

September 15, 2008

Psychemedics Corporation
Meeting with the Office of
Management and Budget
to discuss
SAMHSA Guidelines
Regarding Drug Testing

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Psychemedics Corporation: Overview

- World's largest provider of drug testing laboratory services using hair analysis
- FDA cleared tests
- College of American Pathologists and CLIA certified laboratory
- Public company listed on the American Stock Exchange
- Over 20 years of successfully serving corporate clients after founding in 1987
- Over 4000 corporate clients including over 10% of the Fortune 500, major transportation companies, major police departments and six Federal Reserve Banks.

NEWS RELEASE

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PSYCHEMEDICS CORPORATION RECEIVES FINAL FDA CLEARANCE

Cambridge, Massachusetts, May 6, 2002 – Psychemedics Corporation (AMEX: PMD) announced today it has received 510(K) clearance from the Food and Drug Administration (FDA) for its test for the detection of marijuana use through human hair analysis. Psychemedics has now received FDA clearance for the five drug panel routinely used in drug testing.

Psychemedics' marijuana test system employs radioimmunoassay for the qualitative screening and mass spectrometry for quantification of carboxy – THC in hair for the purpose of identifying marijuana use.

This completes three years of intense preparation for the FDA clearances. Psychemedics previously obtained FDA clearances for opiates, PCP, methamphetamine/ecstasy and cocaine.

“Obtaining FDA clearance for all five of our tests is a major milestone for our Company,” said Ray Kubacki CEO and President of Psychemedics. “The importance of using accurate and reliable testing cannot be overemphasized. Psychemedics is the only company to have any FDA cleared hair tests and we now have them in all the major drugs of abuse categories.”

Psychemedics Corporation is the world's leading laboratory for the testing of hair for the presence of drugs. Its client list includes over 2,200 corporations (over 10% of the Fortune 500), which use hair testing as part of their drug-free workplace programs. In addition, five of the country's largest police departments as well as schools and Federal Reserve Banks rely on Psychemedics' hair testing.

FOR IMMEDIATE RELEASE

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Psychemedics Awarded First CAP Accreditation for Drug Testing Including Hair

Acton, Massachusetts, September 9, 2008 - Psychemedics Corporation (AMEX: PMD) announced today that it has been awarded the first accreditation for forensic drug testing including drug testing with hair by the Commission on Laboratory Accreditation of the College of American Pathologists (CAP). The results were based on a recent on-site inspection of its facility that conducts drug testing.

The laboratory's director, Michael Schaffer, Ph.D., D.A.B.F.T., Vice President – Laboratory Operations, was advised of this national recognition and congratulated for the "excellence of the services being provided."

Psychemedics' dedicated laboratory is located in Culver City, California where hair samples from all over the world are processed. The laboratory is equipped with state-of-the-art instrumentation, which allows it to perform the most advanced drug screening services available.

"For over ten years we are proud to have accreditation by CAP for urine testing," said Raymond C. Kubacki, Chairman and Chief Executive Officer. "Just as Psychemedics was the first provider of drug testing with hair in the workplace, it is fitting that we should have our laboratory be the first certified by CAP specifically including hair testing."

According to CAP, the CAP Laboratory Accreditation Program, begun in the early 1960s, is recognized by the federal government as being equal to or more stringent than the government's own inspection program.

During the CAP accreditation process, inspectors examine the laboratory's records and quality control of procedures for the preceding two years. CAP inspectors also examine the entire staff's qualifications, the laboratory's equipment, facilities, safety program and record, as well as the overall management of the laboratory. This stringent inspection program is designed to specifically ensure the highest standard of care for the laboratory's customers.

About CAP - The College of American Pathologists is a medical society serving nearly 16,000 physician members and the laboratory community throughout the world. It is the world's largest association composed exclusively of pathologists and is widely considered the leader in laboratory quality assurance. The CAP is an advocate for high-quality and cost-effective medical care.

About Psychemedics – Psychemedics (Amex: PMD) is the world's largest provider of hair testing for drugs of abuse with thousands of corporations relying on the patented Psychemedics drug testing services. Psychemedics' clients include over 10% of the Fortune 500, some of the largest police departments in America and six Federal Reserve Banks. For more information, visit the Psychemedics website at www.drugtestwithhair.com.

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Proposed SAMHSA Guidelines for Workplace Drug Testing

Public interest concerns require that drug testing go beyond urine samples and that testing include hair, oral fluid, and sweat testing. The same solid science of an immunoassay screen and confirmation by GC/MS or similar technology that is used in urine drug testing is available in these alternative matrices. However, these new matrices offer useful additional information and go a long way toward solving many of the serious problems with urine drug testing (e.g. the poppy seed problem, cheating etc.).

Two Major Issues with Proposed Guidelines

1) *Preamble needs to either eliminate gratuitous mention of hair color as a “major concern” or include all recognized “major concerns” regarding urine.*

Although there is nothing mentioned in the actual Guidelines on this issue, the Preamble states that there are a number of factors that may influence the amount of drugs incorporated into hair and that the effect hair color may play on the incorporation of drugs into hair is a “major concern.” These claims obviously need to be reconsidered. There are an even greater number of factors that may influence the amount of drug incorporated into urine; among these are gender, body size, age, and activity levels.

More importantly, every study, including those cited in the Preamble, that compared hair with urine testing, found that hair results by color are identical to urine results, i.e.: the positive hair testing rates for dark haired persons are the same as the urine positive rates for dark haired persons. These studies with tens of thousands of data points indicate that either the Department of Health and Human Services should have a major concern with how urine results are affected by hair color – or have no concern for either matrix.

If factors that may influence the amount of drug incorporated into hair are a “major concern” for the Department, it follows that factors that influence the amount of drug incorporated into urine would have to be a “major concern” for urine. (If they are not, this would be a clear example of the Department continuing to hold hair testing to a higher standard than urine testing). Applying the same standard of accounting or normalizing for “factors” that might influence the amount of drug in a sample would have far-reaching negative effects on the urine-testing program. Likewise, breath tests would be negatively impacted if its cutoffs were changed to accommodate the effects of body size, metabolism rates, gender or age.

2) *Guidelines need to be head hair and body hair – not head hair only.*

Another area that indicates that different standards are being applied to hair testing is the Guideline’s limitation of hair collection to head hair only. Some of the largest corporations and police agencies in the country have been using hair testing for over fifteen (15) years and have included body hair collections (arm, leg, chest, underarm) for subjects without head hair.

The Guidelines state, however, that since other specimens are available, if there is no head hair, it seems more appropriate for privacy reasons, to simply collect a different type of specimen, rather than using body hair. The Guidelines still, however, allow for observed urine collection in certain circumstances. Section 8.5 (1A) even provides: "The agency shall select the observer if there is no collectors of the same gender available."

If the privacy concerns expressed by the Department regarding hair collections were applied consistently to urine collections, there would be no observed urine collections since a different sample, hair for instance, could easily be collected instead. In light of the apparent lack of concern for privacy when observed urine is collected, coupled with the fact that the Guidelines allow for sweat patches to be applied to donor's arms, back or chest, it appears that the Department's privacy concerns for arm and leg hair collections are inconsistent.

Conclusion

The incongruous nature of these two issues alone could lead a reasonable person to conclude that a higher standard is still being applied to hair testing than is applied to urine testing. After all these years and the private sector's extraordinarily successful experience with millions of hair tests, we hope this is not the case. Therefore, if these guidelines are to be fair and effective, the Final Guidelines must omit any reference in the Preamble to hair color as a "major concern"; and they must include head and body hair.

accordance with the objectives of these procedures.

Section 4.13 Administrative Record

The administrative record of review consists of the review file; other submissions by the parties; transcripts or other records of any meetings, conference calls, or oral presentation; evidence submitted at the oral presentation; and orders and other documents issued by the reviewing and presiding officials.

Section 4.14 Written Decision

(a) *Issuance of Decision.* The reviewing official shall issue a written decision upholding or denying the suspension or proposed revocation. The decision will set forth the reasons for the decision and describe the basis therefor in the record. Furthermore, the reviewing official may remand the matter to the respondent for such further action as the reviewing official deems appropriate.

(b) *Date of Decision.* The reviewing official will attempt to issue his or her decision within 15 days of the date of the oral presentation, the date on which the transcript is received, or the date of the last submission by either party, whichever is later. If there is no oral presentation, the decision will normally be issued within 15 days of the date of receipt of the last reply brief. Once issued, the reviewing official will immediately communicate the decision to each party.

(c) *Public Notice.* If the suspension and proposed revocation are upheld, the revocation will become effective immediately and the public will be notified by publication of a notice in the **Federal Register**. If the suspension and proposed revocation are denied, the revocation will not take effect and the suspension will be lifted immediately. Public notice will be given by publication in the **Federal Register**.

Section 4.15 Court Review of Final Administrative Action; Exhaustion of Administrative Remedies

Before any legal action is filed in court challenging the suspension or proposed revocation, respondent shall exhaust administrative remedies provided under this subpart, unless otherwise provided by Federal Law. The reviewing official's decision, under section 4.9(e) or 4.14(a), constitutes final agency action and is ripe for judicial review as of the date of the decision.

[FR Doc. 04-7985 Filed 4-6-04; 12:39 pm]

BILLING CODE 4162-20-P

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Substance Abuse and Mental Health Services Administration

Proposed Revisions to Mandatory Guidelines for Federal Workplace Drug Testing Programs

AGENCY: Substance Abuse and Mental Health Services Administration, HHS.
ACTION: Notice of proposed revisions to mandatory guidelines.

SUMMARY: The Department of Health and Human Services ("HHS" or "Department") is proposing to establish scientific and technical guidelines for the testing of hair, sweat, and oral fluid specimens in addition to urine specimens; scientific and technical guidelines for using on-site tests to test urine and oral fluid at the collection site; requirements for the certification of instrumented initial test facilities; and added standards for collectors, on-site testers, and medical review officers.

DATES: Submit comments on or before July 12, 2004.

ADDRESSES: You may submit comments, identified by (insert docket number and/or RIN number), by any of the following methods:

- E-mail: wvogt@samhsa.gov. Include docket number and/or RIN number in the subject line of the message.
- Fax: 301-443-3031
- Mail: 5600 Fishers Lane, Rockwall II, Suite 815, Rockville, Maryland 20857.
- Hand Delivery/Courier: 5515 Security Lane, Suite 815, Rockville, Maryland 20852.

• Information Collection Requirements: Submit comments to the Office of Information and Regulatory Affairs, OMB, New Executive Office Building, 725 17th Street, NW., Washington, DC 20502, Attn: Desk Officer for SAMHSA. Because of delays in receipt of mail, comments may also be sent to 202-395-6974 (fax).

Instructions: All submissions received must include the agency name and docket number or Regulatory Information Number (RIN) for this rulemaking. All comments will be available for public review at 5515 Security Lane, Suite 815, Rockville, Maryland 20852.

FOR FURTHER INFORMATION CONTACT: Walter F. Vogt, Ph.D., Drug Testing Section, Division of Workplace Programs, CSAP, 5600 Fishers Lane, Rockwall II, Suite 815, Rockville, Maryland 20857, 301-443-6014 (voice), 301-443-3031 (fax), wvogt@samhsa.gov (e-mail).

SUPPLEMENTARY INFORMATION:

Background

The Mandatory Guidelines for Federal Workplace Drug Testing Programs (Guidelines) were first published in the **Federal Register** on April 11, 1988 (53 FR 11970), and have since been revised in the **Federal Register** on June 9, 1994 (59 FR 29908), and on September 30, 1997 (62 FR 51118). The Guidelines establish the scientific and technical guidelines for Federal workplace drug testing programs and establish standards for certification of laboratories engaged in urine drug testing for Federal agencies under authority of Pub. L. 100-71, 5 U.S.C. section 7301 note, and E.O. 12564.

In developing and organizing the proposed revisions to the Guidelines, there are a number of issues presented in this preamble, that include the rationale for the order and manner of presentation of what is proposed and why. These issues are first presented by general topic area, and later presented in summary, as they appear in the text of the proposed Guidelines.

History of the HHS Certification Program for Federal Employee Drug Testing Programs, and Related Knowledge

Since the beginning of the program in 1988, many challenges have been overcome and lessons learned from the specific and rigorous HHS certification of laboratories to perform forensic workplace testing for job applicants and Executive Branch Federal employees.

The initial Guidelines were published for a 60-day public comment period, and were first published as a final notice in the **Federal Register** in April of 1988. Originally, it was believed that fewer than 10 laboratories would apply for HHS certification under the Guidelines to conduct Federal employee drug testing, and that the Department would not require even that many to test the urine specimens from all Federal agencies.

This situation changed very quickly when the Department of Transportation (DOT) published a final drug testing rule (54 FR 49854) in December 1989 for its regulated transportation industries. DOT required its regulated industries to use drug testing laboratories that were certified by HHS. This requirement began a close relationship between HHS and DOT. Additionally, the Nuclear Regulatory Commission (NRC) in its Fitness for Duty program contained in 10 CFR Part 26 requires its licensees to use drug testing laboratories certified by HHS.

As the Guidelines received both public and judicial support, the private sector chose to incorporate the requirement to use only a laboratory that has HHS certification under the Guidelines, for employee drug testing. Between July 1988 and early 1990, 50 laboratories had received HHS certification under the Guidelines, while another 100 laboratories were awaiting certification.

In developing the preamble for the proposed expansion and revision of the Guidelines, it has been very helpful to keep in sight important areas of consideration that have remained visible as the program matured over the ensuing fifteen years. These include, but are not limited to, custody and control that ensures donor specimen identity and integrity, specimen collection procedures, analytical testing methods, quality control and quality assurance, reporting results, the role of the medical review officer (MRO), and HHS certification issues that include testing site inspections and performance testing (PT) samples.

The Department has remained committed to maintaining the integrity of the entire Drug-Free Federal Workplace Program by identifying and using the most accurate, reliable drug testing technology available. To accomplish that goal, the Department collaborates with the DOT, NRC, Federal regulators, researchers, the testing industry, and both public and private sector employers on an on-going basis on scientific and program matters. As the number and types of commercial workplace drug testing products and testing options have increased over the past decade, the Department, through SAMHSA's Drug Testing Advisory Board (DTAB), has expressed increasing interest in assessing these new products and procedures for possible use in Federal agency employee testing programs.

Laboratory-based testing using automated screening tests at instrumented initial test facilities (ITFs) was proposed by the same group of individuals that developed the Guidelines as an area of interest immediately after the Guidelines were first published in 1988. At that time, the industries regulated by the NRC began using this approach as part of their Fitness for Duty programs to allow job applicants access to nuclear power plants. A study of 10 sites (including both NRC licensee and other private sector sites) was conducted where such an ITF was used. Point of collection test (POCT) devices were also being developed, but with non-instrumented, visually read end-points. By 1997, the

Department began, as discussed below, a dedicated assessment of drug testing using alternative specimens and drug testing technologies, including head hair, oral fluid (saliva), and sweat, for possible application in Federal workplace drug testing programs.

The Added Specimens—Major Change

The Department proposes to expand the kinds of specimens that may be tested under Federal agency workplace drug testing programs. The proposed addition of head hair, oral fluid, and sweat specimens are the result of a directed Department process that began with a 3-day scientific meeting of the DTAB held in April 1997 to discuss drug testing of alternative specimens and using new testing technologies as they apply to workplace drug testing programs. The entire meeting was open to the public. The first two days consisted of presentations on the principles and criteria of workplace drug testing program requirements and industry representatives discussing alternative specimens (hair, oral fluid, sweat as well as urine) and technologies (non-instrument based on-site tests). The presentations focused on the following areas for each specimen/technology: specimen collection and chain of custody, initial test reagents and procedures, confirmatory test procedures, internal quality control program, reporting test results, interpreting test results, and external quality assurance program. Industry coordinators selected the presenters for the alternative specimens and technologies to ensure a thoroughly unbiased review based on the science available. On the third day, the public was given an opportunity to make official statements or comments.

Following this meeting, the DTAB members continued reviewing the large amount of information presented at the meeting. Their efforts resulted in the identification of specific requirements necessary for the scientific, administrative, and procedural integrity of a comprehensive workplace drug testing program, which includes alternative specimens and technologies. They developed a chart summarizing workplace drug testing program requirements, reviewed the technical materials submitted to them, and identified the necessary workplace drug testing requirements for each alternative specimen/testing technology.

The DTAB has continued its evaluation of the information submitted by the industry representatives on alternative specimens and technologies since September 1997. The first working draft of the new Guidelines was

presented at the June 2000 DTAB meeting. The initial, work-in-progress draft Guidelines were placed on our web site and the public was invited to submit supplemental information and informal comments to help improve our knowledge base. Twenty-eight separate commenters submitted comments on the first working draft. The comments were summarized and presented at the next DTAB meeting held in September 2000. At the September 2000 DTAB meeting, the second working draft of the Guidelines was presented and, again, comments were requested from all interested parties. At the December 2000 DTAB meeting, the public comments submitted were used to prepare the third working draft of the Guidelines.

As the DTAB continued to work on the Guidelines, the Department initiated a voluntary pilot PT program. PT samples were developed and produced at government expense. The PT samples were sent to several laboratories for testing at the laboratories' own expense, using the procedures that they routinely use to test head hair, oral fluid, and sweat specimens. This pilot PT program began in April 2000 and was necessary for two reasons. First, it was necessary to determine if it was possible to prepare stable and accurate PT samples for the different types of specimens that would be needed as part of a laboratory certification program. Second, the results reported by the laboratories would indicate if the PT program could establish credibility, precision, accuracy, and reliability in drug testing with alternative specimens. Based on the information obtained from four rounds of PT samples, it appears that valid PT samples can be prepared, although some further refinement is needed, and that over time some laboratories testing alternative specimens have been able to achieve performance levels approaching those levels applied to urine testing laboratories. The criteria for laboratory-based hair, oral fluid, and sweat testing, and for POCT urine and oral fluid tests have been developed and proposed by the industry-lead working groups.

Although performance in the pilot PT program has been encouraging, with individual laboratory and group performance improving over time, there are still three serious concerns. First, the data from the pilot PT program to date show that not all participants have developed the capability to test for all required drug classes, nor to perform such tests with acceptable accuracy. Second, some drug classes are more difficult to detect than others, for any given type of specimen. Third, the specific drug classes that are difficult to

detect varies by the type of specimen. That means that special awareness will be required to select the most appropriate type of specimen to be collected from a specific donor, when use of a specific drug is suspected. This public comment period is intended to provide an opportunity for all interested parties to review the testing criteria and associated specimen-specific procedures, to be sure that required performance is achievable and sustainable when implemented.

Alternative Specimens

The use of specimens other than urine in workplace drug testing programs have become a frequent topic in scientific meetings worldwide. This includes organizations such as the Society of Forensic Toxicologists, The International Association of Forensic Toxicologists, the Society of Hair Testing, and the American Academy of Forensic Sciences. The most frequently discussed specimens are hair, oral fluid, and sweat. Until recently it was considered too soon for the forensic community to apply these alternative specimens to workplace drug testing. Current scientific literature provides much of the information that was not previously available in peer reviewed literature. Addition of these specimens to the Federal Workplace Drug Testing Program would complement urine drug testing and aid in combating the threat from industries devoted to suborning drug testing through adulteration, substitution, and dilution.

The preamble provides a list of scientific studies that were used in making the policy decisions. The Department asks whether commenters are aware of any other studies or data that would cast more light on the appropriateness of using any of the alternative specimens or on limitations on how the specimens should be used.

Hair

The Department is proposing that hair testing be included in the Federal Workplace Drug Testing Program. Hair testing increases the time period over which drug use can be detected as compared to urine, sweat, or oral fluid. Hair is easily collected, transported and stored, is less likely to transmit bio-organisms than urine or oral fluid, and is more difficult to adulterate than urine. As separation techniques and detection sensitivity and specificity have improved, scientists are now able to detect and quantify drugs and/or metabolites in hair at picogram levels. Like other drug testing specimens, drugs in hair are initially detected using an immunoassay technique and results are

confirmed with a more sophisticated technique, most frequently by gas chromatography/mass spectrometry (GC/MS). Tandem mass spectrometry (MS/MS) using GC or liquid chromatography (LC) separation has emerged in recent years as the testing method of choice in order to increase sensitivity and selectivity and to analyze polar compounds without derivitization.^{10,15,16}

Hair consists of a hair follicle and hair shaft. At the base of the follicle (bulb) are highly vascularized matrix cells. As matrix cells in the dermis of the skin move outward during growth, they form layers of a hair shaft that include the outer protectant cuticle, central cortex and inner medulla. Hair grows in three stages: about 85 percent of hair follicles are in active growth (anagen), while the others are in a transition phase (catagen) before the resting phase (telogen). At the vertex region of the scalp, the average growth rate of hair is about 0.4 millimeters per day or approximately 1 centimeter per month.¹ The Department is proposing to permit agencies as part of their Federal workplace program to test hair with lengths of about 1.5 inches long, representing a time period of 90 days, and to use these specimens for pre-employment, random, return-to-duty, or follow-up testing.

Analytes for the regulated drugs tested in hair are marijuana metabolite (delta-9-tetrahydrocannabinol-9-carboxylic acid (THCA)), cocaine (parent drug and metabolites (benzoylecgonine, norcocaine, and cocaethylene)), phencyclidine (parent drug (PCP)), opiates (codeine, morphine, and heroin metabolite (6-acetylmorphine (6-AM))), and amphetamines (amphetamine, methamphetamine, methylenedioxyamphetamine (MDMA), methylenedioxyamphetamine (MDA), and methylenedioxyethylamphetamine (MDEA)).

Drugs and drug metabolites may be incorporated into hair by several different pathways.^{1,3-7} As drugs and their metabolites travel through the body in blood, they passively diffuse from the bloodstream into the base of the hair follicle. Drugs and/or metabolites are embedded into the hair as bands during the growth process. The amount of drug in the hair band is proportional to the concentration in the blood when the hair was formed. The distance of the drug bands from the skin can estimate the time of drug use. Drugs and/or metabolites may also be incorporated into hair via secretions of the apocrine sweat glands and sebaceous glands, which are in close

contact with hair as it develops in and emerges from the skin. Sweat and sebum can deposit drugs and/or metabolites on the hair shaft that in turn are absorbed into the hair shaft during and after its formation. Sweat can be responsible for drug incorporation at distal segments of hair which does not correspond to the time of drug ingestion.

There are a number of factors that may influence the amount of drug incorporated into hair (e.g., drug dose, length of exposure, drug chemical structure, charge). Of particular concern are environmental contamination and the role of hair color.

Concern has been raised about environmental contamination where a person may claim, for example, that the drug is present because the individual was in a room where others were using marijuana or cocaine. While washing the hair sample may remove some of the contamination, ultimately we can differentiate environmental contamination from actual use because of the presence of the metabolite, which is not present when environmental contamination is the source of the drug.

The role of hair color is also a major concern. Melanin, which is responsible for pigmentation in hair, is produced in the hair bulb and incorporated into the cells that form the cortex and medulla during growth of the hair shaft. Melanin is a polyanionic polymer of two types: eumelanin and pheomelanin, the quantity of each determine hair color. Eumelanin concentration is highest in black hair and lowest in red hair while pheomelanin concentration is highest in red hair and lowest in black hair.² Melanin is absent in white hair.

Animal studies have shown that hair color influences drug incorporation with black hair containing the most and yellow (non-pigmented) hair the least.⁷ In vitro studies in which black, brown, and blond hair from drug-free human subjects were placed in a solution of benzoylecgonine showed the highest concentration of the drug in black hair and the least in blond.⁸ Although there have been a limited number of human clinical controlled studies, data show that higher concentrations of some drugs are found in dark hair when compared to blond or red hair (e.g., codeine², cocaine⁹, amphetamine¹⁰). The limited population studies published in peer reviewed literature at this time do not indicate a significant association between hair color or race and drug analyte.¹¹⁻¹³ In one study, 1852 people that classified themselves as "black" or "white" showed no evidence of a group adversely affected by hair testing, compared to urine

testing, for cocaine and marijuana testing.¹¹ The examination of 500 positive hair samples for each of three drugs (cannabinoids, cocaine, and amphetamine) revealed little statistical evidence of selective binding of drugs to hair of a particular color.¹² Statistical examination of 2791 data points that include heroin and its metabolites, cocaine and its metabolites, MDMA and its analogs, and amphetamine and methamphetamine failed to detect a significant hair color effect.¹³

Despite these suspected limitations, the Department still proposes to go forward with incorporation of this new technology as an alternative to urine for Federal agencies who may find it useful in certain missions and tasks that only individual Federal agencies can identify. Though there continues to be some question about the effect of hair color on the amount of a drug or its metabolite present in hair, there is no question about the fact that the drug or metabolite is present. The purpose of the Federal Workplace Drug Testing Program is to ensure the safety of the workplace which it does in two ways. First, it identifies individuals in security or safety sensitive positions who have been using drugs, and second, it acts as a deterrent for people who might otherwise use drugs lest they be detected. Hair testing can improve the success of the program because it increases the time period over which drug use can be detected as compared to urine; it is easily collected, transported and stored; it is less likely to transmit bio-organisms than urine; and is more difficult to adulterate.

Oral Fluid

Testing methods for drugs in oral fluid have been developed in recent years and have been extensively used in some tested populations (e.g., therapeutic drug monitoring, risk assessment in the insurance industry, and non-Federal workplace testing).¹⁷⁻¹⁹ Many studies support the use of oral fluid as a specimen for forensic drug testing.^{20,21}

Oral fluid offers some advantages over other types of specimens.²² Oral fluid is readily accessible and its collection is perceived as less invasive than a urine specimen collection. Oral fluid collections can easily be observed and, therefore, the specimen is less susceptible to adulteration or substitution by the donor. Drugs can be detected in oral fluids within one hour of use making oral fluids useful in detecting very recent drug use.²⁷

Substitution can be identified by measuring an endogenous component (IgG) in the specimen. Although the

specimen volumes and amount of drug are lower in oral fluid than in urine specimens, current analytical methods (e.g., immunoassay, GC/MS, GC/MS/MS, LC/MS/MS) have the required sensitivity to be used for oral fluid specimen testing.²³⁻²⁶

As with the other relatively new test specimens for drugs of abuse testing, less is known about the pharmacokinetics and disposition of drugs into oral fluid as compared to urine.^{3,28-30} Science shows that opiates, PCP, amphetamines and cocaine and most drugs including prescription medications enter oral fluid through passive diffusion of the drug from the blood stream into the oral fluid. However, the active component of marijuana (delta-9-tetrahydrocannabinol (THC)) does not diffuse into oral fluid.^{26,31,32} The only way to detect marijuana use is through the presence of the parent drug (THC) in the oral fluid because the parent drug was present in the oral cavity. Unfortunately, further scientific study is needed to be able to differentiate between whether the parent drug was present in the oral cavity due to drug use or environmental contamination, *i.e.* the individual was present in a room when others smoked marijuana, for example.

In order to protect Federal workers from incorrect test results for marijuana, the Department proposes that a second biological specimen, a urine specimen, will need to be collected under the current Guidelines at the same time the oral fluid specimen is obtained, primarily for the purpose of testing for marijuana when the oral fluid specimen is positive for marijuana. The Department will revise the Guidelines when the science is available to differentiate between actual use and environmental contamination.

Analytes for the regulated drugs tested in oral fluid are marijuana (parent drug (THC)), cocaine (parent drug or metabolite benzoylecgonine), PCP (parent drug), opiates (codeine, morphine, and 6-AM), and amphetamines (amphetamine, methamphetamine, MDMA, MDA, MDEA).

The pH of oral fluid can affect incorporation of some drugs.³³⁻³⁵ Salivary pH ranges from about 6.2 to 7.4. Increased saliva flow rate raises the pH up to a maximum of 8.0 due to higher bicarbonate levels. Oral fluid collection devices cause some stimulation of saliva flow. Studies have found that concentrations of drugs (e.g., cocaine and its metabolites) in non-stimulated oral fluid specimens were greater than the concentrations of specimens collected using other

methods.³⁴ Mechanical saliva stimulation (*i.e.*, chewing gum) can also lower drug concentrations in oral fluid.³³ To avoid saliva stimulation some recommend spitting into a cup, but some donors may be opposed to spitting, especially when observed, and may experience dry mouth.

The Department finds that the collection difficulties associated with oral fluid collection procedures are not functionally different than other specimen collection difficulties currently encountered with urine. Therefore, despite these known limitations, the Department proposes to incorporate this new technology as an optional selection for Federal agencies because oral fluid testing may be useful in certain missions and tasks that only individual Federal agencies can identify.

Sweat

The incorporation of drugs into sweat is poorly understood but possible mechanisms appear to be passive diffusion of drugs from blood into sweat gland and transdermal migration of drugs to the skin surface, where it is dissolved in sweat.^{3,36,37} The time interval between drug consumption and detection in sweat depends on the nature of the particular drug or drug metabolite and the sensitivity of analytical method used.^{3,36,38}

Sweat may be collected as liquid perspiration,³⁸ on sweat wipes,^{20,39} or with a sweat patch.⁴⁰⁻⁴⁴ Sweat collection is a non-invasive procedure^{37,38} and privacy during collection does not appear to be a concern.³⁸ Commercially available sweat patches may be worn for an extended period of time, are waterproof, and are generally accepted by patients.³⁹ Currently, there are a limited number of commercially available collection devices,^{20,39} only one of which is FDA-cleared. Attempts to remove or tamper with the FDA-cleared sweat patch are usually visible to personnel trained to remove them.^{3,37} Sweat patch contamination issues continue to be a concern.^{3,39,45} For example, one study suggests that sweat patches are susceptible to contamination by a drug that is on the skin before the sweat patch is applied and by absorption into the patch through the surface of the protecting membrane.³⁹ Other studies indicate that the polyurethane (outer) layer is impermeable to molecules larger than dimer water.⁴⁵ Based on that information, the Department believes that external absorption of any drugs through the outer layer is not possible under normal circumstances. With regard to contamination from a drug

Environmental Contamination

We are concerned that the Preamble of the proposed 2004 regulation stated: "While washing the hair sample may remove some of the contamination, ultimately we can differentiate environmental contamination from actual use because of the presence of the metabolite which is not present when environmental contamination is the source of drug." This statement is only partially true. When a sample is above the cutoff for incorporated (not externally-deposited) parent drug, there are certain metabolites that can differentiate with certainty between external contamination and ingestion. However, other metabolites present via metabolic processes can also be present via environmental sources and the latter must be removed by aggressive washing in order for their presence to add to the certainty of ingestion interpretation. It is, therefore, the combination of metabolite identification along with washing of the sample, analysis of the wash, and the application of cutoff levels that completely differentiate environmental contamination from actual use. We, therefore, recommend that this section be changed to indicate that, "...ultimately we can differentiate between environmental contamination and actual use because of the presence of metabolites, in combination with effective washing techniques and cutoff levels". [underlined text for addition]

Incorporation of drug into the hair during growth, before and during keratinization, must be distinguished from external deposition of drug on the keratinized mature hair fiber. Drug found on hair segments not corresponding to the time of ingestion is externally deposited drug that can and must be largely removed or accounted for by aggressive washing techniques. Without such washing to remove drug that is deposited rather than incorporated, neither cutoffs nor metabolite criteria will allow consistent interpretation of hair analysis results. It has been shown, for example, that 100% of hair samples from 72 proven cocaine users in a clinical study contained external contamination in amounts ranging from 4 – 2000% of the drug content of the hair after washing, making the wash step critical in any quantitative determination.

In light of the above, we recommend that a decontamination method include a minimum of three 30-minute washes in aqueous medium to allow swelling of the hair and diffusion of contaminating drug into the wash solution. The aqueous washing should be preceded by a short (e.g., 15 min) wash in an organic solvent to remove non-water soluble substances. Secondly, wherever a definite metabolite (e.g., carboxy-THC) is not present, the method should include a measurement of the drug in the wash solution to evaluate the effectiveness of the decontamination. This evaluation requires a highly effective extraction method for the confirmation step- one that recovers most of the drug remaining in the hair due to ingestion.

Accordingly, the regulation needs to require that external drug depositions needs to be removed or accounted for by validated wash procedures. [underlined text for additions]

The attached studies demonstrate the effectiveness of extensive wash procedures in differentiating external contamination from ingestion in even extreme scenarios where cocaine is soaked directly onto hair. One recent HHS funded study by Peter Stout criticizes wash procedures for not completely removing all cocaine from the samples. However, it is not necessary to remove all externally deposited cocaine, it is necessary only to identify heavily contaminated samples (this is no different from urine testing where it is not necessary to remove adulterants, it is only necessary to identify adulterated samples). The study demonstrated that correctly applied wash mechanisms, while not completely removing all cocaine, could differentiate external contamination from ingestion when wash, wash criteria and cocaine/be ratios were applied even under extreme contamination scenarios. That study transferred 15mg of cocaine from the fingers to the hair. Such an amount of cocaine, of course, would easily create a positive urine or saliva result if the fingers touched the mouth or a donor's food (a scenario just as likely as touching the hair). These studies demonstrate the superiority of hair compared to urinalysis.

Accounting for Environmental Contamination

Psychemedics employs several independent approaches that in combination, rule out the possibility of a positive result from external sources.

- a) The rigorous chemical washing of hair for extended periods of time.
- b) The analysis of the contents of these washes followed by a comparison with the drugs remaining in the hair.
- c) Measurement of metabolites, the unique compounds created by the body's processing of the drugs. Many of these metabolites are normally not present in the environment or in smoke. For example, marijuana smoke does not contain carboxy THC - the metabolite that Psychemedics identifies in marijuana positives.
- d) Use of cut-off levels with hair, as with urine, to prevent any passive internal exposure from producing a positive result. Because of the constancy of drug concentrations in hair, these cut-off levels more accurately reflect use, and are, therefore, safer than those used by urinalysis.

Several studies by Dr. Thomas Mieczkowski of the University of South Florida¹² dealt with the real world issue of external contamination and its removal by appropriate wash procedures. The studies concerned the passive contamination of undercover narcotic officers who, in the course of their duties, had continuing and extensive contact with cocaine, operated in cocaine rich environments and interacted frequently with cocaine users and cocaine dealers. The officers handled cocaine in the process of buying and selling and when they made arrests or seized contraband.

These undercover officers effectively mimicked drug users in all respects, except usage. In his studies, Dr. Mieczkowski found that the officers had some amount of detectable cocaine on the outside of their hair as a contaminant. However, even in this extreme contamination scenario the hair was easily cleansed. Dr. Mieczkowski concluded that the commercial wash procedures utilized by Psychemedics were effective methods for removing external contamination from hair and that external contamination did not present a difficult problem with properly performed hair analysis.

In a contamination study utilizing an early Psychemedics wash procedure, researchers exposed volunteers to crack smoke in a small, unventilated room (2.5 x 3 x 2.5 m) and exposed cut hair to the equivalent of smoke vapors from 5000 lines of cocaine in closed beakers. In all cases, after washing, the exposed, contaminated hair tested negative. The authors concluded that deposition of cocaine from even these extreme contamination scenarios was washable³. Also in the study,

¹ Passive Contamination of Undercover Narcotics Officers by Cocaine: An Assessment of Their Exposure Using Hair Analysis. Microgram, 1995.

² Distinguishing Passive Contamination from Active Cocaine Consumption: Assessing the Occupational Exposure of Narcotics Officers to Cocaine. Forensic Science International (84) 1997.

³ Hair Analysis of Cocaine: Differentiation Between Systemic Exposure and External Contamination. Journal of Clinical Pharmacology, 1992.

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hair from admitted cocaine users tested positive, hair from non-users tested negative and hair from non-users who admitted being present in crack environments also tested negative. It is not likely that any employee would claim an exposure scenario greater than being in an enclosed room while 5000 lines of cocaine were vaporized or handling cocaine more frequently than an undercover narcotics officer or evidence technician.

In a 2002 contamination study⁴ presented at the Society for Forensic Toxicologists, Psychemedics' extensive wash procedures were compared to the short wash results obtained in an earlier cocaine contamination study and were shown to be effective at distinguishing contaminated hair from user hair.

A 2004 study⁵ on Psychemedics wash methodology for removing and identifying contamination demonstrated that soaking hair in high concentrations of cocaine or coating the hair with cocaine and exposing it to sweat for hours, will not be mistaken for drug use. In all cases, the combination of extensive wash procedure and application of wash criteria successfully identified contamination correctly.

In a second 2004 study⁶ Psychemedics' meticulous wash processes were applied to hair samples of over 70 verified cocaine users. Using Psychemedics wash methodology (over 3 ¾ hours), the extensively washed hair samples matched the cocaine-positive urine results, verifying the accuracy of rigorously washed hair samples.

A 2005 study⁷ employing Psychemedics' wash methods demonstrated that thorough wash methodologies can effectively decontaminate hair samples when drug from external sources deposits on hair (e.g., a test subject's exogenous sweat or environmental contamination). This study also showed that Psychemedics methodology is not affected by hair color or hair porosity (the study went on to examine hair of all colors as well as permed hair soaked in high concentrations of cocaine). Applying Psychemedics' wash procedures and wash criteria over the spectrum of hair colors, Psychemedics consistently decontaminated or reported as contaminated (i.e., negative for cocaine use) these hair samples. In addition, all of the permed hair samples were either decontaminated or identified as contaminated. No hair color or cosmetic treatment anomalies exist when Psychemedics methodology is used.

Due to the hypersensitivity of urine tests, it is well recognized by the scientific community that false positives due to passive internal exposure to drugs are far more likely for urinalysis than for hair analysis.

⁴An Evaluation of Two Wash Procedures for the Differentiation of External Contamination Versus Ingestion in the Analysis of Human Hair Samples for Cocaine. *Journal of Analytical Toxicology* (26) 2002.

⁵Removing and Identifying Drug Contamination in the Analysis of Human Hair. *Forensic Science International* (145) 2004.

⁶Levels of Cocaine and its Metabolites in Washed Hair of Demonstrated Cocaine Users and Workplace Subjects. *Forensic Science International* (145) 175-81, 2004

⁷Hair Analysis for Cocaine: The Requirement for Effective Wash Procedures and Effects of Drug Concentration and Hair Porosity in Contamination and Decontamination. *Journal of Analytical Toxicology*, 2005.

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Studies have experimentally demonstrated that as little as one-hundredth of a line of cocaine (i.e., 1 or 2 mg) can produce interpretive false positive urinalysis results⁸. These small quantities can be inadvertently ingested by a non-drug user (e.g., a spouse) who may be in the constant presence of a drug abuser. In contrast to the resistance of hair to drug penetration, the lungs and gastrointestinal tract have absolutely zero resistance. In actual fact, drugs are transported by active transport mechanisms into the interior milieu, i.e., by breathing or by active membrane processes. Such active internalization can cause interpretive false positive urine results by minute amounts of cocaine if the timing of the test is in close proximity to the passive ingestion.

Unlike hair, there is no method to remove this contamination from urine or to differentiate between active drug use and unknowing exposure to a drug that may rise above cut off levels, e.g., spiked or contaminated food or drink. Unlike urine, hair can be segmented to substantiate or refute these claims. Additionally, a completely new hair sample can be obtained that will approximate the same time frame of the original sample, eliminating concerns or claims of sample mix-up. New samples replicating the same time frame cannot be obtained with urine, as most drugs are completely flushed from the system in a couple of days.

January 2006

⁸Passive Inhalation of Cocaine. *Journal of Analytical Toxicology* (19) 1995.

Hair Analysis of Cocaine: Differentiation Between Systemic Exposure and External Contamination

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Cocaine has been shown to accumulate in hair of admitted users. Before using this test to verify cocaine use, however, it is crucial to differentiate between systemic exposure and external contamination from being in contact with crack smoke. In the present studies, the authors document that pyrolysis of crack results in hair accumulation of cocaine, but not its benzoylecgonine metabolite, whereas after admitted cocaine use both species are detectable in hair. External contamination with crack smoke is washable, whereas systemic exposure is not. The authors suggest these two criteria to distinguish systemic exposure from external contamination.

During the last decade the increased use of cocaine in North America has been associated with criminal activities and a variety of serious health problems.¹ The detection of cocaine and its metabolites in blood and urine is limited by the short elimination half-life of these compounds. Consequently, individuals who have stopped consuming cocaine are likely to test negative a few days later.

Cocaine is used on the street in two forms: cocaine hydrochloride and cocaine freebase, otherwise known as crack. Cocaine hydrochloride is a white powder; usually 80 to 100 mg of this powder is spread in a 4- to 6-cm "line" that is snorted (administered intranasally). Freebase cocaine is more volatile and can be administered by inhalation.²

Several studies, including from our own group,³ have recently documented that cocaine and its major metabolite benzoylecgonine (BE) are incorporated into hair during the growth of the shaft and stay there for the whole life of the hair. Because hair grows in adults at an average rate of 1 cm per month, such analysis can also yield the time of the exposure

by cutting the hair into segments. Similar to adults, we have shown that newborn babies born to mothers who used cocaine in late pregnancy have BE in their hair.³

The clinical use of hair testing for cocaine has been heavily criticized as premature, because a variety of important questions have not been answered yet,⁴ including the variability in hair distribution of cocaine, the minimal amount of cocaine and the time needed to produce a positive answer, as well as the dose-response curve of this phenomenon. The most serious doubts about the validity of this test to determine systemic (true) exposure to cocaine, however, relate to the distinction between cocaine incorporation after systemic exposure versus external contamination of hair exposed to cocaine smoke. This is undoubtedly a crucial issue before such a test can definitely distinguish individuals who have used cocaine from those who were just exposed to it environmentally.

The present study was designed to answer the following questions:

Does systemic exposure to cocaine yield different hair deposition of cocaine and its metabolite BE than external contamination?

Can washing procedures eliminate all external contamination of cocaine?

Does deposition of cocaine in fetal hair stem from its incorporation into hair through fetal circulation or from contamination of the amniotic fluids?

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METHODS

Systemic Versus External Exposure to Cocaine

Benzoyllecgonine:Cocaine Ratio in Hair. Hair samples of ten individuals admitting cocaine use and two individuals denying use of cocaine but suspected of being in an environment where cocaine was used, were tested for concentrations of cocaine and BE. An additional ten hair samples from laboratory personal reporting no cocaine use ever and no external exposure to the drug, and whose urine tested negative for BE, were analyzed.

External Contamination of Hair. Hair from adults who reported no consumption of cocaine ever, and whose hair was tested negative for BE before the procedure, was exposed to crack vapors produced by pyrolysis of a cigarette containing different amounts of the drug. The purity of the crack was tested and found to be above 95% using a radioimmunoassay with less than 5% cross-reactivity with BE. In the first experiment, three individuals were exposed to 100 mg crack smoke in an unventilated room (2.5 × 3 × 2.5 m). These conditions were aimed at mimicking an "occasional" exposure to one line of cocaine.

Subsequently, 50-mg samples of uncontaminated hair were placed in several 4-L beakers containing 0.1 to 100 mg crack added to a cigarette. Lighting the cigarette and keeping the beakers closed, the hair was exposed to crack smoke. At the end of pyrolysis, the hair samples were kept in the respective beakers for 60 minutes. The amounts of crack used (0.1–100 mg) in a volume of 4 L were equivalent to 5 to 5000 lines of cocaine (100 mg each) smoked in the room described above.

The cocaine and BE concentrations were measured in each hair sample before and after washing by the procedures described below.

Intrauterine Exposure to Cocaine. Two pregnant guinea pigs were administered 15 µg/kg of cocaine HCl daily during the third trimester of pregnancy (days 40–70). Similar to humans, guinea pig pups' fur grows only during the third trimester of pregnancy. After delivery, maternal and pups' fur was analyzed for cocaine and BE. Amniotic fluid was collected during the delivery, and its BE and cocaine concentrations were measured by radioimmunoassay as described below. These concentrations were subsequently reproduced in aqueous solutions, and control fur was incubated for 30 days. The BE and cocaine concentrations were measured in unwashed and washed fur.

Washing Procedure For hair washing, the method of Baumgartner and Berka⁵ was followed. Briefly, the procedure consists of four 30-minute washes of 2 mg hair with 2 mL ethanol at 37°C, followed by two 60-minute washes with 2 mL ethanol at 37°C.

Analytical Methods

One milliliter methanol was added to the washed or unwashed hair, sonicated for 30 minutes, and incubated overnight at 45°C. The next day, the methanol was pipetted off and the hair rinsed briefly with an additional 1 mL of methanol. After evaporating the methanol at 40°C under a stream of nitrogen, 100 µl of phosphate-buffered saline was added, and BE and cocaine were analyzed by radioimmunoassay. For BE measurements, the Roche Abuscreen (Hoffman LaRoche Ltd., Nutley, NJ) for cocaine metabolite in urine was used. The sensitivity of the assay in our laboratory is 0.25 ng BE/mg hair and there is only 4% cross-reactivity with cocaine. For cocaine measurements, Coat-A-Count for cocaine metabolite in urine (Diagnostic Products Corporation, Los Angeles, CA) was used, but instead of the BE standards provided with the kit, in-house cocaine hydrochloride standards (1–500 ng/mL) were used. Under these conditions, the sensitivity of the assay was found to be 0.025 ng cocaine/mg hair, and cross-reactivity with BE was 0.5%. Nicotine was found not to cross-react in either method. Mass spectrometry of the hair samples was performed at SCIEX Corporation (Toronto, Canada) using the standard thermal desorption profile on Atomic 09.

RESULTS

Table I presents hair concentrations of cocaine and BE before and after washing, in the three individuals

No.	Cocaine (ng/mg hair)		Benzoyllecgonine (ng/mg hair)	
	Before Washing	After Washing	Before Washing	After Washing
1	24	0	0	0
2	30	0	0	0
3	27	0	0	0

HAIR ANALYSIS OF COCAINE

TABLE II

Hair Concentrations of Cocaine and BE in Hair Samples Exposed to Crack Smoke Corresponding to 5-5000 Lines of Cocaine Smoked in a Room

mg Crack Smoke In 4L	Cocaine (ng/mg hair)		Benzoyllecgonine (ng/mg hair)	
	Before Washing	After Washing	Before Washing	After Washing
0.5	13.1	0	0.32	0
1	200.0	0	4.7	0
10	279.4	0	4.6	0
100	312.5	0.25	4.8	0

exposed to pyrolysis of one line of crack in an unventilated room. Before washing, low concentrations of cocaine, but not BE, were measurable. Washing removed all cocaine deposited during the pyrolysis. Table II shows the fate of higher amounts of cocaine smoke, indicating that external contamination of hair was washable, except for the highest amount of crack smoke, corresponding to 5000 lines of crack, (each line, 100 mg), smoked in a 2.5 x 3 x 2.5 m room. In general, pyrolysis caused hair deposition of cocaine only while no BE was deposited on the hair; hence, the ratio between BE and cocaine concentrations after washing was 0 (Table II).

Treatment of pregnant guinea pigs with 15 mg/kg/day for 20 days of gestation resulted in piglet fur concentrations ranging between 10.0 and 54.0 ng/mg hair of cocaine and between 0.8 and 5.7 ng/mg hair of BE. Maternal fur concentrations of both cocaine and BE were detectable (Table III). Exposing cocaine-free guinea pig fur for 20 days to saline containing cocaine and BE at similar concentrations to those measured in the amniotic fluid (50 ng/mL co-

TABLE III

Cocaine and BE Concentrations Measured by RIA in the Fur of Three Adult Guinea Pigs Injected with Cocaine

No.	Cocaine (ng/mg fur)		Benzoyllecgonine (ng/mg fur)	
	Before Washing	After Washing	Before Washing	After Washing
1	2.6	2.7	0.48	0.45
2	6.7	6.7	1.85	1.80
3	8.3	8.1	5.6	5.0

TABLE IV

Cocaine and BE Concentrations in Hair of Ten Adults Admitting Heavy Cocaine Use in Previous Months

No.	Cocaine (ng/mg hair)		Benzoyllecgonine (ng/mg hair)	
	Before Washing	After Washing	Before Washing	After Washing
1	47.2	18.0	3.0	1.8
2	19.9	14.6	7.2	2.9
3	1.35	1.2	0.9	0.2
4	7.5	1.8	6.3	2.6
5	32.6	28.2	14.2	10.0
6	6.8	1.9	2.0	1.4
7	13.1	5.0	8.0	5.0
8	7.3	6.4	6.5	6.3
9	3.4	2.2	0.76	0.6
10	14.5	14.0	3.6	2.1

caine and 350 ng/mL BE) resulted in low, measurable levels of BE (1 ng/mg fur). After washing with ethanol with the procedure described above, levels were undetectable.

Table IV presents cocaine and BE concentrations in hair samples of the ten individuals who admitted chronic cocaine use. In all cases, most of the drug and its BE metabolite could not be washed. The BE:cocaine ratio in washed hair ranged between 0.1 and 1.5.

TABLE V

Cocaine and BE Concentration in the Hair of Ten Individuals Claiming No Cocaine Use Ever and Who Had Negative Urine Test for BE

No.	Cocaine (ng/mg hair)		Benzoyllecgonine (ng/mg hair)	
	Before Washing	After Washing	Before Washing	After Washing
1	0.102	0	<0.30	0
2	0.032	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0.030	0	0	0
6	0.030	0	0	0
7	0.143	0	0	0
8	0	0	0	0
9	0.042	0	0	0
10	0.049	0	0	0

Mean 0.038 ± 0.049

Table V shows cocaine and BE concentrations in hair samples of the ten individuals not exposed to cocaine. Unwashed hair levels of cocaine and BE were close to the lower limit of sensitivity and they became invariably undetectable on washing. Table VI presents cocaine and BE concentrations in hair samples of the two individuals who denied cocaine use but were suspected of being in an environment where crack was smoked. Benzoyllecgonine was not detectable in the unwashed hair of these individuals, whereas low detectable levels of cocaine became undetectable after washing the hair with ethanol.

The determinations of cocaine and BE in hair were verified unequivocally by mass spectrometry; there were no false-positives or negatives in the radioimmunoassay determinations.

DISCUSSION

The use of hair to calculate long-term systemic exposure to xenobiotics is not new, and forensic scientists have measured scores of medicinals and drugs of abuse^{6,7} generally in the context of postmortem examination. Marsh and colleagues⁸ have shown that cumulative amounts of methyl mercury in maternal hair correlate positively with neurologic sequelae in the newborn.

As shown previously by other investigators,⁵ hair may have different compartments that can be entered externally, and other compartments can be entered internally. Those externally accessible by crack or other drugs are also accessible to aqueous or organic solvents, whereas the compartments accessible only through the circulation are not readily accessible to such solvents.

Use of hair to prove cocaine exposure in adults has been established by Baumgartner and Berka.⁵ The routine use of this test to establish exposure has been criticized,^{4,9} however, partially because the methods used by Baumgartner and Berka have been patented,

and therefore not fully published. In the present studies, as well as in our previous investigations,³ we have used published methods to measure cocaine and BE. Moreover, our measurements have been submitted to gas chromatography-mass spectrometry, which obviates the possibility that cross-reactivity of the radioimmunoassay with other species creates false-positive readings.

The present investigation aimed at clarifying whether external contamination of hair can create false-positive readings of cocaine. Because a positive hair test is likely to bear serious consequences to individuals, including loss of jobs, loss of children, or even criminal charges, such a test cannot be acceptable if any source would cause a false-positive reading. In particular, it is crucial to test whether individuals who are in the same room with people smoking crack will test positive even without smoking themselves. Our present results reject such a possibility: external exposure to "occasional" cocaine smoke (one line) did yield measurable amounts of cocaine in hair, but not of BE, after the washing procedure, the cocaine was undetectable. Only when the hair was contaminated with smoke from the equivalent of 5000 lines of crack used in a small unventilated room, was minimal cocaine detectable even after washing, but no BE could be found.

Cocaine is very lipophilic and therefore rapidly crosses biologic membranes.^{10,11} It is rapidly metabolized either spontaneously or by serum and hepatic cholinesterases to active compounds such as norcocaine and to inactive compounds (BE and ecgonine methylester) which are renally excreted.¹² Previous studies have suggested that BE may be the product of spontaneous hydrolysis.¹³ Being less polar, cocaine is accumulated in hair more rapidly than BE; however, this metabolite has a longer elimination half-life, and therefore its hair levels are likely to "catch up" with time.

Our finding that pyrolysis results in deposition of only cocaine itself, and that this deposition is washable, should help in distinguishing external contamination from true, systemic exposure to the drug. In the unwashed hair of the two individuals who denied cocaine use but were suspected of external exposure, the concentrations of cocaine were at least five times higher than in any of the ten individuals whose hair was used as negative controls. Conversely, all ten individuals admitting cocaine use had measurable amounts of BE in their hair, and similar results were obtained in guinea pigs. Washing the hair of these individuals could not deplete the cocaine or BE from the sample. In our earlier study,³ a detergent was used to cleanse the hair, but ethanol was found by other investigators⁵ to be less aggres-

TABLE VI

Cocaine and BE Concentrations in Hair of Two Adults Claiming No Use of Cocaine, But Suspected in Being in an Environment Where Crack Was Smoked

No.	Cocaine (ng/mg hair)		Benzoyllecgonine (ng/mg hair)	
	Before Washing	After Washing	Before Washing	After Washing
1	0.70	0	0	0
2	2.2	0	0	0

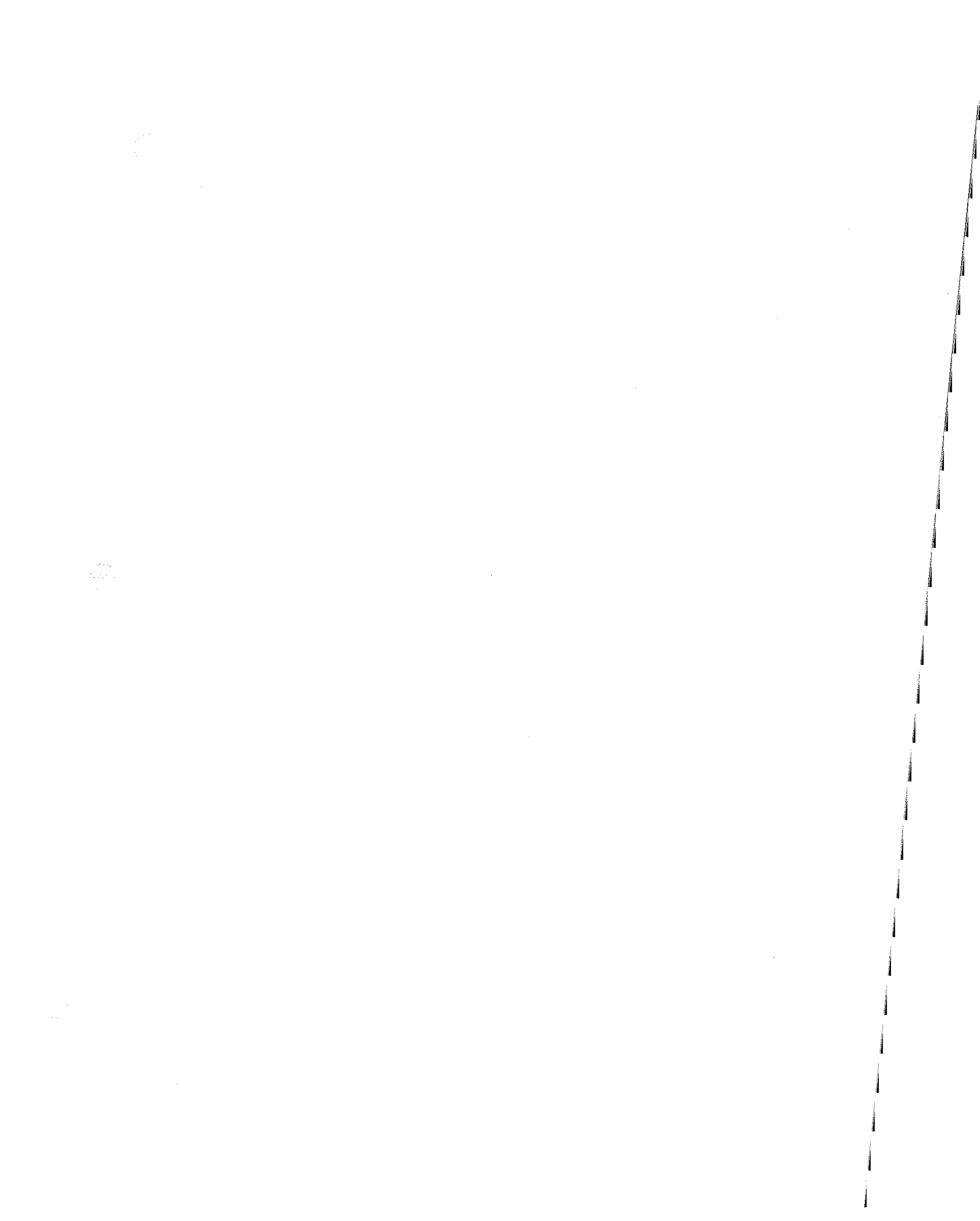
sive in removing internally deposited cocaine and therefore more appropriate for washing the hair.

Our animal experiments indicate that cocaine and BE detected in neonatal fur stem from systemic exposure to the drug and not from external contamination through the amniotic fluid. It is likely that genetic polymorphism dictates the amount of cholinesterase activity, and that different individuals will have various BE:cocaine ratios. In addition there is now evidence that placentae have variable levels of cholinesterase activity, possibly resulting in different amounts of cocaine reaching the fetus.¹⁴

In summary, our studies indicate that external exposure to crack smoke results in cocaine, but not BE, deposition in hair, and that such deposition is washable.

REFERENCES

1. Abelson HK, Miller JP: A decade of trends in cocaine use in the household population. *Natl Inst Drug Abuse Res Monogr Ser* 1985;61:35-49.
2. Commissaris RL: Cocaine pharmacology and toxicology. In Radda K, Walker C, Barnett G (eds.): *Cocaine, Marijuana, Designer drugs. Chemistry Pharmacology and Behaviour*. Boca Raton, FL: CRC Press, 1989;72-81.
3. Graham K, Koren G, Klein J, Schneiderman J, Greenwald M: Determination of Gestational Cocaine Exposure by Hair Analysis. *JAMA* 1989;262:3328-3330.
4. Barrett S: Commercial hair analysis. *JAMA* 1985;254:1041-1045.
5. Baumgartner WA, Berka C: Hair analysis for drugs of abuse. *American Association for Clinical Chemistry* 1989;10:7-21.
6. Baumgartner AM, Jones PF, Baumgartner WA, Black CT: Radioimmunoassay of the hair for determining opiate-abuse histories. *J Nucl Med* 1979;20:749-752.
7. Puschel K, Thomasch P, Arnold W: Opiate levels in hair. *Forensic Sci Int* 1983;21:181-186.
8. Marsh DO, Clarkson TW, Cox C, Myers GJ, Amin-Zaki L, Al-Tikriti S: Fetal methylmercury poisoning. Relationship between concentration in single strands of maternal hair and child effects. *Arch Neurol* 1987;44:1017-1021.
9. Holden C: Hairy problems for new drug testing method. *Science* 1990;249:1099-1100.
10. Chow MJ, Ambre JJ, Ruo TJ, Atkinson AJ, Bowsher DJ, Fischman MW: Kinetics of cocaine disposition, elimination, and chronotropic effects. *Clin Pharmacol Ther* 1985;38:318-324.
11. Chasnoff IJ, Lewis DE, Squires L: Cocaine intoxication in breast-fed infant. *Pediatrics* 1987;80:836-838.
12. Stewart DJ, Inaba T, Lucassen M, Kalow W: Cocaine metabolism: Cocaine and norcocaine hydrolysis by liver and serum esterases. *Clin Pharmacol Ther* 1979;25:464-468.
13. Stewart DJ, Inaba T, Tang BE, Kalow W: Hydrolysis of cocaine in human plasma by cholinesterase. *Life Sci* 1977;20:1557-1564.
14. Roe D, Little B, Bawdon R, Gilstrap L: Metabolism of cocaine by human placentas: Implications for fetal exposure. *Am J Obstet Gynecol* 1990;163:715-718.



Passive Contamination of Undercover Narcotics Officers by Cocaine: An Assessment of Their Exposure Using Hair Analysis

by

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Introduction

Because of increased drug use over the last several decades there has been an increasing interest in using human hair specimens for the detection and quantification of psychoactive drugs. Furthermore, several of the most popular drugs of abuse - most notably cocaine - disappear relatively rapidly from both the blood plasma and the urine, the specimens most frequently relied upon in forensic analysis of drug exposure. In an attempt to develop more effective methods for identifying historic exposure to these drugs, scientists have turned to hair as a specimen for analysis. In contrast to urine or blood, which can identify drug exposure very shortly after use, hair assays do not identify drug exposure until approximately 5 to 7 days after ingestion. Thus urine and blood remain desirable samples for incidence determination, while hair is effective for evaluating chronic exposure to a drug.

Hair Analysis and Its Controversies

The identification of drugs by using hair specimens has, itself, not been particularly controversial. Virtually all published research has shown that drugs can be readily identified in hair by a wide variety of analytic techniques, including the use of radioimmunoassay (RIA), high performance liquid chromatography (HPLC), and gas chromatography/mass spectrometry (GC/MS). Controversy has arisen, however, about how to **interpret** the detection of drugs in hair (Kintz, Mangin 1995). This controversy has primarily and most intensely focused on the issue of **passive contamination** (Kidwell, Blank 1995). It has been suggested that casual passive contamination creates conditions which make the contaminated hair of non-users indistinguishable from the hair of cocaine users.

To date, no field evidence has established that such a hypothetical occurrence has an empirical basis. Outside of synthetic laboratory contamination scenarios, hair analysis appears to do an excellent job in identifying cocaine exposure, and in reliably identifying contamination from exposure caused by ingestion. In analysis of several thousand criminal justice cases, for example, data patterns are not consistent with a view that cocaine contamination has occurred randomly in these study populations (Mieczkowski and Newel, 1993). Furthermore, laboratory studies have generally distinguished quite readily between known cocaine users and known cocaine abstainers when those studies have been done under controlled conditions (e.g., see Cone, Yousenejad, Darwin, Maguire 1991). Furthermore, laboratory-based contamination scenarios lack persuasiveness because the methods used to simulate contamination do not correspond to field events, and such synthetic conditions do not generally account for the presence of corroborating evidence such as benzoylecgonine (BE), ecgonine methyl ester (EME), cocaethylene (CE), or norcocaine (NC) - all metabolites of cocaine - typically used to verify assay outcomes. In general, these metabolites do not appear in hair which is contaminated by external deposition of the drug.

Some published research, employing both synthetic scenarios as well as field-based subjects, has shown that the empirical distinction between passive exposure and active ingestion of cocaine is not as difficult a problem as critics have sometimes suggested (Baumgartner, Hill, 1990; Koren, Klein, Forman, Graham 1992). It is also important to note that in criminal justice contexts there are many investigative circumstances where one is only required to establish the presence of cocaine. Thus distinguishing passive or active modes of

contamination may not be relevant. However, when one is required to distinguish between contamination and ingestion, evidence indicates that in most circumstances, such a determination can be reliably made by hair analysis.

Field research has shown that measurable amounts of cocaine are not easily transferred to hands by simple casual touching of contaminated objects. Maloney, Barbato, Ihm, Nipper, and Cox (1994), for example, have shown that after handling cocaine-contaminated objects such as crack pipes, non-users failed to transfer measurable amounts of cocaine to their hands. Maloney and his colleagues also assayed the hands of 15 bank tellers in a pre/post design to measure contamination of the hands based on handling cocaine-contaminated currency. Tellers from three different banks handled cocaine-contaminated currency for the entirety of a normal four hour shift (and refrained from washing their hands at any time during the work period). Tests on the currency showed it to be contaminated with cocaine, but no cocaine was detectable on the hands of the tellers. Identical results were reported for handling cocaine contaminated steering wheels from seized vehicles. Avolio, Kim, and Radwanski (1994) have shown that dry hair samples placed in physical contact with cocaine-impregnated silica, removed periodically, and washed with methanol, do not begin to acquire methanol-resistant cocaine contamination even at the picogram level until after approximately seven days of continuous, uninterrupted contact. Koren, Klein, Forman, and Graham (1992) have shown that under a variety of conditions when persons are passively exposed to crack smoke in field settings, the use of an initial alcohol and subsequent phosphate buffer washes remove virtually all cocaine contamination from the hair. And even when they simulated passive contamination by using extreme conditions, they successfully removed nearly all cocaine contaminants. They also noted that one could distinguish between contamination and use because contaminated samples contained no cocaine metabolites.

Narcotics Officers: Field Exposure to Cocaine

Because cocaine is a controlled substance with extremely limited medical use, it is difficult to identify occupational groups which have meaningful, known, and chronic environmental exposure to cocaine. However, one such group is undercover narcotics officers. These officers, in the course of their duties, have continuing contact with cocaine, cocaine-rich environments, cocaine users, and cocaine dealers. These officers function in environments where cocaine is used, they handle cocaine in the process of buying and selling it, and they handle cocaine when they make arrests, seize the contraband, and transport and process the seized drug as evidence. Some of these officers also routinely handle cocaine as part of training exercises. Considering these factors, narcotics officers would appear to be a good study group for evaluating the degree of contamination acquired via incidental environmental exposure and the resistance of contamination to wash-based cleaning procedures.

Based on the exposure these officers have to cocaine, a series of simple hypotheses are suggested. First, that narcotics officers are exposed to detectable levels of cocaine via environmental contamination. Second, if environmental contact in natural field settings emulates consumption or ingestion of cocaine, these officers should have measurable amounts of cocaine in their hair as well as cocaine contamination on their hair. Third, if they do have cocaine on their hair, the wash procedures designed to detect contamination as opposed to ingestion should remove this contamination and identify these officers - who have no history of cocaine use - as contaminated non-ingesters of cocaine.

Method

This study presents data based on the analysis of hair samples and responses to survey questions of nine undercover narcotics officers. All of these officers are employed as part of a county-wide narcotics task force, based in a major metropolitan gulf-coast Florida city and have a negative drug use history. These officers volunteered to provide a scalp hair specimen and answer a 24 item survey questionnaire. The hair samples were gathered by a fellow officer, who also passed out and collected the survey. All specimens and survey instruments were anonymous. Samples and surveys were common-coded to allow comparison of responses to

values determined by assay of the hair specimen.

The hair was analyzed for cocaine by the Psychomedics Corporation, of Culver City, CA., using radioimmunoassay. The hair samples ranged from 1 to 2 cms. in length, and consisted of 40 to 60 strands of hair, cut at the scalp by surgical scissors. The hair was subject to an initial anhydrous isopropanol wash, and three subsequent phosphate buffer washes. After the third washing in buffer, the hair was digested by a proteinase enzyme at a neutral pH. Each wash and final hair digest were assayed by RIA. Complete technical description of the sample preparation procedure has been published elsewhere (Baumgartner, Cawing, Donahue, Hayes, Hill, Scholtz, 1995). The data reported here included values for all washes as well as the RIA values for the final hair digest. All values in the tables are reported as nanograms per 10 milligrams of hair sample.

Data

The nine officers in this sample (7 male, 2 female) had a mean age of 33.8 years, with 3.25 years experience in undercover narcotics work. The least experienced officer had six months of narcotics work and the most experienced had slightly more than 4 years, with virtually all of this experience spent in undercover activities, typically "buy and bust" activities. The majority of the cases handled by these officers were cocaine cases (mean value 60%; range from 20 to 90%). And the majority of the cocaine cases were crack cases as opposed to powder cocaine cases (mean value 79.2%; range from 40 to 98%). All officers had no history of cocaine use. All officer reported consistent and ongoing activities relative to cocaine, which included handling, purchasing, seizing, field testing, and transporting of cocaine. Of the 9 officers 5 reported engaging in this activity several times a week, and 4 reported it occurring several times a month. Two officers reported being in the presence of crack cocaine smoke several times a week, and 3 reported this at rates of several times monthly. A rough estimation of exposure incidents for this group yield an average value of 502.5 environmental exposures to cocaine, with an estimated range of from approximately 200 to nearly 1,000 individual exposures

Examining the hair treatment practices of the officers revealed no notable departure from normal washing patterns. Since the study was retrospective, there was no concern with efforts on the part of officers to either avoid or engage in special hair treatment or hygiene. Approximately half of the officers engaged in some form of conventional cosmetic treatment of their hair, ranging from the use of hair spray to occasional perming or dyeing of the hair. Six officers reported daily washing of their hair, one reported washing 3 to 5 times a week, and the balance reported weekly washing. All officers used conventional, retail shampoo products, and three reported using creme rinse post-washing on a routine basis. No other descriptive variable such as age, gender, years of service, etc. had a significant correlation with the hair assay outcomes.

Case ID#	Alcohol Wash	PO ₄ Buffer Washes			Hair Digest
		#1	#2	#3	
1	0.9	1.30	0.14	0.00	0.00
2	0.0	1.00	0.10	0.00	0.00
3	0.0	1.50	0.14	0.00	0.00
4	0.0	3.40	0.30	0.20	0.00
5	0.0	0.80	0.08	0.00	0.00
6	1.1	1.20	0.00	0.00	0.00
7	0.0	3.40	0.10	0.10	0.00
8	0.0	1.10	0.07	0.00	0.00
9	0.0	1.50	0.18	0.00	0.00

Table 1. Wash and Hair Digest Assay Values: Cocaine [ng/10 mg]

Table 1 displays the data outcome for the hair assays for cocaine for all subjects in the study. Examination of the table reveals that none of the hair samples had any cocaine in the hair digest. However, note that every officer had some amount of detectable cocaine on the hair as a contaminant. While the amounts of cocaine present on the hair are well above the limit of detection for RIA technology, none of these specimens attained sufficient values for cocaine to be considered a positive assay even by the lowest recommended cutoff supported by the testing laboratory of 5 ng/10 mg of hair. In fact, none of the cases would attain a value greater than the cutoff even if one were to do no washing of the specimens, since no discrete wash step, nor in fact the summated values for all the washes exceeds the cutoff. Only in the first and second phosphate buffer washes are notable levels of cocaine found in all or nearly all the specimens. For the first PO₄ wash the mean concentration value is 1.688 ng/10 mg of hair (SD=.9955) and for the second PO₄ wash the mean value is 0.123 ng/10 mg of hair.

Conclusions

Based on the data presented here several conclusions may reasonably be drawn for the sample group in reference to the suggested hypotheses.

First, undercover narcotics officers are exposed to cocaine in the course of their work, and such exposure results in the environmental contamination of their hair. This contamination is detectable by RIA.

Second, although these officers were chronically exposed to cocaine through their work, their contamination is slight. As noted, none of these officers had any detectable levels of cocaine in their hair digests. While every officer had some measurable level of cocaine contamination, in every case these levels were well below cutoff. The values were so low that even if one were to sum across all washes and use the summated values for the washes and assays combined, one could not generate a figure large enough to sustain a positive finding using the laboratory-recommended cutoff of 5 ng/10 mg of hair.

Third, it appears that the alcohol and phosphate buffer wash procedure is an adequate method for removing external contamination from hair, at least for the type of exposure experienced by these officers. Thus our data supports the findings of those who have argued that environmental contamination via chronic, casual contact does not present a particularly difficult interpretive problem in using hair assays.

This study also indicates that passive contamination of hair specimens as practiced in laboratory scenarios, at least based on the contamination processes reported to date, are likely to be poor approximations of "real world" contamination. Laboratory studies exposing hair to aqueous cocaine soaks or pyrolyzed cocaine vapors have reported contamination at concentrations many orders of magnitude greater than that reported here. These findings suggest that studying contamination problems is probably most heuristically done in field environments. To minimize the likelihood of misinterpreting a hair assay, when one is trying to distinguish contamination from ingestion, general background values are a necessary piece of information. These background values must be empirically determined in field settings. The data reported here clearly suggest casual exposure produces only slight amounts of contamination, and that for most routine situations, wash procedures and sample preparation techniques similar to those used in this study are adequate safeguards against confusing contamination with ingestion.

References

- Avolio, J., Kim, L., Radwanski, P. 1994. *Ion Mobility Spectrometry (IMS) Detection of Cocaine in Hair*. Paper presented at the Annual Meetings of the International Association of Forensic Toxicology, Tampa, Florida, October, 1994.
- Baumgartner, W. and Hill, V. 1990. Hair analysis for drugs of abuse: Decontamination issues. *Proceedings of the 2nd International Congress of Therapeutic Drug Monitoring and Toxicology*, Barcelona, October 9-12.
- Baumgartner, W., Cawing C., Donahue, t., Hayes, G., Hill, V., Scholtz, H. 1995. Forensic Testing by Mass Spectrometric Analysis of Hair. In *Forensic Application of Mass Spectrometry*, J. Yinon (ed.), pages 61-94. CRC Press: Boca Raton, Florida.
- Cone, E.; Yousenejad, D.; Darwin, W.; Maguire, T. 1991. Testing human hair for drugs of abuse. II. Identification of unique cocaine metabolites in hair of drug abusers and evaluation of decontamination procedures. *Journal of Analytical Toxicology* 15(5):250-255.
- Kidwell, D., Blank, D. 1995. Decontamination Procedures for Drugs of Abuse in Hair: Are They Sufficient? *Forensic Science International* 70(1-3):13-38.
- Kintz, P., Mangin, P. 1995. What Constitutes A Positive Result in Hair Analysis: Proposal for the Establishment of Cut-off Values. *Forensic Science International* 70(1-3):3-11.
- Korea, G., Klein, J., Forman, R., Graham, K. 1992. Hair Analysis of Cocaine: Differentiation Between Systemic Exposure and External Contamination. *Journal of Clinical Pharmacology* 32:671-675.
- Maloney, B.; Barbato, L.; Ihm, B.; Nipper, H.; Cox, R. 1994. The qualitative determination of trace amounts of cocaine obtained through casual contact. *Microgram* 27(6):185-187.
- Mieczkowski, T.; Newel, R. 1993. Comparing Hair and Urine Assays for Cocaine and Marijuana. *Federal Probation* 57(2):59-67.

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