# The Forensic Application of Testing Hair for Drugs of Abuse

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## ABSTRACT

Hair testing is only used by the Federal Bureau of Investigation (FBI) when other information exists that indicates drug use and can remove a person from suspicion or associate them with criminal activity. The detection of cocaine in hair has been the FBI's first priority in hair testing for drugs of abuse because of its prevalence. Several cases when hair testing was used are reported in this chapter. Further, analysis of over 100 samples was performed on hair obtained from a medical examiner's random autopsy collection. Sixty-five percent of the samples tested positive for cocaine or opiates. The results of hair testing for drugs of abuse were found to be consistent with autopsy toxicology reports. The analysis of hair washes and nails from the autopsy samples suggests external contamination of hair with drugs is not widespread.

## INTRODUCTION

The forensic testing of hair for drugs of abuse is a recently acquired law enforcement tool that can be used to ascertain the truth about an individual's consumption of drugs. Lying to an FBI special agent about drug use (or any other matter) is illegal. Yet it can be anticipated that truthful information about self-admitted drug use is not frequently encountered by law enforcement. Alternative methods such as hair analysis are therefore needed to measure the past use of drugs.

One of the primary reasons for a person's lack of candor with law enforcement is the fear of criminal prosecution. People involved in criminal activity frequently conceal, distort, or falsify the truth. In fact, upon initial investigation, no suspect has confessed to the abuse of drugs in the cases the FBI Laboratory has dealt with in the testing of hair for drugs.

Reluctance to admit drug use to law enforcement personnel can occur for reasons other than incrimination. For example, even in instances

when drug use has been surveyed with promises of anonymity and confidentiality among those arrested on criminal charges, it has been found through biological tests (to ascertain the accuracy of the responses) that there is a tendency to conceal or underreport the short- and long-term use of drugs (Mieczkowski and Newel 1993). One of the primary reasons for under-reporting may be to hide the extent of abuse. Moreover, the ability to accurately recollect and self-report may be impaired when the user has been under the influence of a mind-altering drug. Additionally, purchased street drugs are often of unknown purity and composition, and users may unintentionally give inaccurate reports.

It is difficult for drug abusers to accurately self-report which drugs and how much drug they have used when they are frequently consuming illicit substances that may have been obtained from unreliable sources. For example, a recent Drug Enforcement Administration (DEA) publication (DEA 1994) cited several instances of street drugs having a very different composition than their represented contents. In the first case, a small lump of a waxy black solid sold as tar heroin was found to be part of a black crayon. In another instance, a white powder purported to be cocaine was analyzed and found to be ephedrine and caffeine. A substance sold as crack was identified as a mixture of dextrose and paraffin wax. An alleged fentanyl sample was revealed to contain not only the suspected drug but also heroin and nicotinamide. As can be seen from these examples, drug abusers can be consuming very different drugs than intended, or, in extreme cases, no drug at all.

The development of drug-specific hair tests devised in the FBI Laboratory has been driven by the type of drug analysis requests received, which concurs with criminal justice survey data on the high prevalence drugs (i.e., cocaine). According to the 1992 National Institute of Justice annual report on Drug Use Forecasting (DUF), in 24 major U.S. cities, anywhere from 48 to 85 percent (depending on the location) of male or female booked arrestees tested positive for various drugs by urinalysis (Department of Justice 1993). Cocaine was found to be the most prevalent drug at 22 of the 24 test sites, and accounted for as much as 72 percent of the positive drug results in Manhattan for females. Marijuana was the leading drug at two of the sites and was the second most detected drug overall; 38 percent of male arrestees in Omaha tested positive. The third most frequently detected type of substance revealed by urinalysis results came from the opiate class of drugs. The highest percentage of opiate positives from the 24 locations was in Manhattan, with 24 percent of females

testing positive. The arrestees in this study were booked on a variety of charges (mostly felony), not just drug offenses. These results serve to illustrate the link between crime and drug abuse.

Results of the DUF study suggest cocaine is the most commonly abused drug. For this reason it can be understood why the FBI Laboratory has established cocaine testing in hair as its first priority for this type of analysis. The detection of marijuana, the second most prevalent abused drug among arrestees according to the DUF study, has not been pursued in hair by the FBI Laboratory because of its low concentration in this tissue and the persistence of its metabolites in urine. Urinalysis permits detection of marijuana use up to several weeks after its consumption (Liu 1992; Cone, this volume). The FBI Laboratory is developing hair tests for opiates/heroin because of their prevalence and use in society as illustrated in the DUF study.

Hair testing has distinct advantages over other forms of toxicological sampling and analysis. For example, distinguishing heroin use from other opiates via blood or urine samples is more problematic than it is in hair testing because of the short half-life of heroin and its primary metabolite, 6-monoacetylmorphine (6-MAM), in these fluids. Heroin and 6-MAM are detectable in urine for only a few hours. Morphine and codeine are secondary metabolites of heroin and are more persistent in biological fluids than heroin or 6-MAM. In contrast, 6-MAM is the major marker of heroin use in hair. The differentiation of opiate use is important because morphine and codeine can be licitly consumed in foods such as poppy seeds or prescribed in medications such as cough syrups (ElSohly and Jones 1989; Liu 1992). Therefore, one of the largest incentives for the determination of heroin use from hair is the ability to differentiate its use from other opiates via the presence of its unique identifying metabolite.

Due to the rapid metabolism and elimination of most drugs and their metabolites, it is difficult to analyze and quantitate them in body fluids 2 days or more after use. In contrast, cocaine and heroin use can be detected in hair samples collected months after the drugs are consumed. Another advantage of hair testing is the noninvasive nature of sampling compared with the collection of blood or urine.

## APPLICATION OF HAIR TESTING

Hair testing for drugs of abuse has enhanced the ability of law enforcement to corroborate the truthfulness of testimony on drug use. The historical information on drug consumption attainable from

testing hair gives it a distinct advantage over urine drug testing because of the extended detection window. The data obtained from hair testing have had an impact in investigations on a wide variety of offenses. Hair analysis is only used by the FBI Laboratory when there is evidence that drug abuse has occurred and it has a bearing on a case. The results of hair testing can associate subjects with criminal offenses or remove a person from suspicion. Generally, hair testing for drugs is needed as a confirmation technique when there is a disputed positive urinalysis (for example, claims of sample mislabeling or of a single occurrence of drug use, false positives), allegations of criminal activity, parole violations, or a history of drug abuse.

Some cases that have used hair testing at the FBI Laboratory and involve drug-related offenses include a drug smuggler, military personnel, Government employees, law enforcement personnel, prison inmates, parolees, and public officials. A prominent mayor, an attorney, and a prosecutor are included on the hair analysis list of public officials who were suspected of drug abuse. Hair testing for drugs of abuse also has made a critical difference in the outcome of casework seemingly unrelated to the use of drugs, such as investigations of murder, rape, and product tampering.

The FBI Laboratory has processed approximately 76 requests for hair testing related to casework since the first analysis in 1987 for an investi-gation involving a cocaine smuggler (records are kept according to how many cases have requested hair testing). The number of case samples steadily rose from 1987 to 1992, when it peaked at 35 investigations involving hair testing (figure 1). The numbers have tapered off recently as some requests have been referred to other laboratories to prevent casework overload.

The court cases that have used FBI results of cocaine hair testing have been successful, beginning with the smuggler's trial in 1987. Nearly half the cases have been military personnel faced with courts martial over drug abuse. Convictions were obtained in all but one case. Most defendants have pleaded guilty when confronted with combined positive urinalysis

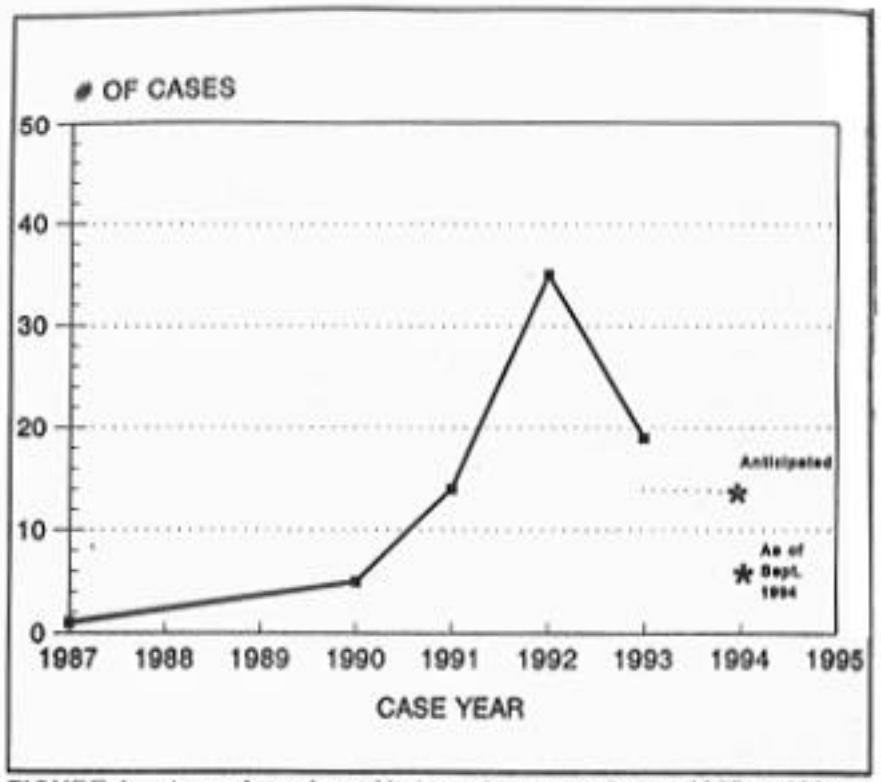


**FIGURE 1.** *Annual number of hair testing cases during 1987 to 1994 for the FBI Laboratory Chemistry-Toxicology Unit.*

and hair testing results. In cases of nonmilitary Federal employees, they have either been found negative and cleared or resigned their positions.

## TESTING HAIR FOR DRUGS

The FBI Laboratory performs hair testing for cocaine. The testing of hair for drugs begins with the voluntary or court-ordered collection of approximately 100 hairs from the vertex of the contributor. To maintain sample integrity, the hair is transferred from the collection official to the laboratory through a documented chain of custody.

Hair is tested for cocaine and its major metabolite benzoylecgonine using mass spectrometry for the determination of cocaine abuse. Both compounds have been detected in the majority of cases. The anticipated hair test for heroin use focuses on the detection of its primary metabolite 6-MAM. The appearance of heroin and/or 6-

MAM is a prerequisite for a declaration of heroin use determination via hair analysis. The presence of morphine and codeine are also examined, but a positive finding is not necessarily an indicator of heroin use.

Details of the procedure for analyzing drugs in hair can be found in the previous publications by the authors, but the method is briefly described here (Martz et al. 1991; Miller et al., in press). A 5 milligram (mg) hair sample is cleaned by washing it twice with solvent (methanol) to remove potential contaminating drugs on the hair surface. Baumgartner and colleagues (1993) established that solvent washing readily removes drugs on the surface of hair.[1] The drugs in the hair are extracted with acid (for cocaine analysis only) or solvent at above ambient temperature after internal standards are added to the solution. Deuterated analogs of the target drugs or related compounds are used as the internal standards for the purpose of quantitation. After extraction and sample preparation, the final concentrate is analyzed by tandem mass spectrometry (MS/MS) or electrospray ionization liquid chromatography/mass spectrometry (ESI LC/MS).

## HAIR TESTING CASES

Examples of how testing hair for drugs can be used in a forensic environment are given below for illustrative purposes. One of the earlier high publicity cases involved the victim of a product tampering by international smugglers (Martz et al. 1991). This case fell under Federal jurisdiction as a consumer product-tampering offense. In July of 1990, a Miami man became extremely ill after drinking an imported malted beverage from Colombia. After drinking the contents of the bottle, the subject thought he may have been poisoned; he stated the beverage tasted bad, and his mouth and tongue were numb. The man went into a coma immediately after making the statement and was rushed to the hospital. At the hospital he was diagnosed as suffering from acute cocaine intoxication after a urinalysis test.

Cocaine was detected in the residue of the bottle consumed by the victim. The subject was maintained alive for 24 days until his life support system was shut off. A recall of the malt beverage found an average of 30 grams of cocaine per bottle of the tampered product.

After the victim died, hair samples were collected to determine whether he was a regular cocaine user who had overdosed or the victim of a product tampering (during the period after the incident but before his death, the victim's hair grew approximately 1 to 1.5 centimeters (cm) (Chatt and Katz 1988)). Historical information on his drug usage was gathered by conducting segmental analysis on the victim's 2.5 cm length hair. The hair was cut into half-centimeter segments and analyzed (figure 2). The hair segments contained a peak concentration of almost 100 nanograms (ng) per mg at a time period that corresponds to the ingestion of the suspect beverage (segment 1-1.5 cm). The high level of cocaine in the two segments at the tip of the hair (segments 1.5-2.5 cm) indicate the victim was a user of cocaine before the incident.[1] Witness interviews substantiated results of the segmental hair analysis during the investigation, which revealed the victim was a chronic cocaine user.

In the next example, a rape investigation was aided by hair analysis for cocaine. A request was made for hair analysis by a small town's police department to contest the alibi of a suspect after a woman reported an

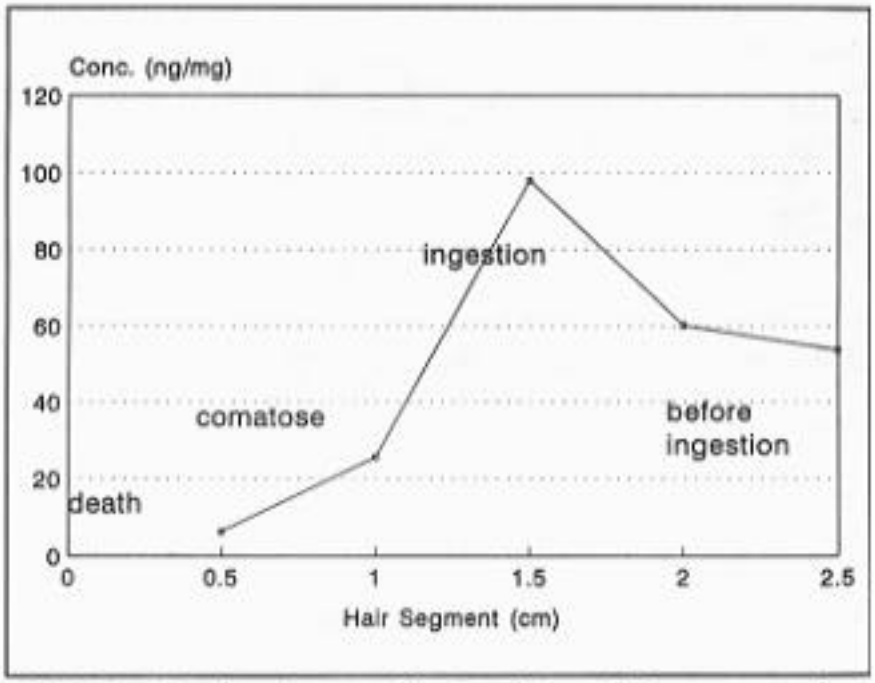


**FIGURE 2.** *Results of segmental hair analysis on 0.5 cm segments from a lethal intoxication of cocaine in imported beverage. The data points represent hair cocaine concentrations.*

acquaintance had raped her in her own home. The suspect stated he and the victim were dating, engaging in sex, and had used crack cocaine together on numerous occasions. She denied his allegations and proof was needed to refute or confirm his alibi. Since the suspect was positive for cocaine and the victim was negative for use of cocaine over the previous several months, hair testing was effective in contradicting the alibi.

The use of hair testing also has been effective in accidental or man-slaughter death investigations. In one case, a child died as a result of cocaine intoxication while in the care of his mother and her common-law husband. The mother indicated that her husband was a cocaine user and the husband implicated the mother as a drug user. Results of hair testing revealed the father was positive for cocaine while the mother was found to be negative. This implicated the father as a user and possible owner of the cocaine ingested by the child and resulted in his confession as being the possessor of the cocaine.

Members of the military are routinely tested for drug usage via urinalysis. Those found to be using drugs are court martialed and discharged from the service. In several instances, hair testing has been used to corroborate positive urine tests as well as other investigative information such as adulterated urine specimens. In one particular case, a military man near retirement whose urine and hair tested positive for cocaine was exonerated from court martial in spite of this evidence. He claimed his wife had spiked his food with cocaine. His wife, who was divorcing him, initially refused to corroborate his story, but later testified to spiking his food several times. Because he was considered a victim of tampering, the jury found him innocent.

## RESEARCH ON DRUGS IN HAIR

A project at the FBI's Forensic Science Research Unit screened random hair samples collected from autopsies conducted by a medical examiner. These samples consisted mainly of homicide, suicide, and accident victims. A small proportion of the people autopsied died of medical illness, drug overdose, or exposure. Thus far, 115 hair samples have been analyzed for cocaine, benzoylecgonine, 6-MAM, morphine, and codeine. Preliminary results for cocaine (58 percent positive) and opiates (29 percent positive) screening suggest abuse of these substances is high in the sampled population. The positives range from 16 to 72 percent for cocaine and 1 to 24 percent for opiates in the 1992 DUF Annual Report.

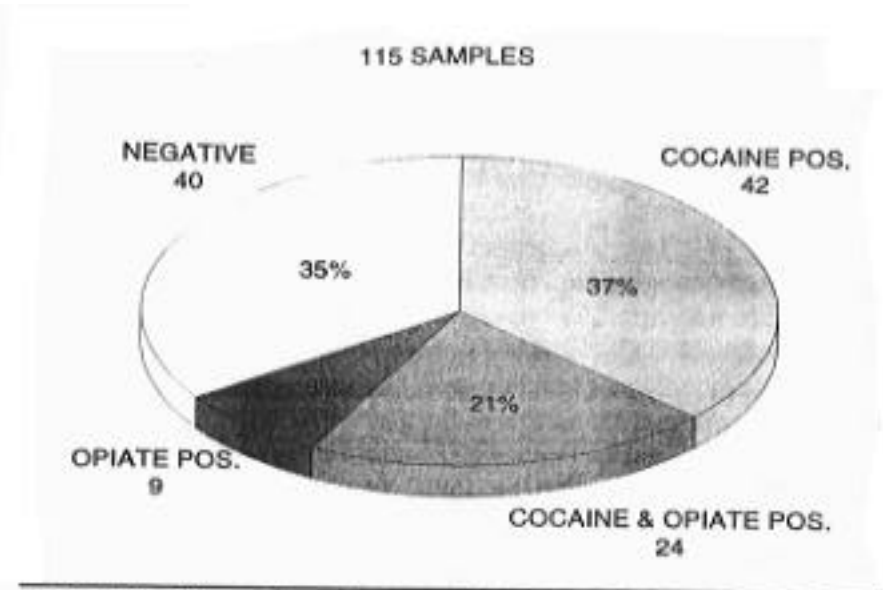


**FIGURE 3.** *Drug testing of autopsy hair from medical examiner's office. Percentage breakdown of autopsy hair which tested negative or positive for cocaine, benzoylecgonine, 6-MAM, morphine, and codeine.*

Only 35 percent of the autopsy samples tested negative for all 5 drugs (figure 3). This observation is consistent with the autopsy results; all of the subjects in this negative group for whom cause-of-death data were obtained had died of either accidents, illnesses, or gunshot wounds. A larger proportion tested positive for cocaine use only (37 percent) and 8 percent tested positive for opiates only. More than one-fifth (21 per-cent) of the subjects tested positive for both an opiate and cocaine.

A compilation of the 66 cocaine-positive hair samples netted an average concentration of 30 ng/mg of hair for cocaine and 4.6 ng/mg of hair for its metabolite, benzoylecgnine (figure 4). The median values of both drugs are much smaller, indicating most of the concentrations are at the low end of the range. The large standard deviations reveal a wide distribution in the minimum and maximum values obtained.

Results of the limited number of samples positive for opiates show the average and median values are approximately 1 ng/mg of hair or less (figure 5). The 6-MAM, morphine, and codeine average concentrations are all much smaller than the average levels of cocaine and benzoylecgnine

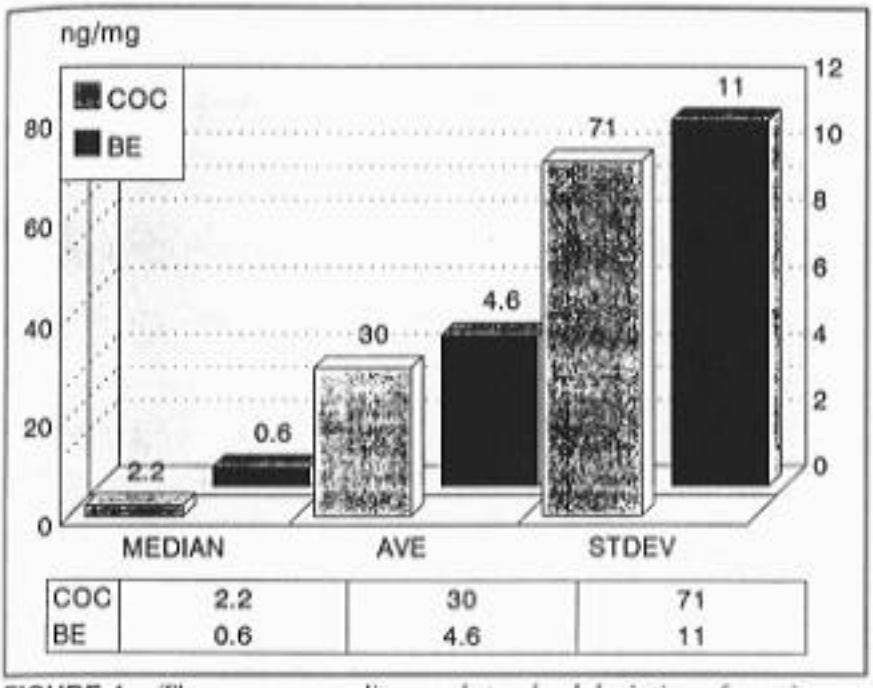


**FIGURE 4.** *The average, median, and standard deviation of cocaine and benzoylecgnine concentrations in 66 cocaine-positive autopsy hair samples. The left and right axes scales apply to the cocaine and benzoylecgnine concentrations, respectively.*

in the hair samples. Most of the values for the cocaine and 6-MAM-positive samples are single digit or smaller (figure 6). However, there were four samples with cocaine concentrations over 100 ng/mg.

The possibility of surface contamination of hair samples with drugs is one of the more controversial subjects in the field. It has been proposed that contamination and incorporation into the hair can result from environmental exposure to drugs, and thus sampling does not necessarily detect use of drugs. However, Baumgartner and associates (1989) have found that most hair samples do not exhibit any external contamination. They further state that drugs on the surface of hair are removed by washing with shampoo.[1] It has also been suggested by Fritch and colleagues (1992) that not all cocaine found in washes is due to external contamination. At a minimum, hair testing is still useful in forensics even if contamination exists because it is an indicator of exposure to a drug environment.

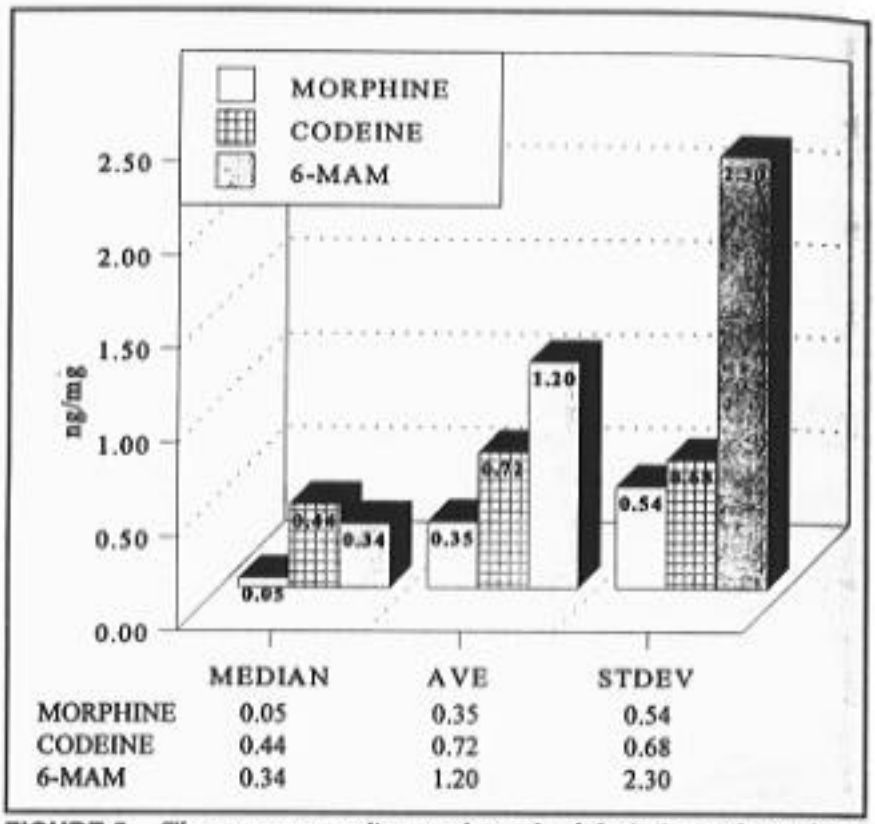


**FIGURE 5.** *The average, median, and standard deviations of morphine, codeine, and 6-MAM concentrations in 12, 11, and 22 drug positive autopsy hair samples, respectively.*

Results of the 115 autopsy samples indicate surface contamination of the hair is not a major problem. With an average of 0.16 for all samples that were drug positive, the cocaine wash-to-extract concentration ratio is very low and indicates most of the drug is in the interior of the hair. The median wash-to-extract ratio was 0.01; this reveals that half of the samples had less than 1 percent of their cocaine on the exterior of the hair. A total of 40 percent of the cocaine-positive hairs showed no detectable traces of cocaine in the wash, and 77 percent had a wash-to-extract ratio of no more than 0.1.

Another argument against the contamination issue is the proportionately large presence of metabolites such as benzoylecgnine and 6-MAM in hair. If surface contact were the mechanism for incorporation, unless

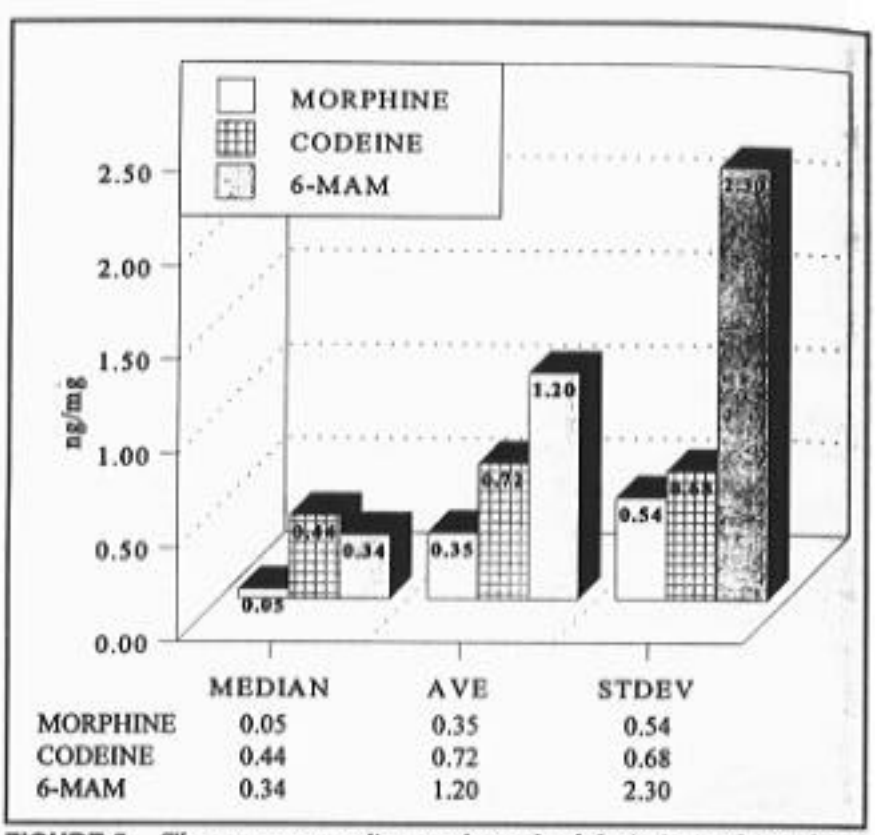


**FIGURE 5.** *The average, median, and standard deviations of morphine, codeine, and 6-MAM concentrations in 12, 11, and 22 drug positive autopsy hair samples, respectively.*

degradation had occurred, only original drugs would be readily detectable in contaminated hair. The contact of parent drugs with hair does not result in the formation of metabolites (Baumgartner and Hill 1993). In the authors' study of autopsy hair, only samples with traces of cocaine (< 0.3 ng/mg of hair) had undetectable levels of benzoylecgnine.

In drug abusers, toenails are less likely than hair to become externally contaminated in the daily handling of illicit drugs. A study of 20 autopsy toenails was conducted; cocaine-positive results were found in 15 of the 16 nail samples that had hair positive for cocaine. The one exception had a cocaine level of only 0.1 ng/mg in the hair. It is not surprising that the nail was negative when it is considered that nails have much lower drug concentrations than hair. In addition, cocaine metabolites benzoylecognine and cocaethylene were found in both hair and the corresponding nails, which suggests that it is unlikely the hairs are routinely contaminated by environmental sources of drugs.

Therefore, positive results in the authors' laboratory for the determination of cocaine in both hair and toenails suggests the controversy over contamination is overstated.[1]

Sample adulteration has been an issue in urine testing for some time, and may also become a concern for the validity of hair-testing results if a method were found to remove drugs from hair in vivo. In 1994, the FBI Laboratory participated in a round-robin test organized by the National Institute of Standards and Technology for the determination of drugs in hair. The blind test samples contained two sets of hair that had been spiked by soaking the specimens in solutions of drugs. Before the results of the round-robin test were known, the test samples were examined microscopically. It was observed that two of the samples had a higher sheen than the others (reddish-brown color). When the results were released, it turned out that these two samples were the adulterated preparations. The higher sheen may be the inadvertent effect of the solvent's cleansing the hairs as they were being soaked in drug solution. This observation could be of use in discovering adulterated hair specimens during testing by looking for this characteristic sheen. The scientific community has yet to agree on how to establish that hair has been adulterated or contaminated.

## SUMMARY

The testing of hair for drugs has been an invaluable aid and often a necessary tool for law enforcement. It has given the forensic investigator a glimpse into the past. In conjunction with the use of urinalysis, hair testing can give a more detailed drug history on a test subject. The two tests should be considered complementary. Hair testing results have helped to incriminate those with hair positive for drugs as well as lessen suspicion for subjects with drug negative hair. Findings from a project on autopsy hair samples are internally consistent and show a positive rate for cocaine within the same range found in other survey data from booked arrestees on the prevalence of drug abuse.

## ENDNOTE

1. Refer to the Technical Note at the end of the Introduction (p. 13).

## REFERENCES


Baumgartner, W.A.; Black, C.T.; Jones, P.F.; and Blahd, W.H. Radioimmunoassay of cocaine in hair. *J Nucl Med* 23(9):790-792, 1982.

Baumgartner, W.A.; Hill, B.S.; and Blahd, W.H. Hair analysis for drugs of abuse. *J Forensic Sci* 34(6):1433-1453, 1989.

Baumgartner, W.A., and Hill, V.A. Sample preparation techniques. *Forensic Sci Int* 63(1-3):121-135, 1993.

Chatt, A., and Katz, S.A. *Hair Analysis: Applications in the Biomedical and Environmental Sciences.* New York: VCH, 1988. pp. 11-12.

Department of Justice. *Drug Use Forecasting 1992 Annual Report: Drugs and Crime in America's Cities*. National Institute of Justice Research in Brief, Department of Justice (DOJ) Pub. No. (NCJ)142973. Washington, DC: Supt. of Docs., U.S. Govt. Print. Off., 1993.

Drug Enforcement Administration. *The Microgram.* (Washington, DC) Vol. XXVII, no. 7, pp. 207-208. July 1994.

ElSohly, M.A., and Jones, A.B. Morphine and codeine in biological fluids: Approaches to source differentiation. *Forensic Sci Rev* 1(1):13-22, 1989.

Fritch, D.; Groce, Y.; and Rieders, F. Cocaine and some of its products in hair by RIA and GC/MS. *J Anal Toxicol* 16:112-114, 1992.

Liu, R.H. Important considerations in the interpretation of forensic urine drug test results. *Forensic Sci Rev* 4(1):51-65, 1992.

Martz, R.; Donnelly, B.; Fetterolf, D.; Lasswell, L.; Hime, G.W.; and Hearn, W.L. The use of hair analysis to document a cocaine overdose following a sustained survival period before death. *J Anal Toxicol* 15:279-281, 1991.

Mieczkowski, T., and Newel, R. An evaluation of racial bias in hair assays for cocaine: Black and white arrestees compared. *Forensic Sci Int* 63(1-3):85-98, 1993.

Miller, M.L.; Donnelly, B.; and Martz, R.M. Research at the Federal Bureau of Investigation in hair analysis for drugs of abuse. *Hair Testing for Drugs of Abuse: International Research on Standards and Technology*. Rockville, MD: National Institute on Drug Abuse, in press.


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**Click here to go to page 161**