Hair Analysis: Exploring the State of the Science

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On 12–13 June 2001, the Agency for Toxic Substances and Disease Registry (ATSDR) convened a seven-member panel in Atlanta, Georgia, to review and discuss the current state of the science related to hair analysis, specifically its use in assessing environmental exposures in support of the agency's public health assessment activities. ATSDR invited scientific experts in the fields of hair analysis, toxicology, and medicine to participate in a discussion of such topics as analytical methods, factors affecting the interpretation of analytical results, toxicologic considerations, and data gaps and research needs. The goal of the panel was to determine the overall utility of hair analysis as a tool to evaluate exposure at hazardous waste sites. The principal lesson learned from the meeting was that, for most substances, data are insufficient to predict health effects from the concentration of the substance in hair. The presence of a substance in hair may indicate exposure (both internal and external) but does not necessarily indicate the source of exposure. Thus, before hair analysis can be considered a valid tool for assessing exposure and health impact of a particular substance, research is needed to establish standardized reference ranges, gain a better understanding of biologic variations of hair growth with age, gender, race and ethnicity, and pharmacokinetics, and further explore possible dose–response relationships. ATSDR intends to use the findings of this panel to develop educational materials to support its site work and to encourage researchers to continue to develop methods that may facilitate reliable exposure assessments. *Key words:* **analytical methods, arsenic, data gaps, environmental contamination, exposure assessment, limitations, methyl mercury, reference ranges.** *Environ Health Perspect* **111:576–578 (2003). doi:10.1289/ehp.5842 available via** *http://dx.doi.org/* **[Online 3 December 2002]**

Recently, the Agency for Toxic Substances and Disease Registry (ATSDR) explored human hair analysis as a potential additional tool to assess exposure. Hair analysis may have useful applications in forensic investigations for trace elements (Fletcher 1982), in screening for the use of illicit drugs (Valente et al. 1981), and in exposure assessment for some occupational settings (Foo et al. 1993; Taylor 1986). However, the general utility of hair analysis to assess environmental exposures (Bencko 1995; Frisch and Schwartz 2002; Hammer et al. 1971; Hindmarsh 2002; Manson and Zlotkin 1985), especially those that might occur because of exposure to contaminants from hazardous waste sites, remains largely unproven (Esteban et al. 1999).

In this report, we summarize the deliberations of an ATSDR-sponsored expert panel that met in June 2001 in Atlanta, Georgia, to discuss the state of the science related to hair analysis for environmental substances found at hazardous waste sites (ATSDR 2001). The panel consisted of individuals representing state and federal government agencies, academia, and the private sector and whose expertise, interests, and experience covered a wide range of technical disciplines critical to the issues being discussed. This report highlights the lessons ATSDR learned from the panel deliberations about the utility of hair analysis to assess exposure to contaminants.

ATSDR's recent interest in hair analysis is 2-fold. First, the agency is seeking and using more direct and specific measures of exposure rather than relying on default exposure assumptions to strengthen and support its public health assessments and recommended public health actions. Among the measures being used are biologic measures of exposure (typically target substances or metabolites in blood and urine), point-of-contact environmental measures (e.g., personal air samplers), geographic information systems (GIS) integrated with fate and transport models, and direct observations made by the health assessment team during site visits. Integrating these techniques has increased our capacity to assess exposure, both qualitatively and quantitatively.

To date, ATSDR has conducted hair analyses or worked with its state partners to obtain and analyze hair samples at only a limited number of sites. At several of these sites, hair analysis was considered an adjunct to other biological tests (urine or blood) to assess current exposures or provide information not obtainable from blood or urine testing, particularly where past exposures may have been a concern. At certain times, the agency has performed hair analysis to assure communities that all possible tools are being used to assess exposure. However, before embarking on more routine hair sampling at sites, ATSDR needs to know whether the science supports this effort and determine when it is appropriate.

Second, the agency is increasingly being requested by communities to perform hair analysis and also to interpret the public health implications of individual residents' reports obtained from commercial laboratories. Many of these laboratories advertise their ability to identify in hair samples harmful levels of toxic substances and deficiencies of essential nutrients. The recently published case reports about the pitfalls of hair analysis (Frisch and Schwartz 2002) are similar to the experiences ATSDR has encountered, one of which served as an impetus for convening the expert panel (ATSDR 2001). In accordance with its mission, the agency wants to use the best science to provide trusted health information to concerned communities and individuals.

The Panel Meeting

The panel consisted of seven experts representing a broad range of experience, interest, and affiliations. Panel members were Robert Baratz, Thomas Clarkson, Michael Greenberg, Michael Kosnett, Dan Paschal, and Sharon Seidel. LuAnn White chaired the meeting. For more complete biographical information on each of the panelists, refer to the panel summary report (ATSDR 2001).

The panel's goal was to determine the overall utility of hair analysis as a tool to evaluate exposure at hazardous waste sites. The panel was charged to address the following series of questions:

- For what substances do reliable hair analysis methods exist?
- When is it appropriate to consider hair analysis in assessing human exposures to environmental contamination?
- What data gaps exist that limit the interpretation and use of hair analysis in the assessment of environmental contaminants?

Before the meeting, panelists prepared written responses to a series of questions that would form the basis of the discussions (ATSDR 2001). The questions covered a wide variety of topic areas: analytical methods; factors influencing the interpretations of analytical results; toxicologic consideration; data gaps and research needs; and scenarios for which hair analysis may be appropriate.

Each panelist was provided with copies of several publications (Barrett 1985; Hopps 1977; Miekeley et al. 1998; Seidel et al. 2001; Sky-Peck 1990; Steindel and Howanitz 2001;

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Wennig 2000; Yoshinaga et al. 1990) that focused the discussions, as well as a bibliography of additional literature pertaining to hair analysis (ATSDR 2001). Panelists were also asked to identify additional relevant references to accompany their premeeting comments.

Panel discussions were held in an open public forum that was attended by approximately 50 observers. Panel discussions focused on gaining a better understanding of the science related to the analysis of contaminants in hair and, most important, the interpretation of results with respect to environmental exposure from hazardous waste releases.

Several time periods were designated specifically for observers to ask questions and provide comments. These comments are summarized in the final meeting report along with the panelist's responses as appropriate (ATSDR 2001). In all cases, the observers were encouraged to also submit their comments in writing and to provide references to support their statements.

ATSDR intends to use the information and data presented during the panel meeting to develop interim guidance for its health assessors on the use and interpretation of hair analysis data for evaluating exposure and to determine how best to discuss the merits and limitations of hair analysis with an increasingly interested and, perhaps, misinformed public. The final summary report of the panel formed the foundation for the following lessons learned.

Lessons Learned

During the discussions, panelists reviewed the state of the science of human hair analysis in relation to exposure assessment, including the advantages, limitations, and research gaps. Insights gained from the panel discussion will guide ATSDR staff in evaluating human hair analysis as a tool in assessing exposure risk.

For what substances do reliable hair analysis methods exist? Except for drugs and substances of abuse, panelists concurred that accurate analytical methods for measuring organic contaminants in human hair are generally lacking. As a result, panel discussions focused primarily on the measurement of metals and trace elements in scalp hair and on the analytical methods. Panelists considered the distinct differences in using hair analysis for identifying exposures (is the substance reaching people? does a completed pathway exist?) versus using it for predicting, diagnosing, or treating disease (i.e., what is the threshold for adverse health effects?). Although analytical methods can detect trace or low amounts of metals in the hair, panelists identified the difficulties in determining whether the measurement of a substance in the hair accurately reflects external exposure or internal body dose. Panelists generally agreed that except for methyl mercury (and perhaps arsenic), data are insufficient to reliably indicate the source of exposure and the internal dose or predict a resultant health effect from the measurement of a particular substance in hair.

Conclusions. *a*) Measurement of a substance in a hair sample could indicate exposure; however, it may not indicate internal exposure or the source of the exposure. *b*) For most substances, data are insufficient to predict a health effect from the measurement of the substance in hair.

When is it appropriate/inappropriate to consider hair analysis in assessing human exposures to environmental contamination? While scalp hair growth rates are generally cited as being approximately 12 cm/year or about 1 cm/month, actual rates may vary between 0.6 and 3.6 cm/month (Harkey 1993). Because of this variability, the panel concluded that hair analysis is not generally useful for evaluating recent exposures or those occurring more than 1 year ago. Segmental analysis of hair (i.e., looking at concentration trends along the length of the hair) could have a role in documenting exposures over time (e.g., identification of a high-dose, acute exposure). However, this type of hair analysis would need to be considered on an individual-, substance-, and situationspecific basis.

Conclusions. Because of the growth rate of human hair, hair analysis is not generally useful for evaluating recent exposures or those occurring more than 1 year ago. Segmental analyses of hair could have a role in documenting exposure over time under very specific circumstances.

What data gaps exist that limit the interpretation and use of hair analysis in the assessment of environmental contaminants? No specific section on hair analysis is included in the Clinical Laboratory Improvement Act (CLIA), which was passed in 1988 to regulate clinical testing (Seidel et al. 2001). In addition, a federally approved proficiency testing reference laboratory or program for hair element/mineral analysis does not exist (Seidel et al. 2001). For all elements analyzed, no hair standards are certified for laboratories to validate their analytical technique (Seidel et al. 2001). As a result, verification methods and criteria for accuracy are left up to each laboratory (Seidel et al. 2001). Using this information, the panelists discussed a number of significant problems encountered in the laboratory methodology of hair analysis, including:

- Variations in hair sample scalp location and homogenization processes
- Variations in laboratory sample preparation and washing methods
- Variations in laboratory calibration standards, proficiency testing, and quality assurance/quality control (QA/QC) programs
- Unselective analytical approach of multielement analysis, which sacrifices accuracy and/or sensitivity for each specific element
- Intralaboratory variability in results and interpretations
- Interlaboratory variability in reference ranges, results, and interpretation.

The panelists agreed that laboratory methodologies and procedures should be standardized to help ensure more accurate and reliable results (this includes establishing consistent sampling protocols, washing protocols, QA/QC procedures, etc.).

Conclusions. Laboratory procedures for hair analysis should be standardized to help ensure more accurate and reliable results.

The panelists identified several other factors and data gaps that limit the interpretation of even the most accurate, reliable, and reproducible laboratory results, including:

a) The lack of reference (or background) ranges in which to frame the interpretation of results. To help assessors interpret whether detected levels are elevated as a result of environmental releases, they need a better understanding of geographical or regional differences in background levels in the absence of environmental exposures.

b) Difficulties in distinguishing endogenous (internal) from exogenous (external) contamination in hair. This distinction is important in evaluating internal doses of the substance of interest. The panelists expressed different viewpoints on the effectiveness of washing hair before analysis to eliminate external contamination. Identifying metabolites (or other unique markers of internal exposure) for substances of interest would be most helpful in distinguishing internal from external contamination. Because exposure to methyl mercury is only through diet—eating contaminated fish—and not by external sources, this contaminant was identified by the panel as a unique substance that could be reliably interpreted through hair analysis as to source and internal dose, assuming the samples are properly handled and analyzed.

c) Incomplete understanding of how and to what extent environmental contaminants are incorporated into the hair. Establishing the biologic plausibility of uptake of the substance of concern is critical when determining the utility of hair analysis.

d) The lack of correlation between levels in hair and blood and other target tissues, as well as the lack of epidemiologic data linking substance-specific hair levels with adverse health effects. Understanding these correlations is needed before hair analysis results can be used as a diagnostic tool or to predict health end points. The panel noted that hair analysis is not likely to serve a role in evaluating the more common health concerns associated with hazardous waste sites (e.g., cancer, birth defects).

e) Limited data on studying organic compounds in hair. The panel recommended exploring lessons learned about hair analysis from testing drugs of abuse.

Conclusions. *a*) In most environmental settings, with the exception of methyl mercury, hair analysis is not a reliable indicator of environmental exposure or internal body burden or a predictor of toxicity or disease. *b*) Hair analysis, if conducted, should be viewed only as a supportive tool and the results put into perspective with other more reliable data (e.g., blood and urine concentrations).

Recommendations

In moving forward, the group encouraged standardization of sampling protocols and identified possible research areas. Before hair analysis can be considered a valid tool for a particular substance, research is needed to establish standardized reference ranges, gain a better understanding of hair biology (variations of hair growth with age, gender, race, and ethnicity) and pharmacokinetics, further explore possible dose–response relationships, establish whether and when hair may serve as a better measure or predictor of disease than other biologic samples (e.g., blood or urine), and learn more about organic compounds in hair.

Summary

Although ATSDR did not seek a consensus from the panel, the panel developed the following summary statement:

> For most substances, insufficient data currently exist that would allow the prediction of a health effect from the concentration of the substance in hair. The presence of a substance in hair may indicate exposure (both internal and external), but does not necessarily indicate the source of exposure.

Universally, the panelists expressed concern about the misuse of hair analysis to justify and support unnecessary and unethical medical therapy. This view is consistent with the 1984 policy statement of the American Medical Association (AMA), which was reaffirmed in 1994 (AMA 1994). The AMA stated:

> The AMA opposes chemical analysis of the hair as a determinant of the need for medical therapy and supports informing the American public and appropriate governmental agencies of this unproven practice and its potential for health care fraud.

On the basis of these issues and concerns raised by the expert panel, ATSDR is proceeding in a careful manner to ensure that the best science will be used to provide trusted health information to concerned communities. ATSDR conducts public health activities at hundreds of sites a year and is frequently asked about the use of hair analysis to assess exposures or help interpret the results of tests individuals may have already had done. In these instances, there is a great opportunity and challenge to educate the community about the utility and limitations of hair analysis. ATSDR will proceed in the areas of education and applied research.

Education services. ATSDR plans to develop health education materials about what hair analysis can and cannot reveal about exposure to hazardous substances in the environment. These materials will be useful in communicating to the public the serious limitations of hair analysis at this time. In addition to the expert panel report posted on ATSDR's website, these educational materials could easily be added to the site. The consistent message will be that there is a serious absence of good science to support hair analyses, except for methyl mercury. These tests have limited use and cannot be used to validate exposure or predict health risks. Until there is a good science base and reliable laboratory tests, hair analysis for identifying environmental exposures in individuals should be discouraged, and the public needs to understand the test limitations.

Research activities. ATSDR encourages researchers to continue development of valid analytic techniques that can accurately measure specific hazardous substances in human hair. ATSDR is in a position to assist researchers in identifying exposed populations to study in real field settings. Applied research is needed to test new technology, establish reference ranges, understand pharmacokinetics, and explore time and dose relationships. ATSDR also encourages researchers to conduct studies that collect environmental and biologic samples on exposed and unexposed individuals to better interpret hair analysis findings and predict or determine adverse health outcomes. The science and utility of hair analysis can only advance through well-designed and conducted research.

References

AMA. 1994. Hair Analysis: A Potential for Abuse. Policy No. H-175.995. Chicago:American Medical Association.

ATSDR. 2001. Hair Analysis Panel Discussion: Exploring the State of the Science. Summary Report. Atlanta, GA:Agency for Toxic Substances and Disease Registry. Available: http://www.atsdr.cdc.gov/HAC/hair_analysis/ [accessed 12 February 2003].

Barrett S. 1985. Commercial hair analysis: science or scam? JAMA 254:1041–1045.

Bencko V. 1995. Use of human hair as a biomarker in the assessment of exposure to pollutants in occupational and environmental settings. Toxicology 101:29–39.

Esteban E, Rubin CH, Jones RL, Noonan G. 1999. Hair and blood as substrates for screening children for lead poisoning. Arch Environ Health 54(6): 436–440.

Fletcher DJ. 1982. Hair analysis – Proven and problematic applications. Postgrad Med 72:79–88.

Foo SC, Khoo NY, Heng A, Chua LH, Chia SE, Ong CN, et al. 1993. Metals in hair as biological indices for exposure. Int Arch Occup Environ Health 65:S83–S86.

Frisch M, Schwartz BS. 2002. The pitfalls of hair analysis for toxicants in clinical practice: three case reports. Environ Health Perspect 110:433–436.

Hammer DI, Finklea JF, Hendricks, RH, Shy, CM, Horton, RJM. 1971. Hair trace metal levels and environmental exposure. Am J Epidemiol 93:84–92.

Harkey MR. 1993. Anatomy and physiology of hair. Forensic Sci Int 63:9–18.

Hindmarsh JT. 2002. Caveats in hair analysis in chronic arsenic poisoning. Clin Biochem 35:1–11.

Hopps H. 1977. The biologic bases for using hair and nail analyses for trace elements. Sci Total Environ 7:71–89.

Manson P, Zlotkin S. 1985. Hair analysis: a critical review. Can Med Assoc J 133:186–188.

Miekeley N, Dias Carneiro MTW, Porta da Silveira CL. 1998. How reliable are human hair reference intervals for trace elements? Sci Total Environ 218:9–17.

Seidel S, Kreutzer R, Smith D, McNeel S, Gilliss D. 2001. Assessment of commercial laboratories performing hair mineral analysis. JAMA 285:67–72.

Sky-Peck HH. 1990. Distribution of trace elements in human hair. Clin Physiol Biochem 8(2): 70–80.

Steindel SJ, Howanitz PJ. 2001. The uncertainty of hair analysis for trace metals [Editorial]. JAMA 285(1):83–85.

Taylor A. 1986. Usefulness of measurements of trace elements in hair. Ann Clin Biochem 23:364–378.

Valente D, Cassini M, Pigliapochi M, Vansetti G. 1981. Hair as the sample in assessing morphine and cocaine addiction [Letter]. Clin Chem 27:1952–1953.

Wennig R. 2000. Potential problems with the interpretation of hair analysis results. Forensic Sci Int 107(1–3):5–12.

Yoshinaga J, Imai H, Nakazawa M, Suzuki T, Morita M. 1990. Lack of significantly positive correlations between elemental concentrations in hair and organs. Sci Total Environ 99:125–135.