Pitfalls in hair analysis*

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Abstract

Hair analysis has become a routine technique for the retrospective detection of exposure to illegal drugs in driving ability examination, criminal liability cases and several other forensic cases. It was shown in many papers that in the same way also therapeutic drugs, doping agents and alcohol metabolites can be determined in hair as a prove of previous or chronic intake. Based on the steady growth, segmental hair analysis can give information about the time course of the substance use. Even a previous single drug application, e. g. in drug facilitated sexual assault cases, could be detected by the increased sensitivity of up-to-date MS-MS techniques. However, the physiological basics as well as the analytical performance of hair analysis are very complicated and there are several sources of error and misinterpretation which should be known and handled with responsibility. In this presentation reasons of such pitfalls and ways of its avoidance are considered from the collection of the hair sample to the interpretation of the analytical outcome.

1. Introduction

There are different meanings of the term hair analysis:

- Very popular is the measurement of mineral ion concentrations in hair as a presumed mirror of the health state of a person.
- A hairdresser understands by hair analysis the characterisation of the hair status as a starting point for decision about a fitting hair style and hair cosmetics.
- The Toxicologist takes it as a method for retrospective detection of illegal and therapeutic drug exposure

This presentation will be confined on the drug analysis in hair and will show some pitfalls that should be known in order to avoid wrong results and wrong interpretation of correct results. Hair results have serious consequences (Fig. 1). The German national soccer trainer Christoph Daum as well as the talk master Michel Friedman lost their jobs after cocaine was detected in their hair samples. On the other hand, the Senator for the Interior of Hamburg, Ronald Schill could stay in his position for a while with a negative drug test in hair. The German singer-song writer Konstantin Wecker circumvented 2 ½ years jail for possession of a large amount cocaine by regular hair control. Beside these prominent examples there are more than 4000 hair samples of non-prominent cases in Germany per year controlled for drugs in context of driving ability examination, criminal liability, right to have contact to his own children, work-place testing, retrospective detection of a poisoning or other reasons. In all these cases the analyst takes a high responsibility for a correct result.

The steps of hair analysis are shown in Table 1. Each step involves several possible sources of error. It may start with insufficient information about the purpose of investigation and even the wrong decision to choose hair as the sample material. During sampling and storage of the sample insufficient labelling may lead to a mix-up with other samples. Inappropriate methods or conditions may be used for decontamination and extraction of the hair sample. The analytical method may be lacking in specificity, sensitivity or accuracy. Finally, a correct result may be inadequately interpreted with respect to drug concentration, exposure time or specific background of the case. Some selected aspects shall be considered more in detail.

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Konstantin Wecker
Hair control instead of 2.5 years in jail

Michel Friedman
Cocaine positive, lost his job

Ronald Schill
Cocaine negative, stayed in job for a while

Christoph Daum
Cocaine positive, lost his job

Figure 1. Prominent cases of hair analysis

Table 1. Steps of hair analysis and sources of errors

Step	Sources of error
Case of investigation	• Insufficient information about case history and purpose of investigation • Wrong choice of hair as sample material • Wrong decision with respect to segment lengths
Sampling and storage	• No unambiguous identification of the individual • Insufficient sample amount and order of hair tuft • Insufficient labelling, mix up with other samples • Danger of contamination and degradation
Decontamination	• Choice of wrong solvent or solvent sequence • No analysis of the wash solution
Extraction	• Inappropriate choice of extraction or digestion method • Wrong time and temperature of extraction • Decomposition of the drug • High level of impurities
Analysis	• Insufficient specificity, sensitivity, accuracy • No deuterated standards in GC-MS • Loss of substance in clean-up • Wrong positive or wrong negative result
Expertise	• Inadequate interpretation of the concentration • Inadequate interpretation concerning exposure time • Case specificity and sample properties not considered

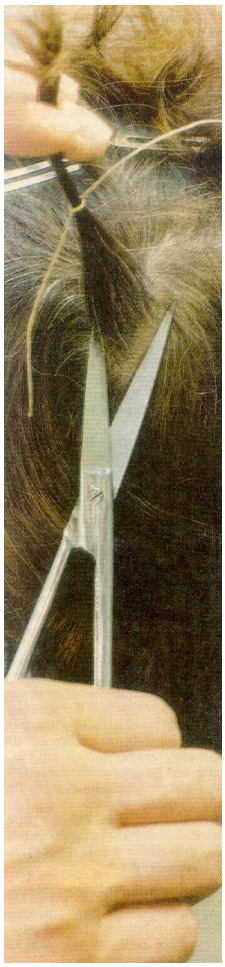
2. Performance of hair analysis

2.1 Collection of the hair sample

A very careful and correct collection of the hair sample is often neglected. Errors at this step are difficult to repair. Some important aspects are summarized in Fig. 2. The person must be unambiguously identified. Beside the personal data also characteristics of the hair sample should be recorded. Hair sampling and hair analysis are not allowed in laboratories or departments where the drugs themselves are handled. Although more sensitive methods were

introduced in the last years, the practical performance of sampling has not changed: A tuft of hair with a diameter of 3 to 4 mm is fixed by a string and carefully cut directly on the skin surface.

In all forensic cases it is advisable to collect two separate samples A and B. Sample A must be sufficient for the whole analysis including confirmation or repetitions. Sample B is stored in a separate cover and is left untouched for any cases of objection. We feel much better since we have introduced this system of two samples.



Collection of the hair sample

Identification of the person:

Passport, comparison with photograph, signature

Protocol:

Personal data, date and site of collection, weight of sample, hair lengths, residual length on scalp ,colour, special characteristics (dyeing, bleaching etc.)

Place of sampling:

Hair sampling and hair analysis are not allowed in laboratories and departments where the drugs themselves are handled

Practical performance:

Tuft of hair fixed by a string, cutting directly above skin, ∅3-4 mm, marking of the proximal end

Collection of two samples A and B:

***A: Analysis sample**, sufficient for the whole analysis including confirmation or repetition*

***B: Reserve sample**, left untouched for cases of any objections*

Separate storage in different covers, labelled with name, date of collection and sample No.

Proximal end

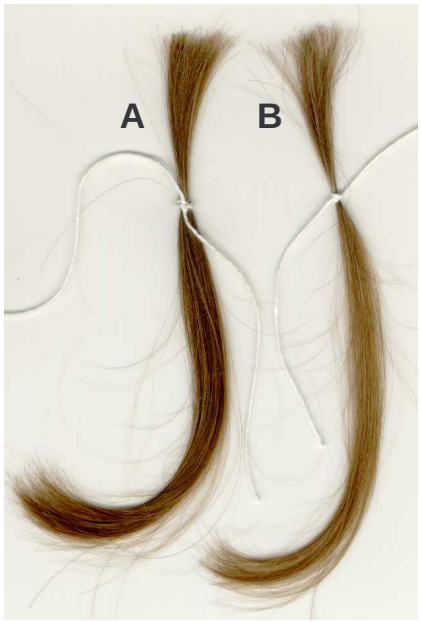


Figure 2. Some important aspects to be taken into account when collecting a hair sample

2.2 Extraction of drugs from hair

The extraction of drugs from hair is the most sensible step of the hair analysis. The drugs are firmly enclosed in the hair structure and partly bound to proteins, melanin or lipids of the cell membrane complex. The extraction yield depends on the drug structure, the state of the hair matrix, grinding, polarity of the solvent, duration of the extraction or use of ultrasonic bath. There are excellent procedures for many drugs described in literature. The most important are hair hydrolysis by sodium hydroxide and subsequent solid phase extraction or hair extraction with methanol or aqueous buffer in ultrasonic bath.

The sodium hydroxide method provides high yields in case of drugs which are stable to alkaline medium such as cannabinoids or amphetamines. Methanol is universally applicable but the extracts have a high degree of contamination from the hair matrix. Basic drugs are best extracted by a neutral or slightly acidic aqueous buffer and subsequent solid phase extraction.

A frequent error in hair extraction is a too short extraction time. This can be controlled in a step by step extraction experiment as shown in Fig. 3 for the methanol extraction of the hair sample of a heroin fatality. It is seen that in this case at least 15 hours are necessary and that the less polar compounds heroin and 6-acetylmorphine are faster extracted than the more polar drug morphine. Since the rate of extraction differs strongly between the cases, a second extraction step can be useful for control.

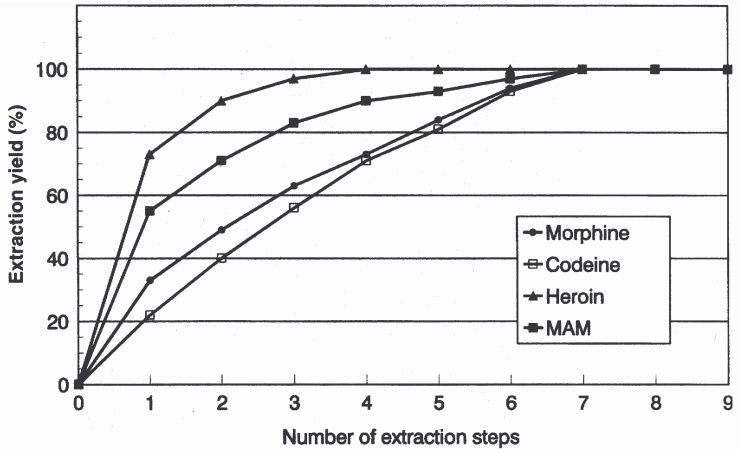


Fig. 3. Extraction of opiates from hair by methanol/ultrasonic bath. Step by step extraction of the hair sample of a heroin fatality with methanol.

From this experiment the necessary extraction time can be determined Non-polar substances are faster extracted than polar substances. The rate of extraction depends on the individual sample

Frequent errors in hair extraction are:
- Insufficient extraction time
- Decomposition of the drug,
- No deuterated standard used

2.3 Analytical methods in hair analysis - unambiguous identification of the drug

The instrumental methods used in hair analysis are in a steady development. Immunoassays can be used only as pre-tests and need a confirmation by a mass spectrometric method. At present, GC-MS with electron impact ionisation in the selected ion monitoring mode is the standard method. It enables for most drugs a detection limit of about 0.03 ng/mg hair. If it is performed according to the quality requirements no second method is necessary for confirmation. Negative or positive chemical ionisation have extended the applicability, particularly to benzodiazepins, by decrease of the detection limit into the pg range. However, this advantage is paid by a decrease in specificity.

The lowest detection limits below 1 pg/mg and high selectivity are provided by GC-MS-MS, allowing to detect the abuse of the low dose opioids fentanyl or sufentanyl or the confirmation of cannabis consumption by determination of the metabolite THC-COOH in hair with concentrations below 1 pg/mg. LC-MS is still an upcoming technique in hair analysis and has advantages for polar analytes.

In order to avoid wrong positive results, the drug must be unambiguously identified. GC-MS in the SIM mode has a very high standard with respect to this requirement. The use of deuterated standards is an inevitable prerequisite. It enables the exact control of the retention time, which is by 0.01 to 0.03 min longer for the drug peaks than for the standard peaks. However, deuterated standards frequently contain small amounts of the non-deuterated drug which may lead to wrong positive results if very low concentrations have to be detected, e. g. after a single drug application.

A further criterion is that the peak area ratio of at least three ions are in a characteristic range, which again can be controlled by the deuterated standard. As an example in Fig. 4 the SIM traces of the cocaine metabolite benzoylecgonine are shown with the ions 321, 442 and 275 for the standard D_3-benzoylecgonine and with the ions 318, 439 and 272 for the substance from the hair sample. From the calibrated peak area ratio of analyte and internal standard the concentration of benzoylecgonine was determined at 3.0 ng/mg in this case. A further confirmation of the drug identity is provided by the presence of metabolites.

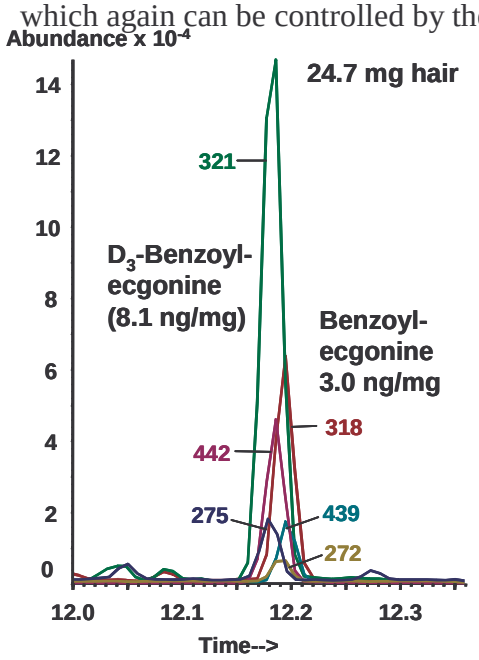


Fig. 4. Identification of benzoylecgonine in a cocaine case

It is shown in the Table 2, that the detection limits of this GC-MS technique are below the hair concentrations usually found after frequent abuse for the most important illegal drugs. Exceptions are the cannabis metabolite THC-COOH with concentrations between 0.1 and 10 pg/mg and LSD where other methods have to be used.

Table 2. Limits of detection and concentrations found in hair after drug abuse.

Drug or metabolite	Concentration in hair	Limit of detection
Amphetamine	0.1-7	0.03
Methamphetamine	0.1-10	0.03
MDMA	0.1-15	0.03
MDE	0.1-15	0.03
MDA (Metab.)	0.1-2	0.03
Cocaine	0.5-30 (>100)	0.03
Benzoylecgonine	0.1-20	0.03
Ecgonine methylester	0.1-3	0.1
6-Acetylmorphine	0.3-20	0.03
Morphine	0.1-10	0.03
Codeine	0.1-20	0.03
Methadone	0.3-20	0.03
THC	0.02-5 (-20)	0.01
THC-COOH	0.0001-0.01	MS-MS required
LSD	< 0.001	EmunElut Extr., HPLC-Fluor.-Det.

2.4 Accuracy of hair concentrations

Having the drug unambiguously identified, the next question is: How exact are the concentrations determined in hair. In Fig. 5 the concentrations of cocaine and its main metabolite benzoylecgonine measured by 17 laboratories in the proficiency test of the Society of Hair Testing 2003 are shown. It was a real and not ground sample of a drug addict. There is a very large inter-laboratory variation, e. g. for cocaine from 0.5 to 4.5 ng/mg. The main reasons of this large variation are differences in the yields of sample preparation. The

hydrolysis of cocaine into benzoylecgonine is not essential as a reason for these deviations, since the same laboratories have positive or negative deviations for both cocaine and BE.

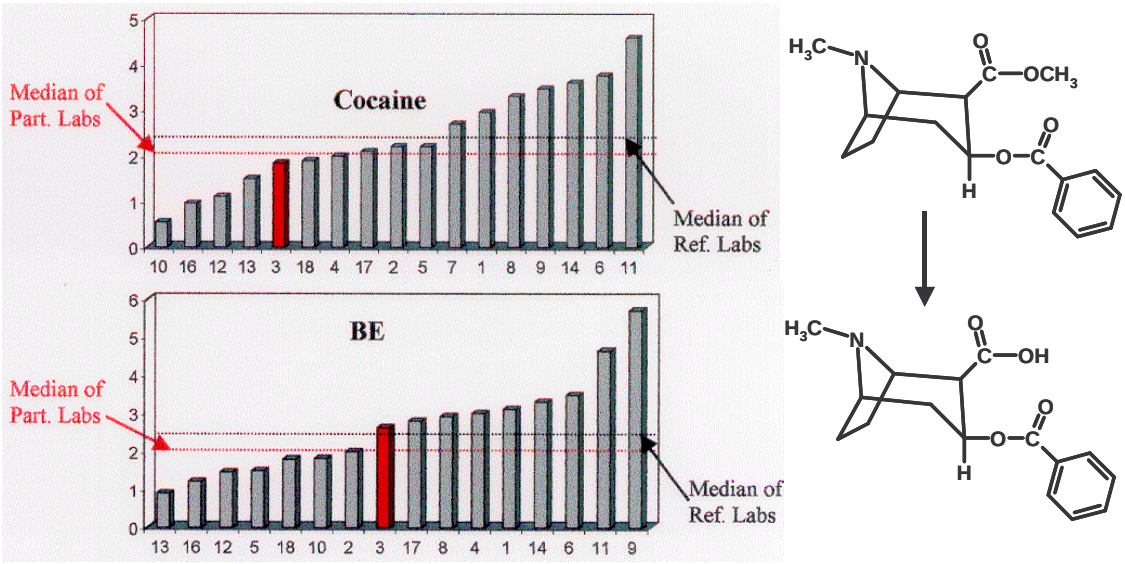


Fig. 5. Concentrations of cocaine and benzoylecgonine determined in the proficiency test of the Society of Hair Testing 2003. It was a real sample of an addict. The hydrolysis of cocaine into benzoylecgonine is not essential as a reason for these deviations, since the same laboratories have positive or negative deviations for both cocaine and BE.

Slightly better results were obtained in this proficiency test of the GTFCh for the heroine metabolites 6-acetylmorphine and morphine also with a real hair sample of a drug addict (Fig. 6). In this case the hydrolysis of the ester groups plays an essential role. Heroin itself is found only after methanol extraction. With buffer extraction 6-acetylmorphine and morphine are detected in different ratios depending on the degree of hydrolysis during the extraction. The very high morphine values can be compensated by low 6-acetylmorphine values. From these results of the proficiency tests follows that on one hand more must be done to improve and to standardise the analytical procedures and that on the other hand quantitative hair results should be interpreted with precaution.

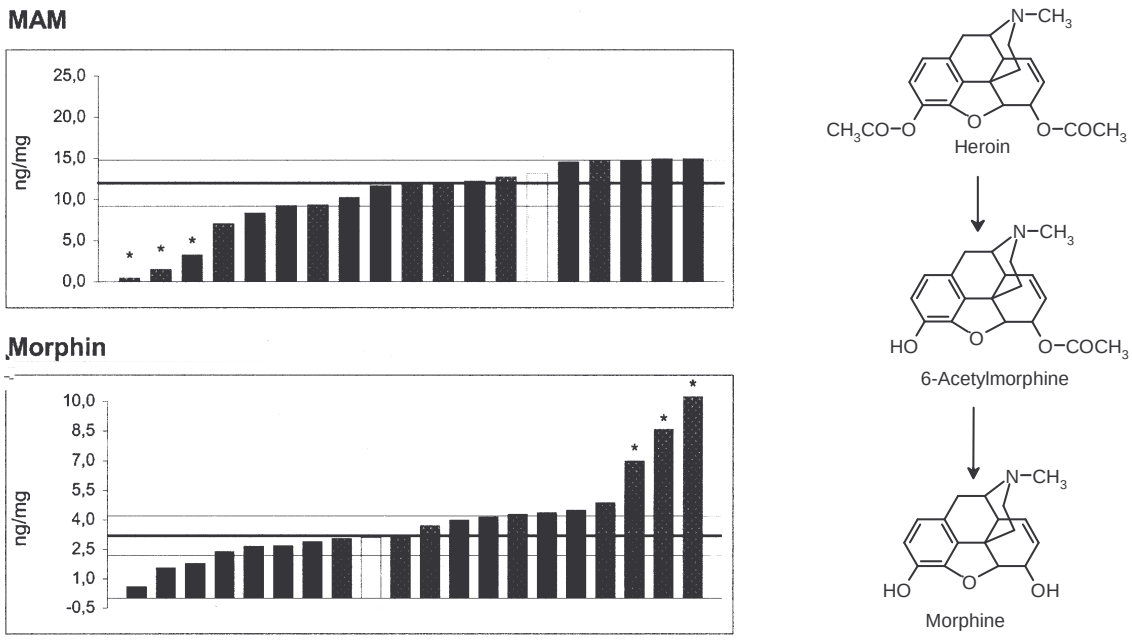


Figure 6. Opiate concentrations measured in the Proficiency test of the GTFCh DHF 2/03 (real sample of an addict). Heroin is detected only after methanol extraction. With buffer extraction 6-acetylmorphine and morphine are detected in different ratio depending on the degree of hydrolysis during extraction.

2.4 The objection of external contamination

A frequent objection in hair analysis is that the drug in hair does not originate from consumption but could have been incorporated from external sources. There are two ways for differentiation: Firstly, in case of external incorporation the drug should be detected in the wash solution in higher concentration than in the hair extract. A specific but very labour-intensive procedure of wash kinetics was developed by the laboratory of Baumgartner and Hill from Psychemedics Corporation in Culver City in California. The second possibility is the detection of metobolites in a typical ratio to the drug. E. g. after cocaine abuse, besides cocaine the metabolites benzoylecgonine, ecgoninemethylester and norcocaine and in case of simultaneous alcohol consumption also cocaethylene can be found (Fig. 7). However, it must be taken into account that the hydrolytic metabolites benzoylecgonine and ecgonine methylester could also be formed from cocaine outside of the body. Unambiguously endogenous metabolites are only norcocaine and cocaethylene.

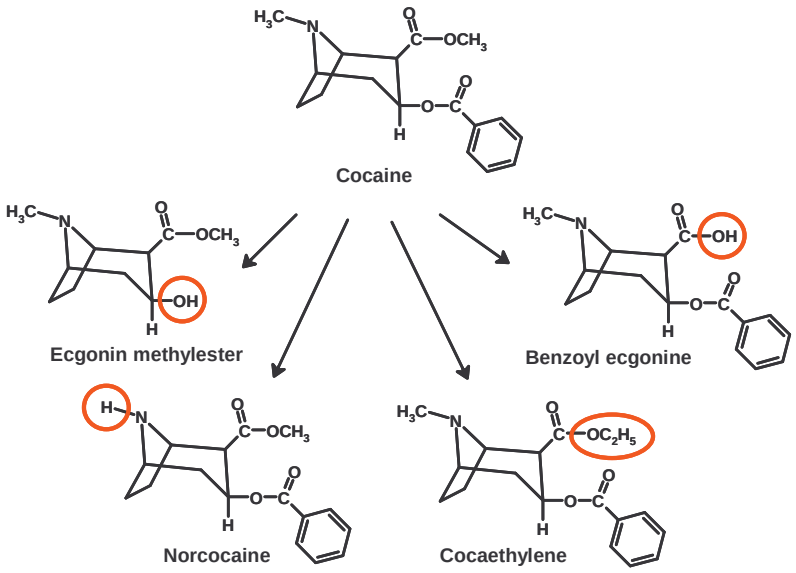


Figure 7. Detection of metabolites for exclusion of external decontamination.

The hydrolytic metabolites benzoylecgonine (BE), and ecgonine methylester (EME) are no real proof of endogenous origin, they could also be formed outside the body. Typical ratio in hair is BE/COC > 0.05.

Unambiguous endogenous metabolites are norcocaine (very low concentrations) and cocaethylene (only detected after simultaneous alcohol consumption)

3. Interpretation of hair results

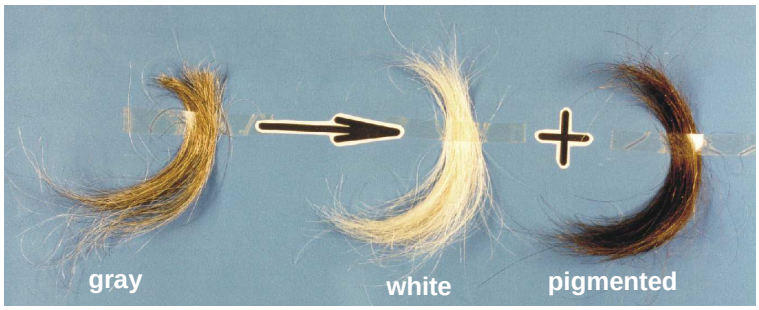
The most serious pitfalls of hair analysis are not in the practical performance but in the interpretation of the results. I will discuss two aspects: interpretation of hair concentrations and interpretation concerning the time of drug use.

3.1 Interpretation of drug concentrations in hair

It is a main problem that there is no inter-individual correlation between frequency of drug use and concentration in hair. This can be concluded from therapeutic drugs since there are almost no prospective and really controlled studies about illicit drugs. Reasons are that already an inter-individual dose – serum level relationship does not exist. Furthermore, the incorporation efficiency differs strongly between individuals. There is an effect of hair pigmentation particularly for basic drugs. Hair differs strongly in its physical state and a

damaged cuticle leads to a faster drug elimination by shampooing. Finally, drugs can be decomposed by bleaching, dyeing and permanent wave.

The effect of pigmentation can be best demonstrated at grey hair samples which are in practice a mixture of pigmented and white hair (Fig. 8). For instance, cocaine was found in white hair only between 5 and 85 % of the concentration in pigmented hair. The reasons for the phenomenon are that melanocytes have a decreased pH leading to pharmacokinetic accumulation of basic drugs, and that basic drugs are also adsorbed to melanin, probably by charge-transfer interactions.



Drug	Concentration ratio wight/pigmented
Cocaine	0.05-0.86 (mean 0.38)
Benzoylecgonine	0.10-1.20 (mean 0.66)
Amitriptyline	0.18-0.58
Maprotiline	0.21
Metoclopramide	0.09

Figure 8. The Effect of pigmentation on drug concentrations in hair was investigated by separate analysis of white and pigmented hair in gray hair. Basic drugs accumulate in pigmented hair.

Nevertheless, despite this large variability, judge, prosecutor, physician or other customer expect a comment what a certain concentration in hair means. It is generally not possible to state for instance in a definite case that a concentration of 10 ng/mg cocaine in hair is an indication for the consumption of 1 to 5 g cocaine per day. The maximum that can be done is to compare the actual value with the data of a typical clientele and state that this value is in the lower, middle or upper range of this clientele.

Jurado proposed for this purpose a statistic evaluation of the own data as in Table 3 for heroin addicts. The lower range is from minimum to percentile 25, the middle range from percentile 25 to percentile 75 and the upper range above percentile 75. In an actual case with 4.2 ng/mg 6-acetylmorphin and 1.1 ng/mg morphine the interpretation would read as follows: The concentration in hair of this individual is in the middle range of those values usually found in cases of heroin abuse.

Table 3. Opiate concentrations (ng/mg) in hair of illegal heroin consumers (n = 73, C. Jurado, 2001)

	6-Acetylmorphine	Morphine	Range
Cut-off	0.1	0.1	
Mean	7.2	3.7	
Minimum	0.0	0.0	Lower range
Percentile 25	1.3	0.9	
Median	3.3	1.9	Middle range
Percentile 75	6.3	4.1	
Maximum	65	54	Upper range
Actual case	*4.2*	*1.1*	*Middle range*

3.2 Interpretation of a negative result

Depending on the offence, a negative result may be favourable as well as unfavourable for the accused. Therefore, also a negative result must be carefully interpreted. It does generally not exclude a single or rare drug consumption and it does not overrule previous positive blood or urine tests.

Case report1: In a homicide case by shooting (March 16, 2001) a witness claimed that the 33 year old violent and unpredictable accused was a cocaine consumer. The 4.5 cm long hair sample was collected three weeks after the date of crime (April 05, 2001). No cocaine and benzoylecgonine was found with a detection limit of 0.03 ng/mg. The usual concentration range of these substances in hair after regular consumption is 0.5 to 30 ng/mg. This result was interpreted in the following way: There is no evidence for a cocaine consumption in the time period of the incident. Addiction to cocaine is improbable. Single or rare cocaine consumption during this period cannot be excluded. In particular it cannot be excluded that the accused was under the influence of cocaine at the time of the shooting.

3.3 Interpretation concerning the time of drug use

One of the advantages of the segmental hair analysis is that a certain statement about the time of drug intake can be made from the position where it is detected along a hair tuft. However, such an interpretation is restricted by experimental as well as biological sources of inaccuracy. Experimental errors could be that the hairs were not directly and not homogeneously cut on the skin surface. In routine samples, this leads usually to a mutual shift of single strands by at least 5 mm corresponding to a time error of about two weeks (Fig. 9).

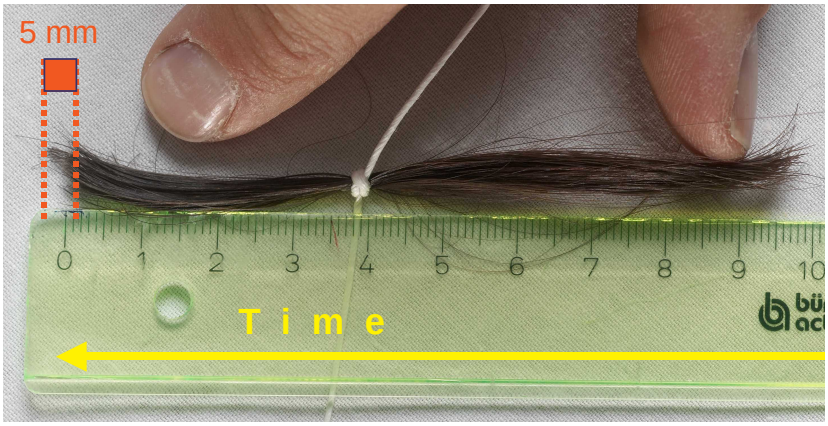


Figure 9. Experimental errors in interpretation of segmental hair analysis with respect to time of drug intake. The hair was not directly and not homogeneously cut on the skin surface. The mutual shift of the single strands is > 5 mm (≈ 2 weeks) in routine samples.

However, in very important cases and for analysis of short segments, e. g. 2 mm, such experimental errors can be minimised if the sampling is very accurately performed and special techniques are used (Fig 10).

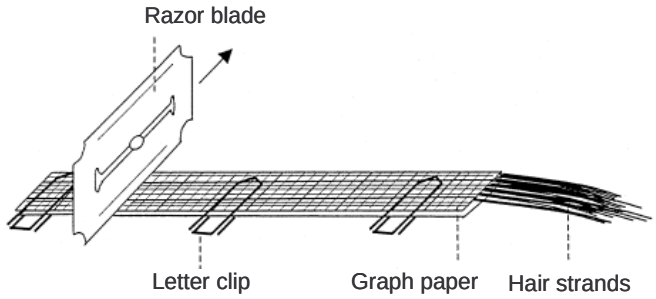


Figure 10. Example of performance of hair segmentation in important cases (e. g. segment lengths 2 mm): Careful cutting directly on skin surface, correction of the alignment of the single hair, arrangement in folded graph paper, cutting with razor blade.

However, a hair tuft is also inhomogeneous for biological reasons (Fig. 11). Human hair grows in a growth cycle consisting of three stages: the anagen or growing stage which lasts 2-6 years in scalp hair, the catagene or transition stage of about three weeks in which the hair bulb degenerates, and the telogen or resting stage of 2-6 months during which the so-called "club hair" still stays in the skin and is finally pushed out by a new anagen hair. The duration of the stages depends on the anatomic site, age of the person and gender. As a consequence a scalp hair tuft contains between 5 and 20 % hair in the telogen stage which can be up to 6 month elder than the majority of anagen hair. As shown in Table 4, pubic, axillary or body hair sample contains about 50 % telogen hair which may be up to 12 or 17 months elder than the growing hair.

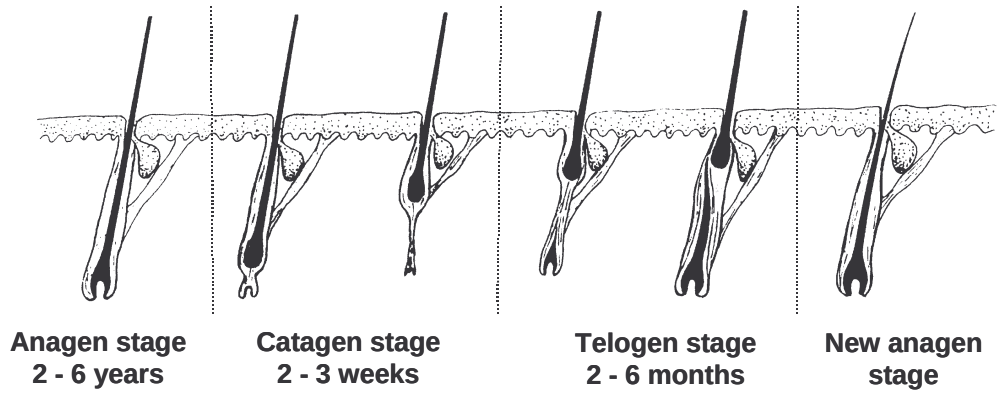


Figure 11. Human hair growth cycle, time periods for scalp hair.

Table 4. Duration of stages and percentage of telogen hair in samples from different body sites

Anatomical site	Anagen	Catagen + telogen	% Telogen
Scalp	2-6 year	2- 6 months	5-20
Scalp, vertex, alopecia			53-84
Beard	14-22 months	9-12 months	35-40
Pubic, Axillary	11-18 month	12-17 months	50
Arm	5-15 weeks	8-24 weeks	60

Furthermore, also the growth rates of the single hairs in a hair tuft differ widely. In Fig. 12 the individual growth rates of 30 to 50 strands were measured by Hayashi et al. in the vertex and in the temporal region for a non-bald person, a person with slight baldness and a person with alopecia. It is seen that the individual grows rate varies by more than 50 %. The growth rate

of a single scalp hair within a tuft may vary from 0.8 to 1.6 cm/month (0.27 – 0.53 mm/day) Pubic hair which is preferentially used if scalp hair is not available grows slower than scalp hair (Table 5).

The consequences of this biological variability on segmental hair analysis are schematically demonstrated in Fig. 13 at the example of a person who stopped drug use 12 month before collection of the hair sample. There is no sharp border between positive and negative hair sections but a more or less broad transition zone. Although the person was 12 month abstinent, the hair sample is positive already from 6 cm in distal direction.

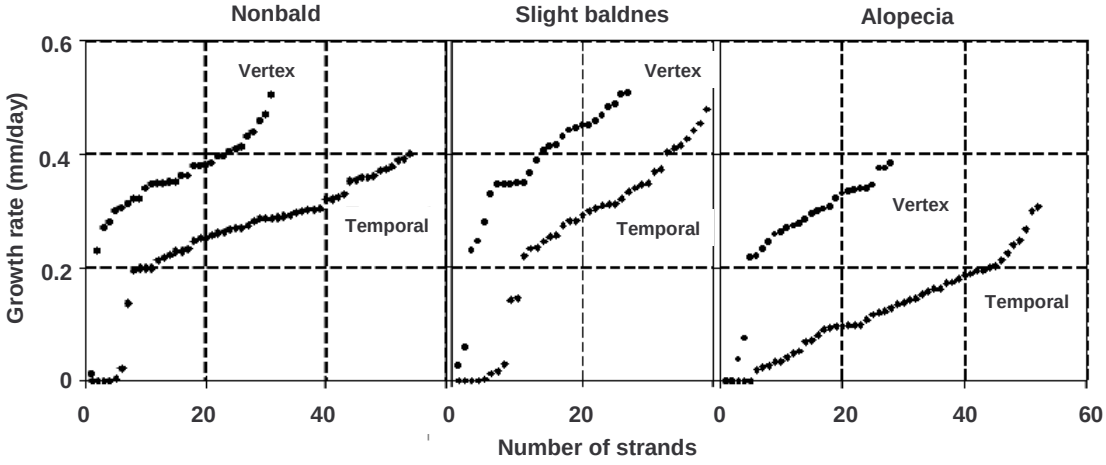


Figure 12. Growth rates in the vertex and in the temporal region for a non-bald person, a person with slight baldness and a person with alopecia (Hayashi et al., 1991).

Table 5. Growth rate of hair at different body sites

Anatomical site	Growth rate	
	mm/day	cm/month
Scalp vertex	0.28-0.47	0.84-1.41
Pubic	0.2-0.3	0.6-0.9
Axillary	0.29-0.33	0.87- 1.0
Beard	0.25-0.29	0.75-0.87
Body	0.22-0.32	0.66-0.96

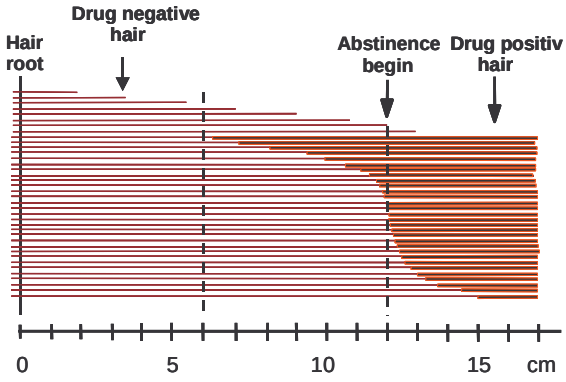


Figure 13. Consequences of hair growth cycle and variation in growth rate on segmental hair analysis of a hair tuft. The drug use was stopped 12 months before sampling. Nevertheless, the hair sample is positive already from 6 cm in distal direction.

The use of hair as a diary of drug use may be even more impaired by the fact that the drug is not only incorporated in the hair root. An essential part can also be deposited from sweat or from sebum. A further possibility is the delayed incorporation from depots in the surrounding tissues. These incorporation ways lead to broadening and superimposition of the primary drug pattern. This shall be shown on three examples.

Case report 2 (Fig. 14): A 26 year old man with habitual marihuana and occasional cocaine use was summoned to hair analysis because of doubts about his driving ability. He stopped drug use and shaved his had. The 2.5 cm long hair sample was cut almost three month later with the result of a high concentration of THC and traces of cocaine. He shaved his head again and appeared another one and a half month later for a new hair analysis. In the 1.5 cm long sample still 0.25 ng/mg THC were measured. This result in hair which grew three months after stopping drug use and twice shaving the head can be explained by delayed incorporation from tissue depots.

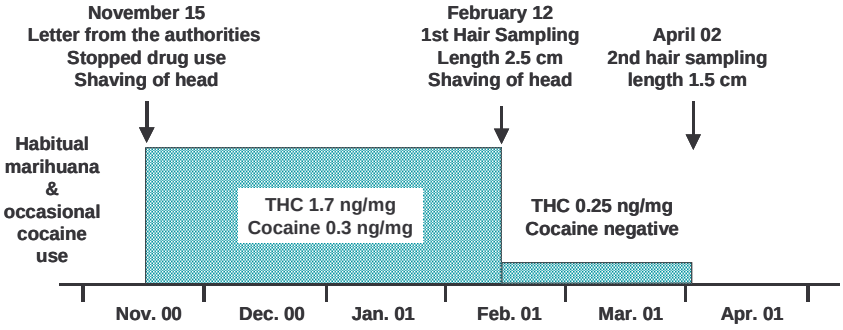


Figure 14. THC concentrations in hair in a driving ability case, 26 m. Positive THC results were found three months after stopping drug use and twice shaving the head. This can be explained by delayed incorporation from tissues.

Case report 3 (Fig. 15): An essential incorporation from sweat was concluded in the case of this female ecstasy consumer. She used the drugs only on techno parties. She reported to have taken only two tablets with the rather rare substance MBDB within 6 weeks. The tablets were marked by a dollar sign. Nevertheless this substance was found in all distal hair segments (most right columns). Usually, techno dancers sweat very much.

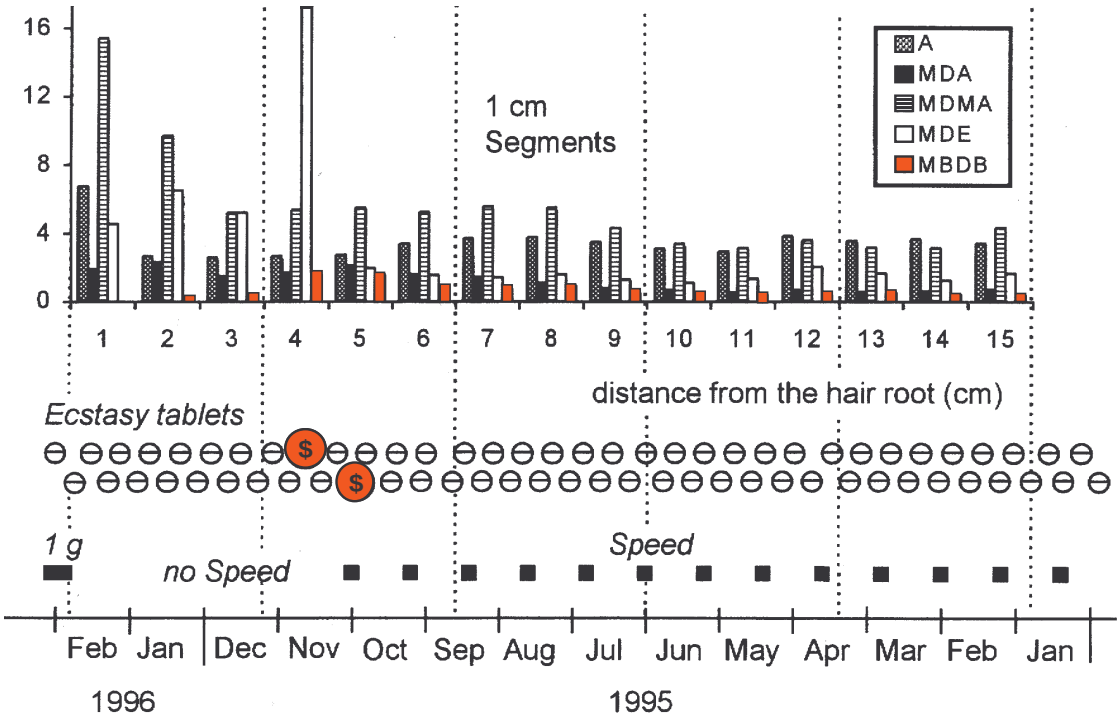


Figure 15. Concentrations of amphetamines and ecstasy drugs in 1cm long hair segments of a 31 year old female ecstasy consumer. She consumed only 2 tablets MBDB (marked by a $ sign) on two rave parties within 6 weeks. Nevertheless, the substance was deposited into all distal segments by sweat (right column).

Case report 4 (Fig. 16): No correlation between consumption time and position in hair was found for fatty acid ethyl esters. These substances can be used as alcohol markers and are incorporated mainly from sebum. Although in this case the 51 year old man had only a relapse of two weeks after 14 months abstinence, the esters were found in high concentration over the whole hair length.

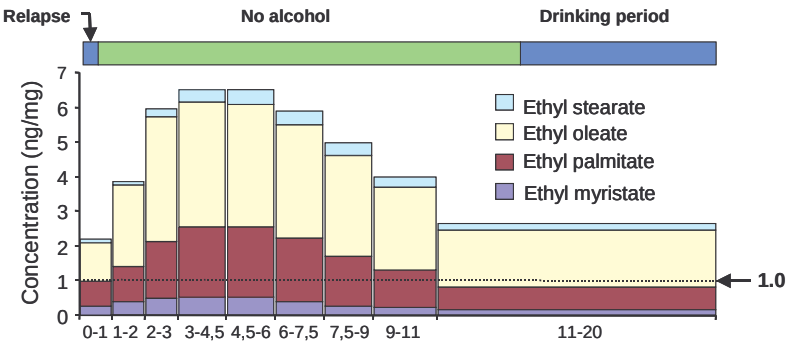


Figure 16. Fatty acid ethyl ester (FAEE) concentrations in hair as markers of alcohol abuse. The 51 year old male alcoholic had a relapse after 14 months abstinence and drunk for 2 weeks 350-400 g EtOH/day (brandy). No correlation is seen between drinking time and position of FAEE in hair. Reason: The FAEE are incorporated into hair mainly from sebum and accumulate with increasing age of the hair.

However, despite these complications hair analysis is a valuable tool for retrospective detection of drug abuse. The incorporation from sweat or sebum does not interfere with the abstinence control in the proximal hair segments. An example is the 33 year old patient shown in Fig. 17 (case report 5). The hair sample was collected more than two years after detoxification from opiates. From the segments of the 50 cm long sample still the change from dihydrocodeine to methadone three years before sampling is seen and it is confirmed that the withdrawal with respect to opioids was successful. But, there was a continued polytoxicomanic behavior with respect to cocaine, ecstasy and cannabis.

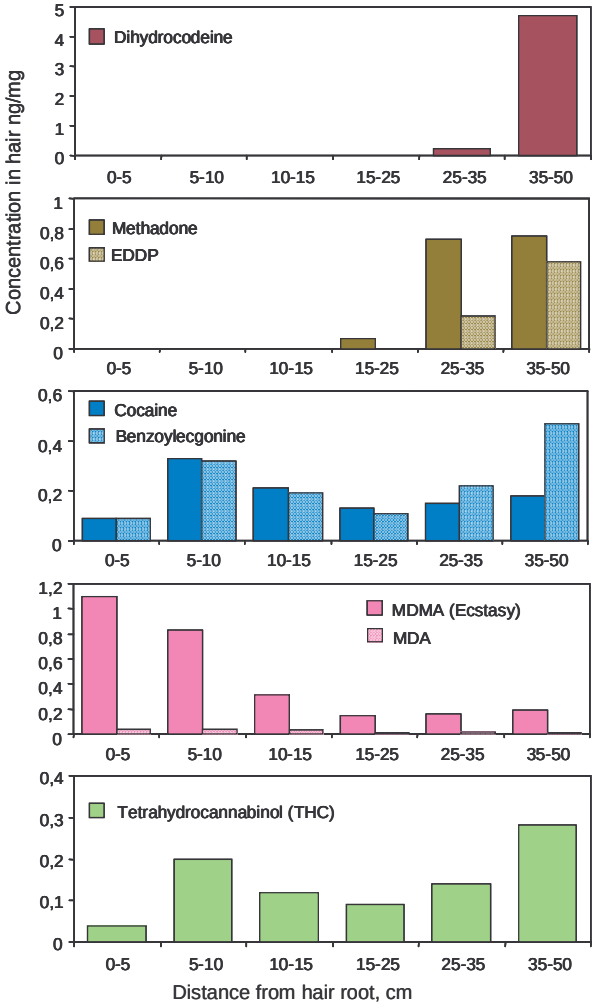


Figure 17. Concentrations of drugs in the hair sample of a 33 year old patient in withdrawal treatment. The incorporation from sweat or sebum does not interfere with the abstinence control in the proximal segments.

The last example to the time aspect of hair analysis shows that scalp and pubic hair may have quite different results which nevertheless complete each other and suit very good to the case history (Figure 18).

Case report 6 (Fig. 18): A 42 year old man was arrested on January 12, 2002 while buying a large cocaine amount. He claimed it was only for his own use. The last cocaine use was on January 11, 2002. The 2 cm long scalp hair and 2.3 cm long pubic hair samples were collected 4 ½ months after arrest. No drug use was possible in this jail. In the scalp hair sample only very low concentrations of cocaine and its metabolites were determined. On the other hand, the concentrations in pubic hair were in the middle range of the values usually found after frequent cocaine use. In this case the time before arrest is not represented by the 2 cm long scalp hair and the low concentration in is only from a small percentage of telogen hair. However, despite the almost equal length the pubic hair sample represents a much longer time period because of the smaller growth rate and the high percentage of telogen hair. This sample confirms the frequent cocaine use in the time before arrest.

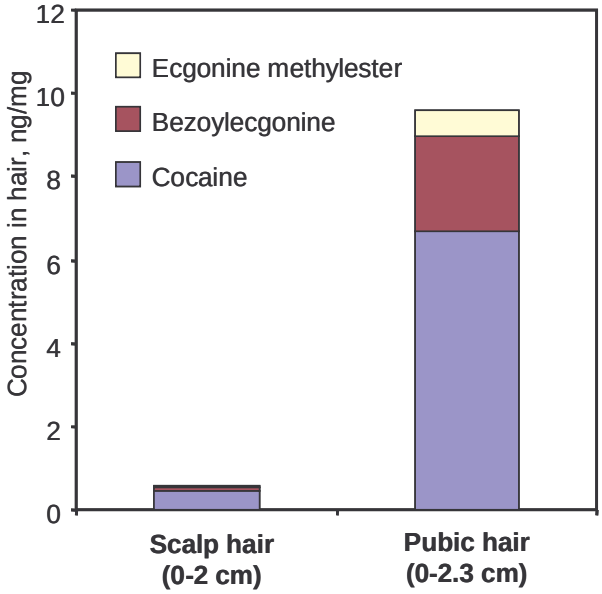


Figure 18. Concentrations of cocaine and its metabolites in scalp hair and pubic hair of a 42 year old drug dealer who was arrested January 12, 2002 while buying a large cocaine amount: The scalp hair and a pubic hair sample were collected on May 31, 2002.

4. Conclusions

Hair is a unique material for the retrospective investigation of drug consumption or poisoning, in selected cases even after a single administration. However, hair varies strongly in its physiological and pharmacokinetic behaviour as well as in its analytical properties. Therefore, hair analysis is not a routine procedure but must occur from sampling to interpretation of the results on the basis of a profound knowledge about physiology of hair growths and incorporation and elimination of drugs in hair. Hair analysis should be performed and interpreted by experienced scientists, who know the limitations of the method and should see the results in the context of the individual case including the data obtained from blood, urine or saliva. The recommendations of the Society of Hair Testing (SoHT) for hair analysis in forensic cases offer a suitable help to prevent sample mix-up, wrong sample treatment, analytical errors and unreasonable interpretation of the results.

References

A comprehensive information about literature to the topic of this paper and special references to the data and examples given above can be obtained from the author on request.