with friends, around a campfire using the same wood. It was determined that this wood had been supplied by one of the people attending that campfire, and that more such wood was found stacked at his home place. Seized logs of this mesquite wood (Prosopis glandulosa) at these 3 locations were consecutively analyzed by Oak Ridge National Laboratory by Laser Induced Breakdown Spectroscopy (LIBS). Chemical fingerprinting led to the conclusion was that this wood showed a highly specific metal signature, matching with only one nearby industrial site where the suspect had been paid to cut wood. In this case elemental tracers predicted with 99.999% certainty the exact origin.*

2.2. Genetics

Whenever plant material is found in association with a crime scene, part of investigator's job is to find out what evidence it can add. Dozens of cases have occurred where the genetic analysis of leaves, fruits, or needles has aided investigators. Such a case is evidenced in **Ex 3**. where DNA analysis was used to exclude some theories and confirm an exact killing place, after a body had been moved from the murder location to the discovery site.

Ex 3: *Maricopa, Arizona, USA: 1992 (State v. Bogan). A woman's body is found, partly buried below a Palo Verde tree (Parkinsonia microphylla). A fruit of this species is found in the trunk of one suspect's car. DNA investigations were conducted on 30 different trees of the area, and it was subsequently concluded that the fruit found in the suspect's car came from the exact same tree, confirming that the suspect had been by the crime scene - which he had earlier denied.*

3. Trafficking protected species

Many organisms have been listed as protected species, which are banned for trade under national laws and international treaties e.g., CITES. However, historic customs and the commercial value of these products on illegal trade networks means that authorities have to manage an ever-evolving field of wildlife trafficking. This applies not only to animals, but also to rare tropical wood. These types of crimes have traditionally been investigated solely through biological based methods (e.g., genetic techniques). However, more recently authorities have been teaming up with scientists to use chemical methods along with advanced biological methods to identify instances of wildlife trafficking. For example, genetic methods (**Ex 4.**) were used to establish the exact origin of protected wood species. These methods can be used to determine the type of species and location from logs, bark, insects, or even fungi. There have also been cases where chemical and genetic methods have been used to identify traders who have claimed a product to be of plant origin to hide a more sinister animal-based trade source. Dendrochemical methods were used to quickly confirm suspected fraud, the extent to which was only proven after further genetic testing (**Ex 5.**).

Ex 4: *A major guitar US maker has used regulated rose wood (Dalbergia spp.) for its guitar necks. On investigation it was revealed that the provider of the wood had changed its practice which meant that rather than obtaining wood from a legal source, it was obtaining wood from an area where rose wood logging was banned. Genetic evidence was provided to support this case, the associated wrongdoers were identified, and those responsible were found guilty.*

Ex 5: *Until 2018 "Hatha Jodi" was widely sold across the globe through online distributors (e.g., Amazon). The product was sold under many guises claiming that it was a rare root containing magical powers and was found only in a few inhospitable places across the Himalayas (D'Cruze et al. 2018). Chemical* *analysis using Fourier-transform infrared spectroscopy (FTIR) was used to identify within several seconds that a sample was of animal (rather than plant) based origin. Further genetic analysis and investigation using micro-computed tomography (µCT) was used to confirm that the material was actually a monitor lizard's penis. The findings lead to several arrests of traders across India and voluntary removal of the product from sale on many websites (some of which specialized in ethical trading). However, despite presentation of evidence, some major global distributors are defiant and are still selling the product in the U.S.*

4. Pollution crime

Contaminated sites that require extensive cleanup are present worldwide. Part of the judicial process involved with these sites includes seeking out and prosecuting parties that violated environmental laws. Determining the offending party can become complicated when multiple companies occupied the contaminated property over differing periods of time. To determine the origin and fate of the pollution, supporting evidence for the timing of the contamination is critically important, as is insight to potential multiple releases of pollution. When historic pollution events have occurred, it is important to understand the value of trees as living records that can collect chemical signatures and elemental tracers to document the history of a site. Scientific understanding of the fate and behavior of the contaminants in question in trees is imperative, and failure to do this can lead to misleading and erroneous results. In pollution crime events the data presented to courts can often be more complex than in the previously mentioned examples involving tree evidence. There can be more scientific uncertainty in the data which can open it up to more scrutiny or challenge. It is only more recently that we have been utilizing dendrochemistry from the research landscape and embedding it in the courtroom, so examples in this section focus on the techniques available through the scientific literature, with a focus on two cases (Ex 6 and Ex 7) showing how these techniques can be effectively adopted. With time we expect to see more of these methods and technologies transfer from the scientific literature, into the courtroom.

Our fundamental understanding of dendrochronology teaches us that tree rings provide a documented history in layers, however when pollution events occur this might not be that straightforward, so we need to be aware; is it possible for trees to lie?

4.1. Source identification—Using chemical fingerprinting and matching signatures

It is important to understand that the chemical signature recorded in a tree is unlikely to perfectly match the source of pollution. Contaminants released into the environment will undergo various forms of weathering. This can be more pronounced for organic pollutants which are normally a mixture of many different individual compounds. Each of these compounds has different physiochemical properties which can be degraded post release and may not be absorbed and stored in trees in the same way; e.g., polychlorinated biphenyls (PCBs) are poorly absorbed by tree roots, but can enter the tree through stomata as SVOCs indicating an atmospheric deposition pathway (Liu and Schnoor, 2009; Hermanson et al., 2016). For inorganic pollutants there are certain tree species that can hyperaccumulate certain metals and minerals resulting in a different signature in the trees than the source material. Once in the tree, some pollutants may move and accumulate in different areas (e.g., roots, shoots, fruit, & tubers) (Unterbrunner et al., 2007). Therefore, understanding the transport mechanisms for pollutants in, out and within the tree are essential. Furthermore, when using trees to monitor organic groundwater pollution each tree that has been affected by the same source/plume of contamination may show a different chemical signature. Based on the size of the site there will be a variation in the time taken for a plume to migrate between the different tree locations. During this time the plume may degrade into stable or non-stable abiotic or biotic breakdown products (e.g., toxic metabolites) and the chemical signature will therefore change. However, this challenge can also be an opportunity as a dendrochemist with access to dendrochemical records and hydrogeological data can use these differences to calculate plume migration rates and hence "age date" the release date of a contaminant source (Balouet et al., 2007, 2012). A similar approach can also be taken with atmospheric pollutants where diffusion coefficients can be used to help recreate past atmospheric concentrations of pollutants (Rauert and Harner, 2016).

Since the 1990s there have been a considerable number of dendrochemical studies attempting to reconstruct the pollution histories for inorganic pollutants which have had varying degrees of success. Doubts have been raised concerning pollution pathways and the spatio-temporal accuracy of tree-ring archives. But if key criteria are met such as isolated point sources of pollution and the consideration of multiple site dendrochemical records, reconstructed pollution chronologies can bear close comparison to known or estimated pollution outputs (Smith and Shortle 1996; Watmough 1999; Lageard et al., 2008).

4.2. Age dating pollution events

Age dating cases can normally be performed through two different dendrochemical approaches: The "one time" or "instantaneous" method only looks at one sample at a time. Typically, this is what the dendrochemist does when performing phytoscreening to document the current exposure of the tree (**Ex 2. & 3.**). The second approach is the line scanning method, such as methodologies developed in the 1990s by using energy-dispersive X-ray fluorescence (EDXRF) Itrax multiscanners (Balouet and Chalot, 2015) which provide access to past chemical time series with the capacity to go back to decades, eventually centuries, and generate hundreds to thousands of data points in a nondestructive way. Other destructive line scanning methods that involve the use of mass spectrometry for inorganic pollutants, and organic pollutants are also available (Odabasi et al., 2015; Rauert and Harner, 2016).

It is important to note all these influences and considerations when using data gathered from trees. The trees do not lie, but it is possible for us to misunderstand and misinterpret the data provided by them. When understood correctly, trees can provide valuable lines of evidence to support cases.

Trees have been used successfully for both source identification and age dating in the courtroom. This is evidenced through the following example investigating the pollution history of chlorinated solvents (**Ex 6.**) and fuel (**Ex 7.**) in groundwater at industrial sites.

Ex 6: *(confidential penal case) An important industrial site was contaminated with trichloroethylene which had been used on the site for several decades. The cost of remediation was extensive and so the two consecutive owners of the site argued that the contamination did not occur during their tenure. Dendrochemistry was used to reveal the existence of several consecutive/asynchronous increases in the chlorine content of tree rings, some of which occurred during the first ownership, with others attributed to the second owner. In addition to providing a date for the release, the amplitude of the respective chlorine peaks in tree samples provided an indication of impact severity which allowed for respective contributions of the different release events to the total site pollution. From this data the court was able to allocate respective torts.*

Ex 7 *(confidential civil case) Fuel contamination had been identified in a river at a point that was located close to a series of underground storage tanks. Samples were obtained from trees that were located between the tanks and the river. These samples were analyzed to determine concentrations of several elemental tracers (Ni, V, Ba, Sr, Cl, S, Pb), and create a multi-element fingerprint. This data was used to identify releases from two specific diesel tanks and an elevated lead concentration revealed a leak in a tank that had contained leaded gasoline.*

5. Conclusions

Trees are living organisms acting as proxies, they can record chemical conditions at a set point and time. The scientific community involved in dendrochemistry is relatively small; however, the applications of dendrochemistry are increasing. Conventional dendrochronology has successfully provided informative evidence for over a century in science and judicial forensics cases. The application of dendrochemistry is a younger and less well documented field of study. In spite of its youth, there is a growing body of supporting research in which dendrochemistry has been used to assist investigations as a line of independent judicial evidence or in plume characterization in groundwater studies. The repeatability and precision of the analytical data being produced by these methods are robust, and multivariate statistics and advanced modeling methods are being used more often to interpret this data. To apply the data to forensic judicial cases, researchers will need to separate naturally occurring in-tree chemical signatures from chemical signatures reflecting an environmental event. The timing of the environmental event, as determined by dendrochemistry, then has potential application in forensics investigations. As with any emerging methodology it can be perceived as a challenge to have it accepted by the court. Even the emerging field of dendrochronology experienced this, as the defendants in the 1932 Charles Lindbergh's son case requested that the dendrochronologist's testimony shouldn't be heard. Fortunately, the judge disagreed. Today in the U.S. legal system the Daubert criteria is perceived as a hurdle that emerging techniques have to overcome before they can be accepted as evidence. This has been discussed previously by Balouet et al. (2009) specifically for dendrochronology and dendrochemistry. In the rest of the world there is more flexibility, but there is still a strong degree of scientific rigor. It is important to note that where studies have been performed in a robust manner, data from trees has been accepted as a valuable line of evidence. Attorneys and judges using these methods often point out the fact that *"the trees do not lie!"* This is only the case when the data has been fully understood, considered, analyzed and properly reported.

Acknowledgement

This article is submitted in homage to Dr Francis Gallion, honorary president of the French National Company of Judicial Experts in Environment. Acknowledgement go to the forensic and dendrochemist communities, especially Gil Oudijk, Kevin Smith, Andrea Hevia, Raúl Sánchez-Salguero and Don Vroblesky for their long and constant support, as served by their most valuable suggestions. This article is published in memory of Jean-Christophe Balouet who sadly passed away earlier this year.

Conflict of interest

The authors have no conflict of interest in writing this article.

Data availability

The authors will certainly be available to answer readership eventual questions and enlarge the worldwide database of legal precedents.

References

Balouet, J. C., Burken, J. G., Karg, F., Vroblesky, D., Smith, K. T., Grudd, H., et al. 2012. Dendrochemistry of multiple HVOC releases at a former industrial site. *Environmental Science & Technology* 46(17):9541–9547.

Balouet, J. C., Gallion, F., Martelain, J., Megson, D. & O'Sullivan, G. 2015. Forensic investigations in complex pollution cases involving P CBS, dioxins and furans: potential pitfalls and tips. eds O"ullivan, G. and Megson, D. in Environmental Forensics, 31–40.

Balouet, J. C., and Chalot, M. 2015. Methodological guide. In *Pollution Investigation by Trees (PIT/ADEME)*. eds. Morrison, R., and Murphy, B. Angers, France: Elsevier. 671–731

Balouet, J. C., Gallion, F., Martelain, J., Megson, D., and O'Sullivan, G. 2014. Forensic Investigations in complex pollution cases involving PCBs, Dioxins and Furans: Potential pitfalls and tips. In *International Network for Environmental Forensics*, eds. G. O'Sullivan and D. Megson, London: Royal Chemical Society, 31–40.

Balouet, J. C., Oudijk, G., Petrisor, I., and Morrison, R. 2007. Emerging forensic techniques. In *Introduction to Environmental Forensics*, 2nd ed., eds. Morrison, R., and Murphy, B. London: Elsevier, 671–731.

Balouet, J. C., Smith, K. T., Vroblesky, D., and Oudijk, G. 2009. Use of dendrochronology and dendrochemistry in environmental forensics: Does it meet the Daubert criteria? *Environmental Forensics* 10(4):268–276.

Bernabei, M., Bontadi, J. and Rognoni, G. R. 2010. A dendrochronological investigation of stringed instruments from the collection of the Cherubini Conservatory in Florence, Italy. *Journal of Archaeological Science*, 37(1), 92–200.

Büntgen, U., Wacker, L., Galván, J. D., Arnold, S., Arseneault, D., Baillie, M., et al. 2018. Tree rings reveal globally coherent signature of cosmogenic radiocarbon events in 774 and 993 CE. *Nature Communications* 9: 3605.

D'Cruze, N., Singh, B., Mookerjee, A., Macdonald, D., Hunter, K., Brassey, C., et al. 2018. What's in a name? Wildlife traders evade authorities using code words. *Oryx* 52(1):13–15.

Dormontt, E. E., Boner, M., Braun, B., Breulmann, G., Degen, B., Espinoza, E., et al. 2015. Forensic timber identification: It's time to integrate disciplines to combat illegal logging. *Biological Conservation* 191:790–798.

Graham, S. 1997. Anatomy of the Lindbergh kidnapping. *Journal Forensic Science* 42(3):368–377.

Grissino-Mayer, H. D., Sheppard, P. R., Cleaveland, M. K., Cherubini, P., Ratcliff, P., and Topham, J. 2010. Adverse implications of misdating in dendrochronology: Addressing the re-dating of the 'Messiah' violin. *Dendrochronologia* 28:149–159.

Hermanson, M., Hann, R., and Johnson, G. W. 2016. Polychlorinated biphenyls in tree bark near former manufacturing and incineration facilities in Sauget, Illinois, United States. *Environmental Science & Technology* 50(12):6207–6215.

Hevia, A., Sánchez-Salguero, R., Camarero, J. J., Buras, A., Sangüesa-Barreda, G., Galván, J. D., et al. 2018. Towards a better understanding of long-term wood-chemistry variations in old-growth forests: A case study on ancient *Pinus uncinata* trees from the Pyrenees. *Science of the Total Environment* 625:220–232.

Jozsa, L. A. 1985. Contribution of tree-ring dating and wood structure analysis to the forensic sciences. *Canadian Society of Forensic Science Journal* 18(4): 200–210.

Köse, N., Okan, T., and Akkemik, U. 2018. Understanding the impacts of illegal logging in Turkey: A case study of Junipers in Eskişehir. *Baltic Forestry* 24(1):109–116.

Lageard, J. G. A., Howell, J. A., Rothwell, J. J., and Drew, I. B. 2008. The utility of *Pinus sylvestris* L. in dendrochemical investigations: Pollution impact of lead mining and smelting in Darley Dale, Derbyshire, UK. *Environmental Pollution* 153(2):284–294.

Liu, J., and Schnoor, J. L. 2009. Uptake and translocation of lesser-chlorinated polychlorinated biphenyls (PCBs) in whole hybrid poplar plants after hydroponic exposure. *Chemosphere* 73(10):1608–1616.

Locard, E. 1934. *La police et les méthodes scientifiques*. London: Rieder, 8.

Odabasi, M., Falay, E., Tuna, G., Altiok, H., Kara, M., Dumanoglu, Y., et al. 2015. Biomonitoring of the spatial and historical variations of persistent organic pollutants

(POPs) in an industrial region. *Environmental Science and Technology* 49, 2105–2114. http://refhub.elsevier.com/S1352-2310(16)30456-3/sref14

Rauert, C., and Harner, T. 2016. A preliminary investigation into the use of Red Pine (*Pinus resinosa*) tree cores as historic passive samplers of POPs in outdoor air. *Atmospheric Environment* 140:514–518. http://dx.doi.org/10.1016/j.atmosenv.2016.06.024

Smith, K. T., and Shortle, W. C. 1996. Tree biology and dendrochemistry. In *Tree Rings, Environment and Humanity. Proceedings of the International Conference on Dendrochronology*, eds. Dean, J. S., Meko, D. M., and Swetnam, T. W. Tuscon, AZ: Radiocarbon, 629–635.

Unterbrunner, R., Puschenreiter, M., Sommer, P., Wieshammer, G., Tlustos, P., Zupan, M., et al. 2007. Heavy metal accumulation in trees growing on contaminated sites in Central Europe. *Environmental Pollution* 148(1):107–114.

Watmough, S. A. 1999. Monitoring historical changes in soil and atmospheric trace metal levels by dendrochemical analysis. *Environmental Pollution* 106:391–403.

Winchester, V. 2003. The peripatetic hedge: A case for dendrochronological dating. *Science & Justice* 43(I):23– 28.

Wiltshire, P. E. J. 2006. Hair as a source of forensic evidence in murder investigations. *Forensic Science International* 163:241–248.

Wiltshire, P. E. J., and Black, S. 2006. The cribriform approach to the retrieval of palynological evidence from the turbinates of murder victims. *Forensic Science International* 163:224–230.

Wolodarsky-Franke, A. and Lara, A. 2005. The role of "forensic" dendrochronology in the conservation of alerce (*Fitzroya cupressoides* ((Molina) Johnston)) forests in Chile. *Dendrochronologia* 22:235–240.

Yaman, B., and Akkemik, U. 2009. The use of dendrochronological method in dating illegal tree cuttings in Turkey. *Baltic Forestry* 15(1):122–126.