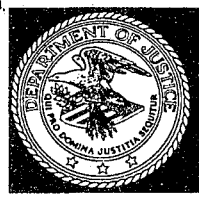
U.S. Department of Justice
Office of Justice Programs
National Institute of Justice



National Institute of Justice
Research in Brief

Michael J. Russell, Acting Director

October 1993

Developing Drug Testing by Hair Analysis

by Bernard A. Gropper, Ph.D., and Judy A. Reardon, Ph.D.

The link between drug use and crime is one of the most compelling arguments for drug testing. There is indisputable evidence that use of illegal drugs is far greater among the offender population than among the general population and that offenders who are drug-positive are more likely to commit further crimes than those who are not. The National Institute of Justice's (NIJ's) Drug Use Forecasting (DUF) program, which measures drug use among samples of booked arrestees in 24 jurisdictions, confirms this widespread use. Findings for 1992 showed that the percentage of arrestees who tested positive for any drug ranged as high as 78 for males and 85 for females.[1]

In the criminal justice system, drug testing is used to monitor compliance with the requirements of treatment programs. It can also supply criminal justice professionals with information needed to decide the disposition of drug-using offenders and with data to assess the prevalence of drug use among suspects and offenders. Drug testing also has deterrent power, as proven by the experience of the military, where testing helped to reduce use.[2]

Drug testing in the criminal justice system has expanded during the past several years with increased recognition of the link between drugs and crime and with the growth of the drug problem. The development of accurate, relatively inexpensive, and more readily available testing methods has also played a role in the increased use of testing.

Status of drug testing methods

In the past three decades, the most extensively employed source of data on drug use has been interviews with individuals ("self-reporting"). Urinalysis screening, now the most commonly employed testing technique, is the method used in the DUF program to confirm self-reporting. (Screening tests are normally followed by a confirmation test that uses another method of analysis, especially if the urine test results are used for disciplinary action.) The widespread adoption of urinalysis has been driven in part by its accuracy and low cost compared to some other testing methods, as well as by the availability of standardized technology.

Approximately 10 years ago, the National Institute of Justice (NIJ) began to sponsor research in drug testing among arrestees. The extent of drug use revealed through the early studies took both the research and criminal justice communities by surprise. The testing method, urinalysis, identified many more drug users than did self-reporting. Such a large discrepancy had not been anticipated, and it was even more startling in view of the fact that the true incidence may have been still higher. This is because for most substances the narrow "window" of detectability available through urinalysis reveals drug use in only the 2 or 3 days before testing.

These findings prompted NIJ to establish the Drug Use Forecasting (DUF) program. Begun in 1987, DUF uses urinalysis to test booked arrestees at 24 sites nationwide and has become a major indicator of drug use in this population. The DUF findings are valuable indicators not only of the extent of use, but also of trends in use—they can reveal changes in amount and types of drugs used and identify emerging use patterns.

In a search for methods that overcome some of the limitations of urinalysis, NIJ began to sponsor pioneering studies of hair testing to detect drug use. The first such project, begun in 1986, was an exploratory study that compared the results of hair testing and urinalysis among probationers and parolees in Los Angeles.

This Research in Brief reports on the progress of NIJ research since then in establishing the validity of hair testing technology and its application by criminal justice agencies. NIJ's 5-year plan for developing the capabilities of hair testing includes supporting the ongoing epidemiological studies, developing laboratory procedures and standards, and establishing the acceptability of hair test results as evidence in court. Much of this research is being conducted by NIJ in collaboration with the National Institute on Drug Abuse.

Because hair analysis and urine testing address different time windows of illicit drug use, hair testing should not be expected to replace urine testing, but it offers exciting possibilities as a supplementary technique. Since hair testing detects exposure over prolonged periods of use, it can also be done less frequently than urinalysis and could potentially reduce program costs. These advantages would make hair testing a valuable part of drug treatment for arrestees, providing the information the criminal justice system needs to place offenders in treatment programs and monitor compliance with program requirements.

Michael J. Russell
Acting Director
National Institute of Justice

Hair analysis, by contrast, has been in development for slightly more than a decade. The status of hair test findings as legally admissible evidence is still uncertain, although they have been accepted in some jurisdictions.[3] (See "Hair Testing in the Courts.")

Criminal justice system applications of hair testing have thus far been largely exploratory. In part because the methods are so new, they are not yet routinely used by any criminal justice agency, although a few agencies at the State and local levels have begun to use them, either in research or in operations.

In at least three States—Massachusetts, Ohio, and New Jersey—hair testing is used in correctional settings. For example, a program in Trenton, New Jersey, uses hair analysis on offenders in intensive supervision probation. Officers use hair analysis selectively, usually when they believe that a negative result of urinalysis is incorrect, when an offender challenges the results of urinalysis, or when the officer believes the offender has violated conditions of probation by using drugs despite having recently passed urine tests.

Hair Testing in the Courts

The results of hair testing have been found reliable and acceptable as corroborative evidence of drug use in a number of court rulings.

Probation conditions

A case brought before the U.S. District Court in Brooklyn, New York, involved a defendant who pleaded guilty in 1988 to violation of the narcotics laws. He was sentenced to 5 years' probation, and as a condition of probation was required to refrain from using narcotics. The following year, in a routinely administered drug urinalysis, he tested positive for cocaine, admitted using it, and was ordered to participate in a treatment program.

At a hearing on subsequent probation violations, the probationer indicated that he had not used drugs for several months. The court ordered a hair test to determine whether the conditions of probation had in fact been violated. Test results were positive for cocaine.

Concluding that "radioimmunoassay is an effective and accurate method of detecting the presence of various compounds including narcotics," the court accepted the results of the hair analysis report as partial proof that the probationer had violated the conditions of probation.

U.S. v. *Medina*, 749 F. Supp. 59 (E.D.N.Y. 1990).

The workplace

Hair analysis was ruled acceptable as part of an employee substance abuse policy in a 1990 court ruling in the State of Nevada.

The substance abuse policy for employees of Harrah's Lake Tahoe Resort Casino was challenged in court as a violation of the right to privacy. The policy included a RIAH test to screen for use of illicit drugs, although the findings of hair analysis alone were not used by the company as the basis for a decision to terminate an employee. If the results of the hair test were found to be positive, a confirmatory GC/MS test was administered. Employees who tested positive by GC/MS but denied they used drugs were required to undergo unannounced urine tests for the next 60 days. If any of these tests were found to be positive, the GC/MS method was used to confirm the finding. Only if that test proved positive was the employee terminated for violation of company policy.

The Ninth Judicial Court of Nevada ruled that hair testing alone was insufficient to form the basis for termination, but that Harrah's substance abuse policy, which included hair testing, was "valid, reasonable, fair and lawful ... and not violative of any constitutionally protected right." The court stated further that the policy "does not constitute an unlawful invasion of privacy."

Koch v. *Harrah's Club*, No. 23740 (9th Dist. Ct. Nev. Sept. 12, 1990).

Hair and urine as testing mediums

The analytic techniques used to detect drugs in hair are basically similar to those used for urinalysis. (See "Testing Technologies.") Here, however, the resemblance between the two techniques ends. Each method monitors different effects or indicators of drugs on the body: urinalysis detects short-term metabolic effects, while hair analysis detects long-term organic effects.[4]

Thus, hair analysis offers an important advantage. To understand this advantage, it is necessary to compare what happens when a drug is absorbed by the hair to what happens when it enters the urine. Although knowledge of the mechanisms by which drugs are incorporated into hair is still in the developmental stage, it is known that growing hair absorbs drugs and their metabolites (the products of the body's breakdown of a substance through metabolism) from the circulating blood into the structure of the hair shaft. Once a drug enters the hair shaft, it remains there almost permanently.[5]

As hair grows, it produces a "history" of an individual's drug use, with each 1/2-inch of growth from the scalp line reflecting drug use in approximately the past month. Thus, a strand of hair 2 inches long could reveal use over a 4-month period.

The retentive power of hair means that, through hair analysis, drugs can be detected long after ingestion. The use of arsenic by Napoleon was indicated by analysis of hair specimens taken from him just after he died and analyzed more than 100 years later.[6]

In contrast to hair analysis, urinalysis is useful for only a short period, after which drugs can no longer be detected in urine. Urine lacks the capacity for long-term retention because the body rapidly excretes substances through the kidneys. Opiates and cocaine, for example, are water soluble and thus are almost totally eliminated from urine after 2 to 3 days. Other drugs such as marijuana and PCP that are fat soluble are retained longer and may be detectable in urine for as long as 2 to 3 weeks.

Hair's wider "window" of detectability—its retention of drugs long after use—constitutes its greatest strength as a test method. Hair testing also has a number of additional advantages:

- Because the samples are obtained from the scalp, it is not as intrusive as obtaining specimens for urinalysis.
- The opportunity for adulteration or sample switching is much lower.
- Lost or contaminated samples can be easily replaced.
- Hair is inert, easy to handle, requires no special storage arrangements, and presents fewer risks of disease transmission.

Despite all these advantages, hair analysis has certain drawbacks. For one thing, it is more expensive than urinalysis; for another, the analytic process is more time consuming. Hair also cannot compete with urinalysis in revealing very recent drug use. Its comparatively slow growth rate means that drugs do not become detectable in the hair visible above the scalp for several days after ingestion, while drugs are much more rapidly detectable in urine—about 1/2 hour after ingestion.

Emerging issues in hair testing. Hair analysis has a number of unknowns, some of which involve establishing its utility and determining how it will be applied to obtain information about drug use. Among questions to be explored are:

- Is environmental contamination of hair (the entry of drugs through smoke, for example) significant, and can current testing procedures distinguish between exposure and use?
- Can detection of drugs be evaded through hair treatments (for example, shampoos and conditioners)?
- Do some hair types retain drugs more than others? (Does thicker hair, for example, retain more than thinner hair?)
- To what extent can drugs enter hair through sweat or other nonblood routes; how does this affect the distribution of the drug along the length of the hair shaft and associated time profiles?
- How long does it take for a drug to appear in the hair? Do the absorption rates of various drugs differ?

Testing Technologies

The technologies used in testing for drugs of abuse are generally the same for hair as for urine—immunoassay and chromatography.[7] For both these methods, the hair is first treated to extract and concentrate the drug-related materials in a solution, which is then chemically analyzed much as a urine sample would be.

Immunoassay

This type of test uses antibodies to detect the presence or absence of drugs in a urine sample or in a solution made from hair. An antibody is a protein that reacts only in the presence of a specific substance (the antigen) or group of chemically similar substances. In testing for drugs, a label or "tag," which can be identified and measured after the reaction of the antigen with the antibody, is mixed with the drug being tested (the tagged antigen). Commonly used tags include radioactive materials (as in radioimmunoassay—RIA and RIAH), enzymes (as in enzyme-multiplied immunoassay test—EMIT™), or fluorescent materials that glow (as in fluorescent polarization immunoassay—FPIA).

The tagged antigen, the dissolved hair shaft that may contain the drug in question (the untagged antigen), and the antibodies are mixed. Mixing causes the tagged and untagged antigens to compete to react and bond with the antibodies. The amount of unbonded tag that remains is then compared with a known quantity of the drug being tested. If the amount in the sample specimen is higher than or equal to the known quantity, the test is considered positive; if lower, it is considered negative.

Gas chromatography/mass spectrometry (GC/MS)

In this process, a nonreactive gas (one that will not react chemically with the substance tested) sends the test solution to a special tube that is part of the chromatograph instrument. Here the solution is separated into its component chemicals to form a fragmentation spectrum. The components exit the column and enter a detector—the mass spectrometer—which identifies the substance and measures the amount of the drug present. The mass spectrum "signature" is specific to a given substance.

How tests differ

For large-scale applications, testing methods that are relatively cheap, fast, and simple are preferable. Depending on the drug being tested for, the tests may also vary in degree of sensitivity. Tests may also vary in their specificity; that is, their ability to react to the drug being tested for or its metabolite rather than to a group of chemically similar substances.

Screening versus confirmation tests

In some cases, when an initial (screening) test indicates the presence of a drug, a second test may be performed on the same specimen to confirm the initial results. The second, confirmatory, test is generally a different type. For example, GC/MS may be used to confirm RIA results. In addition, the second test should be equal to or greater than the first in being able to specify the targeted drug and in ensuring that the result is not a reaction to other similar substances.

GC/MS is generally considered the most accurate standard method. However, compared to immunoassay, it is expensive, complex, and time consuming and, therefore, is typically used as a confirmatory method rather than as an initial screening test.

Future methods

In the future, methods that are now being explored only on a limited, experimental basis may come into wider operational use. One such method dispenses with the need to prepare a solution of the hair and instead tests the vapors produced when the solid hair shaft is heated. Although the chemical composition of such vaporized hair may be different from that of the solution, the test would be useful as long as the results remain distinct for the targeted drug. This method would be faster, as it would eliminate the time needed to dissolve the hair in a solution.

- To what extent is the concentration in the hair related to the amount of drug taken? How does the concentration vary for different drugs?

The need for standardization. Standards have not yet been established for hair analysis that would place it on a par with urinalysis for widespread application by the criminal justice system—either in decisionmaking or as evidence. For example, standards must be established for specifying the amount of hair and the part of the scalp from which to take a sample, for determining how close to the scalp the sample should be cut, for mounting specimens, and for avoiding contamination in handling the specimens.

NIJ support of hair testing research

Common interests in developing drug testing methods and applications have led to a close partnership between NIJ and the National Institute on Drug Abuse (NIDA), an agency of the U.S. Department of Health and Human Services. The two agencies are working together to develop scientifically valid and accurate procedures for hair analysis as a method to supplement urinalysis.[8] NIJ, directing its efforts to applied research, will benefit from the basic research that is the purview of NIDA. Joint efforts may include coordinated planning, information sharing, and cosponsored research.

Goals and strategy. Because of its potential to complement urine testing and its advantages for certain applications, hair testing has been the subject of considerable interest. NIJ has developed a 5-year plan for making these emerging capabilities available for criminal justice application through research and development in three complementary areas:

- Technological issues, which focus on hair testing methods and standards, including development of techniques for the extraction and analysis of drug-related information from hair.

- Scientific and interpretive issues, which focus on the use of hair as a test medium and its acceptability as evidence.

- Program development and evaluation research, which focus on potential applications of hair testing in actual operational criminal justice settings.[9]

In addition to sponsoring and collaborating in research in these areas, NIJ has also established research and information links with other major organizations conducting related research, including the American Academy of Forensic Sciences and the Society of Forensic Toxicology.

Recent studies conducted in criminal justice agencies have compared the merits of hair analysis to other methods of drug detection when used with arrestees.

Arrestees in Pinellas County. One of Florida's most highly urbanized and densely populated counties was the site of one such study. The Pinellas County (Tampa and St. Petersburg) study generated the first data comparing state-of-the-art urinalysis techniques and hair analysis in identifying drug use among arrestees in a criminal justice program. Self-reporting was also studied.

The researchers found that both hair testing and urinalysis were superior to users' self-reports in that they produced a larger number of drug-positive results. The outcome was consistent with the recent literature, in which patterns of arrestee underreporting of drug use are commonly cited.

A more significant finding was that hair testing consistently yielded a larger number of positive results than urinalysis. Forty-seven percent of the subjects tested positive for opiates and cocaine by hair analysis, while only 20 percent tested positive by urinalysis. Of the 256 samples tested by both methods, 88 were found to be positive by hair analysis but negative by urinalysis. (See exhibit 1.) A confirmatory test using the gas chromatography/mass spectrometry (GC/MS) method (see page 3, "Testing Technologies") was performed on 9 of the 88 samples. All nine were found to contain cocaine.

The Pinellas study furnishes evidence of the wider window of detectability available through hair analysis. Since the 1/2-inch hair segments effectively reported cocaine use for the previous month, while the narrower window of the urine samples covered only the previous 2 to 3 days, some infrequent users missed by urine testing were identified by the hair test. For infrequent and low-level users, hair analysis identified about 10 times as many drug users as did urinalysis. (When cocaine use was at frequent and high levels, urinalysis and hair analysis became equally effective, a finding that makes sense intuitively because extremely frequent and intense use should be easily detectable by either method.[10])

In a followup project, a pilot program is under way to conduct hair testing among probationers in a Florida State correctional agency. The testing protocol will be integrated into the agency's daily routine in an attempt to find out how feasible it is, what management and administrative difficulties may arise, and what effects there might be on workload and normal work procedures. Some cost-benefit analysis will also be conducted. Test results will be compared to those from the agency's current urine-based testing system.

Juvenile arrestees in Cleveland. A similar comparison among hair analysis, urine testing, and self-reports was conducted in Cleveland, Ohio, in conjunction with NIJ's DUF program. This study was unique in at least two respects: it expanded on DUF's practice of using only urinalysis and self-

Exhibit 1. **Comparison of Urine and Hair Test Results for Opiates and Cocaine (n = 256)**

Urine results by FPIA and EMIT™	Hair test results	
	(+)	(-)
Both positive (+)	40	6
Both negative (-)	88	113
One positive (+) and one negative (-)	7	2

Source: Tom Mieczkowski, Harvey J. Landress, Richard Newel, and Shirley D. Coletti. *Testing Hair for Illicit Drug Use*, National Institute of Justice Research in Brief, January 1993.

report among arrestees, and it may be the first study of its kind to use the three detection methods among juvenile arrestees.

In the interview (self-reporting) phase, the subjects were asked about their drug history during the previous 3 months. Urine specimens were taken and analyzed for evidence of recent use of 10 different drugs. Although the hair samples were tested for five drugs, the researchers focused on cocaine in their analysis. (Data previously gathered indicated that, in Cleveland, cocaine is used more often by juvenile arrestees than any other drug.)

The study provided further evidence of the importance of obtaining a longer historical record of drug use rather than recent use only. Of the 88 juveniles tested for cocaine, 8 percent (n = 7) had positive urine test results, but 56.8 percent (n = 50) tested positive by hair analysis. Only 7.4 percent (n = 6) reported they had ever used cocaine. The period of detection measured by hair analysis covered approximately 3 months prior to the sample collection.[1]

Project on laboratory practices. Establishing laboratory methods and standards for hair testing is the objective of a multiyear study being conducted by the National Institute of Standards and Technology (NIST). Part of the collaborative effort between NIDA and NIJ, the project involves a study of cocaine and heroin. In the first phase, 10 laboratories, set up as a panel, are evaluating the specificity and sensitivity of the methods used at each laboratory to wash, extract, and analyze hair samples. (Specificity refers to the ability of a given method to identify a single-chemical component in a mixture; sensitivity refers to the ability to detect a minimum concentration of a drug.)

Using controlled samples of hair containing calibrated amounts of target drugs (cocaine, heroin, and blank controls), the researchers are developing techniques for preparing standardized test materials and evaluating currently used testing procedures—GC/MS and immunoassay. They are also studying a number of issues involving hair as evidence, including the differences among hair types and environmental exposure of hair samples.

Study of drug absorption mechanism. The scientific bases of hair testing are being explored in a project under way at the University of California at Davis. This study, which focuses on cocaine, is addressing questions about the mechanisms by which drugs are absorbed into hair and other issues related to the value of hair test results as evidence. Among the research questions are:

- Is the amount of the drug (or its metabolites) found in hair related to the amount ingested?
- What is the time lag between drug ingestion and its appearance in hair?
- Is it possible to distinguish between drugs ingested and drugs that show up in the hair through external exposure? (For instance, if a drug user puts a sweaty hand on a nondrug user's hair, the nondrug user's hair may test positive.)
- Can externally applied drugs be removed from the hair by washing or other means?

On the basis of answers discovered, it may be possible to draw inferences about drug use. For example, if the answer to the first question is yes, it may mean there is a way to identify heavy users through hair analysis that is not possible through other means.

The issue of contamination may well be a double-edged sword for the criminal justice system. If hair can be contaminated by drugs applied externally, arrestees who test positive by hair analysis may deny, perhaps rightfully, that they ingested the drug. On the other hand, if drugs externally applied (for example, while making illegal substances in a clandestine lab) are found to be difficult to remove, offenders may be unable to conceal drug involvement.

With the study still under way, results are preliminary. NIDA is considering expanding the initial study to assess possible differences in hair types that should be taken into account in sample acquisition and handling, or establishing criteria ("cutoff levels") for determining whether a result is positive or negative.

Orleans Parish Diversionary Program

NIJ is currently sponsoring a diversionary program for first-time drug offenders by the Orleans Parish (Louisiana) District Attorney's Office, using both hair and urine testing. This pilot project will develop, implement, and evaluate a 6-month diversionary prosecution program for persons charged with first-time, nonviolent drug possession. Offenders who agree to take part in the program are enrolled for 6 months; charges are dropped for those participants who successfully complete the program. Failure to complete the program results in prosecution on the original charge.

Intended to provide effective intervention between initial drug use and its growth into continued criminal activity, this demonstration program is employing a comprehensive approach involving urinalysis, hair testing, and outpatient drug treatment, and represents a major innovation in determining and controlling offender drug use.

The need for continuing study

No single drug testing method is optimal for all information and decisionmaking needs in the criminal justice system. The availability of alternative testing techniques with complementary capabilities can strengthen detection and control of drug use and its consequences. For this reason, NIJ will continue to support research toward the development of rigorous standards that establish the scientific validity of hair testing and toward its adoption in criminal justice settings. (See "Orleans Parish Diversionary Program.")

The NIJ-sponsored study of arrestees in Pinellas County offers evidence that hair analysis permits a longer retrospective evaluation of drug exposure than does urinalysis. This finding, in turn, suggests that because urinalysis detects only very recent use, dependence on it alone may risk underestimating the scope of the need for education, treatment, or other intervention. Hair analysis shows promise as a method useful in identifying patterns of long-term drug abuse. The next phase of NIJ's 5-year strategy will extend the initial focus on cocaine and heroin to other major drugs.

Notes

1. Bureau of Justice Statistics, *Report to the Nation on Crime and Justice, Second Edition*, 1988, p. 50; National Institute of Justice, *Drug*

Use Forecasting (DUF) 1992 Annual Report, forthcoming.

2. Eric D. Wish and Bernard A. Gropper, "Drug testing by the criminal justice system: Methods, research, and applications," in *Drugs and Crime*, vol. 13, ed. Michael Tonry and James Q. Wilson. Chicago: University of Chicago Press, 1990, pp. 330–331.

3. Martha R. Harkey and Gary L. Henderson, "Hair analysis for drugs of abuse," *Advances in Analytic Technology*, vol. 2. Foster City, California: Biomedical Publications, 1989, p. 324.

4. *NIJ Reports*, March/April 1987, p. 5.

5. Harkey and Henderson, pp. 306, 307; Tom Mieczkowski et al., *Testing Hair for Illicit Drug Use*," National Institute of Justice Research in Brief, January 1993.

6. H. Smith, S. Forshufvud, and A. Wassen, "Distribution of arsenic in Napoleon's hair," *Nature*, vol. 194 (April 7, 1962, to June 30, 1962), pp. 725–26.

7. For a fuller discussion and comparison of testing technologies, see Wish and Gropper, "Drug testing," in *Drugs and Crime*, pp. 336–348.

8. Bernard A. Gropper, "Hair analysis for drug testing: National Institute of Justice–National Institute on Drug Abuse Collaboration," report to the Community Epidemiology Work Group, December 1991, pp. 463, 467.

9. National Institute of Justice *Research and Evaluation Plan, 1992*, p. 99.

10. Mieczkowski et al.

11. Thomas E. Feucht, Richard C. Stephens, and Michael L. Walker. "Drug Use Among Juvenile Arrestees: A Comparison of Self-Report, Urinalysis, and Hair Assay." Unpublished report, National Institute of Justice, 1992. (Grant 91–IJ–CX–0014)

Bernard A. Gropper, Ph.D., former manager of the National Institute of Justice's research program on drugs, alcohol, and crime, helped set up and develop the NIJ research program on drug testing by hair analysis. He now teaches and conducts research in related issues in the Department of Criminal Justice and Legal Studies at the University of Central Florida.

Judy A. Reardon, Ph.D., is a senior writer and editor with NIJ's National Criminal Justice Reference Service.

This report is an updated version of an article that appeared in the April 1993 issue of the *National Institute of Justice Journal.*

The National Institute of Justice is a component of the Office of Justice Programs, which also includes the Bureau of Justice Assistance, Bureau of Justice Statistics, Office of Juvenile Justice and Delinquency Prevention, and the Office for Victims of Crime.

NCJ 143456

U.S. Department of Justice
Office of Justice Programs
National Institute of Justice

Washington, D.C. 20531

Official Business
Penalty for Private Use $300

BULK RATE
POSTAGE & FEES PAID
DOJ/NIJ
Permit No. G–91