engender the behavior. Personal responsibility must be a part of any safety program, but we need to understand the environmental and other factors that encourage such behavior. We may not be able to change these forces, but research can illuminate the driving forces for alcohol and drug abuse, and may give us insight for other approaches to their control.

A cross cultural look, both within the U.S. and in comparison with other societies, might give some further insights into what we will need to know about alcohol and its abuse. Certain attitudes or behaviors involving use of drugs and alcohol that are found in small groups in society may become more widespread in the future, as often happens with popular culture. We may get insights into the nature and limits of alcohol abuse and impaired driving by looking at cultures that view alcohol use differently than we do.

Exploring these kinds of issues, forces, and scenarios can provide useful pictures of the future. This meeting easily can identify other issues and plausible scenarios, and can provide insights into their relative importance. A strategic planning process, including scenario development, would be an important early project for this decade's research agenda. Simply advocating that we now do the research that was left undone in the 1980's would be short-sighted at best. The 21st Century will demand more forward thinking, more creativity, and a more daring and thoughtful research agenda.

APPENDIX D2
DETECTION AND DETERRENCE OF DRUG AND ALCOHOL ABUSE IN THE TRANSPORTATION WORKPLACE

George M. Ellis, Jr.

INTRODUCTION

Although trends have concerned scientists and industry professionals for at least the past decade, only in the past few years has the extent of drug and alcohol abuse in the transportation industry caught the attention of both the federal government and the American public. Drug and alcohol abuse in transportation has triggered concerns about public safety, environmental protection, and economic impact. Use of these substances is no longer seen as an issue of personal choice or morality. But in spite of warnings, it has taken a few highly visible and catastrophic events to focus public and political attention on the problem.

Three Northwest Airline Pilots were convicted in 1990 for being under the influence of alcohol while flying a commercial airliner during an early morning flight. Ninety-one passengers were on board. The pilots were arrested after landing the flight safely. Tests showed blood alcohol concentrations ranging from 0.06 percent to 0.13 percent (the captain). All three pilots admitted drinking heavily the night before.[1]

In 1988, a Trans-Colorado Airlines Commuter operating as Continental Express crashed at Durango, Colorado, killing the two crew members and seven of the fifteen passengers on board. The National Transportation Safety Board (NTSB) found that the captain's use of "a bag" of cocaine the night before resulted in a degradation of performance which contributed to the cause of the accident.[2]

In 1987, a Conrail freight train improperly passed a stop signal at Chase, Maryland, and entered a main line where it was hit by an Amtrak passenger train at 120 miles per hour. The Amtrak engineer was one of the sixteen people killed. Over 170 people were injured. Both the Conrail engineer and brakeman were judged by the NTSB to be impaired at the time of the crash by their very recent use of marijuana.[3]

In 1989, a Exxon oil tanker ran aground in the Prince William Sound, Alaska. Over 250,000 barrels of oil were spilled causing extensive environmental damage. The ship's captain, who had a known alcohol problem, was judged by the NTSB to be impaired by alcohol at the time of the accident. He had left control of the ship to a junior officer at a critical time in the movement of the vessel.[4]

These catastrophic accidents, however dramatic, should merely draw attention to the very real problem employers face each day in deciding how to detect the impaired operator performing safety-sensitive functions and how to best create a workplace free from the effects of drug and alcohol abuse.[5] In this paper, these topics will be examined from the perspective of looking at research needs for the next decade based on an assessment of the current state of knowledge. Topics to be covered include both chemical and non-chemical based methods of detection and deterrence. In addition, the paper will examine other complementary research needs which may contribute directly or indirectly to these goals.

STATEMENT OF THE PROBLEM

Transportation workers provide their services in complex environments which may change instantaneously from highly tedious and monotonous to extremely stressful and dangerous. They may do so under conditions of

excessive fatigue or temperature, or under other adverse environmental conditions. Regardless of public policy or the public will, some operators will continue to use drugs and alcohol to either medicate or mediate their lives, putting at risk public safety.

It is the feeling of the American public, affirmed by our legal system, that employers of workers in safety sensitive positions have the right to a safe, drug-free workplace, and to protection from the economic and personnel costs associated with the substance abuser. In support of that right, transportation employers may elect or be required to conduct direct or indirect testing for drugs or alcohol[6] and/or to put in place other detection and deterrence programs, including education, prevention, or supervisor intervention. Over the next decade, decisions need to be made on where to place research emphasis to expand our knowledge of how to detect the impaired operator in the transportation workplace. Solutions need to be practical and demonstrate clear cost-benefit to employers.

METHODS OF DETECTION AND DETERRENCE: CHEMICAL BASED

The use of chemical tests to detect drug and alcohol use can be an effective deterrent against workplace substance abuse if properly applied and complimented with non-chemical deterrence programs. In the case of pre-employment, periodic, or random workplace chemical testing, it may be sufficient to know that the applicant or employee is a user of drugs or alcohol. In other cases, notably reasonable suspicion and post-accident testing, an indication of impairment or recency of use may prove important. In all cases, extending our knowledge of both the meaning of tests results and the scientific capability of chemical testing can only serve to improve the detection and deterrence ability for employers.

The Chemical Analysis

The human body excretes some drugs only in the unchanged (parent) form. For most drugs, however, the body will either excrete both the unchanged drug and one or more metabolites, or just the metabolites. In some cases, a metabolite may be unique to that drug. In others, a metabolite may be common to any one of several drugs which may make the identity of the administered drug difficult. Today's chemical-based methods of detection and deterrence seek unchanged drug and/or specific unique metabolites in the body's distribution or excretion systems, including in the blood, urine, breath, saliva, and hair.

It is the consensus of scientists today that an effective analytical system for the detection of drugs of abuse in biological specimens should consist of: (a) a sensitive, drug-class-selective technique such as one of the immunoassays, employed as the initial screening process to identify negative specimens and to select presumptive positive specimens; and (b) a highly specific technique such as gas chromatography/mass spectrometry (GC/MS), used for confirmation of any presumptive positive results.[7]

Immunoassay Screening

Immunoassays are the required technology for initial drug screening for most federally regulated testing[8] and, in combination with GC/MS (gas chromatography/mass spectrometry) is the combination of choice by scientists for the testing of drugs of abuse[9]. Immunoassay techniques can be useful in the analysis of urine, blood, saliva, and hair, although not every type of immunoassay is equally capable in each of these mediums. There are three generally accepted immunoassay techniques commercially available today: radioimmunoassay (RIA), enzyme immunoassay (EIA), and fluorescence polarization immunoassay (FPIA).[10]

The immunoassays are not necessarily comparable. In some cases, there can be marked inconsistencies between the various immunoassays in their cross-reactivity with the same analytes. Variances in sensitivity to a specific analyte within a particular drug class may make a clear difference in the ability to detect a drug-using operator depending on the immunoassay which has been selected by the employer's laboratory.

As an illustration, the current principal RIA kit manufacturer provides separate methamphetamine and amphetamine specific assays. Depending on the choice of the assay, under certain circumstances, use of methamphetamine or amphetamine by an individual will remain undetected. The other two immunoassays detect both drugs in the same analysis.[11] All of the opiate immunoassays, on the other hand, are specific for both codeine and morphine. Codeine and morphine based drugs, heroin, and poppy seed use can be detected. However, RIA, EIA, and FPIA are all unable to effectively detect most of the synthetic narcotics. Hydrocodone, meperidine, methadone, oxycodone, and propoxyphene are essentially not detected with the opiate test.[12]

Another type of problem with the various immunoassays is that within large drug groups such as the barbiturates, the assay's capability to detect a specific drug may vary depending on the drug's cross-reactivity with the "anchor" analyte. With the barbiturates, all

three immunoassays are constructed around a drug which is no longer prescribed very often (secobarbital) and are not very sensitive to the more commonly used barbiturates (notably butalbital and phenobarbital). At low to moderate concentrations in urine, the drug(s) will often be missed.[13] Similarly, the benzodiazepine immunoassays have varying degrees of sensitivity to most of the newer more potent versions (including alprazolam, triazolam, and lorazepam). Differences in sensitivity for both parent drug and metabolites can severely limit the detectability of these drugs.[14]

Although it is recognized that reworking an immunoassay is time consuming and costly, the issues identified here are illustrative of some of those that are likely to continue to impact the ability to detect the impaired or drug using operator. Among employers, there is the reasonable assumption that the immunoassays are completely comparable and they can detect equally a much broader range of drugs then they do.

Recommendations for Future Research: Over the next decade, it would be beneficial to encourage manufacturers to update and upgrade their immunoassays to adequately and consistently detect a broader range of analytes then is currently true. Manufacturers should be encouraged to try to develop more flexible technologies capable of broadening the existing drug classes, such as the opiates, in order to detect additional drugs from the general class in a single test, such as some of the non-opiate narcotics. The development of immunoassay "cocktails" covering a broader spectrum of analytes should be encouraged. Additionally, manufacturers should work to increase the sensitivity of their assays to some of the more important analytes so that significantly impairing drugs will no longer be missed.

Gas Chromatography/Mass Spectrometry

The gas chromatograph using a mass spectrometer as a detector (GC/MS) has exceptional capabilities.[15] However, it has been shown that all drug confirmations performed by the GC/MS are not going to be unequivocally correct unless care is taken in selecting the analytical procedures to be used and the operating parameters for the method. Depending on what drugs are to be detected, and whether they are to be evaluated qualitatively or quantitatively, currently determines what methods of operation are to be used (full scan or selected ion monitoring, chemical ionization or electron impact, etc). While GC/MS provides the most specific technique available, it is also costly and still demands a high degree of technical expertise to operate and maintain the equipment and—most importantly—to interpret the results.

Over the next decade, several areas of evolving hardware technology for confirmatory testing may prove worth watching.[16] These include MS/MS, GC/MS-MS, GC/Ion Trap MS, and HPLC (high pressure liquid chromatography)/MS.[17] Most of these will involve a significant financial investment by a laboratory, along with a commitment to a much more complex set of technologies. At the present time, most of them do not seem to offer a significant increase in analytical capability for the standard drugs of abuse.

Recommendations for Future Research: In the upcoming decade, increasing emphasis should be made on upgrading the hardware and software technology of standard GC/MS based confirmation systems. Areas of interest should include increasing the speed of the analysis, lessening the expertise needed to conduct the test, evaluating new robotics capabilities, and improving the hardware and software capability of the instrumentation to identify, confirm, and quantify with absolute certainty the drugs of interest. Attention should also be given, however, to the question of whether existing standard GC/MS hardware will continue to be adequate for the commercial drug testing laboratory, or are the new hardware combinations going to offer such a significant improvement in detection capacity as to warrant the substantial investment and the consequent increase in operational complexity.

On-Site Testing

Current regulations mandate that all drug testing conducted under federal authority be done at a specially certified laboratory.[18] Both the screening and confirmatory analyses must be done under the same roof under very strict scientific conditions established and monitored by the National Institute on Drug Abuse (NIDA).[19] This requirement is unlikely to be changed in the near future. In spite of the fact that most drug testing is laboratory based, the use by employers of on-site chemical testing (i.e., at the workplace or at a medical clinic) still occasionally occurs using urine, saliva, and breath. Because of limits in the technology involved, most on-site testing strategies should prudently limit themselves to initial screening-level tests only. Nonetheless, employers are still interested in lower cost alternatives to some of the higher costs of mandated laboratory-based analyses.

Currently, the commercial interest in on-site testing seems to be directed more towards the development of inexpensive, completely self-contained screening devices which can accurately detect the presence of the drug of interest or alcohol and not require expensive equipment,

trained personnel, or the significant mixing of any chemicals or reagents. Although they are often touted for pre-employment testing as well, their principal value may be for reasonable suspicion and post-accident testing situations in isolated locations, for emergency rooms, and/or for substance abuse treatment facilities.

In urine, self-contained screening tests for drugs have had a slow start and previous commercial efforts in the past decade have had problems with both false positives and false negatives. Recent efforts appear to be more successful and show greater promise for commercial application. Most of these applications are designed to be inexpensive and require little technical training to use. Currently, the better of these devices have a built-in quality control check and are often based on a latex agglutination immunological reaction.

In saliva, most current interest in a commercial application continues to be in the detection of ethyl alcohol. Like urine, previous attempts at a commercially marketed test devices have had problems with false positives and false negatives.[20] Some of the more recent commercial saliva alcohol testers appear to have resolved most of the technical problems of the earlier devices. Devices based on an enzyme reaction, offering a rough quantitative measure of blood alcohol concentration using a color bar "thermometer" approach, and with an attempt at an internal quality control measure would seem to hold the most interest. There have not been many saliva on-site test devices for drugs other than alcohol, in spite of the promise of the specimen type[21] (see also Section 3.4.4.).

With breath, there have been a proliferation of alcohol test devices that are applicable to on-site testing. Many of these operate on the principal of chemical oxidation and result in a color change which gives a qualitative result varying in accuracy depending on the quality of the device. Better quality hand-held devices offering accurate, quantitative readouts are available using electrochemical oxidation (fuel cell) and other technologies. Currently, proposed federal regulations for many transportation workers will mandate use of breath-alcohol testing devices in pre-employment, random, reasonable suspicion, and post-accident situations.[22]

Recommendations for Future Research: Over the next decade, policy attention should be given to consideration of on-site screening devices in urine, salvia, and breath as an alternative (backup) or emergency alcohol or drug screen for carefully limited types of testing situations. In addition to encouraging far more research in the validation of these commercial applications, efforts should be made to establish standards for their use. These should include, but not be limited to, use of an approved or scientifically accepted technique (such as immunoassay for drugs), the requirement of at least a negative (and hopefully also a positive) control located on the device, sufficient research to establish capability at the established cutoff, a qualitative readout which does not require any real level of subjective interpretation, and stability of the readout for at least several weeks after collection under protected conditions.

Drug and Alcohol Levels and Impaired Performance

There has been sufficient experimental data and scientific reports which suggest that drugs, alone or in combination, can significantly impair an individual's ability to perform safety-sensitive duties such as those which dominate the transportation workplace.[23] The challenge and the complexity of establishing impairment levels for individual drugs other than alcohol, however, is substantial. Concentrations of a drug and/or its metabolites in body fluids must be correlated to dose-related impairment of selected tasks in a laboratory setting. If possible, concentrations which show impairment in one body fluid, for example, will also need to be extrapolated to equivalent concentrations in other fluids.

One recent review attempted to summarize the research relating the presence and concentration of specific drugs with measures of performance.[24] The purpose was to evaluate the feasibility of using chemical testing in plasma/blood, urine, and/or saliva to determine when performance is impaired. Conclusions were drawn primarily from single dose studies in controlled laboratory environments. In the review, sufficient data was available to discuss only a very few drugs (marijuana, diazepam, secobarbital, diphenhydramine, and methaqualone).[25] An attempt was made by the authors to set conservative threshold drug concentrations to establish presumptive impairment levels for these drugs, similar to those already established for blood alcohol concentration (BAC). The concentrations provided in the review have not yet been generally accepted by the scientific community.

It is clear from a review of the research literature that many of the drugs of interest do not have completely developed pharmacokinetic or pharmacodynamic profiles. In many cases, there is insufficient existing data to establish plasma level vs. impairment curves, so only impairment duration calculations could be made. Extrapolations, interpolations, and logical extensions are often required to overcome what appears to be a very limited data base. Continuing to pursue this scientific problem over the next few years by post-study manipulation of data is

unlikely to be particularly useful.

Recommendations for Future Research: The principal scientific question is whether certain concentrations of drugs can be correlated with transportation workplace impairment as has been possible with alcohol. If this area is to be a productive avenue of research over the next decade, substantial resources have to be dedicated and specific research protocols have to be established to pursue these problems in a controlled laboratory situation with one or more drugs that are of interest. In order to do that, it may be necessary for a number of additional questions to be debated, including the type of tests necessary to measure impairment in the transportation workplace, drug and dose issues, specimen type availability, and the ability to extrapolate or interpolate from limited data.[26]

The Search for Impairment Levels for Identifying the Impaired Operator: Specimens of Interest

The most common method of detecting the impaired operator continues to be urine drug screening. It is generally concluded by the scientific community that urine tests reveal previous use of a particular drug (within certain timeframes), but cannot tell exact recency of use or how much drug was used. Other specimen types (blood, breath, saliva, hair) have varying degrees of potential for detecting the impaired worker or determining recency of use.

Blood

It is the consensus of scientists that all factors considered, blood remains the most valuable specimen available to determine impairment or intoxication, level of use, or recency of use. With blood, the presence (or absence) of parent drug and/or specific metabolites gives a much more useful picture for the interpreting scientist then is generally true for other specimen types. It is also the type of specimen which can best protect a donor from false charges of being impaired or under the influence. Regardless, because of its arguably invasive nature, blood will continue to be rarely taken as a specimen under most drug testing programs except in the occasional reasonable suspicion/reasonable cause or post-accident provisions of a few company policies.

Even with blood results, the interpreting expert may be still very limited and may only be able to give broad ranges of the meaning of a result. Research directly affirming the presence/absence of specific analytes at certain levels is far from absolute evidence about the behavioral effects of a drug on an individual. When drugs are used in combination or chronically, the interpretive picture is substantially muddied. This is true even for drugs with a reasonably developed research literature, such as marijuana (see Section 3.5).

Blood alcohol concentration (BAC), however, has found forensic acceptance as a "per se" indicator of impairment and is certainly the most widely requested analysis in analytical toxicology. In spite of the lay community's confidence in the meaning of BAC, there are many factors which may color interpretations in both live donors and deceased subjects.[27] The literature is extensive, however, and the physiological and pharmacological factors which effect the correct interpretation of BAC are for the most part known. Although perfect consensus in the scientific community has been far from achieved, the debate may be made on the basis of the interpretation of reasonable evidence.

Urine

It is the consensus of scientists that the results from urine testing only indicate the presence of a drug and that the donor has been using or abusing that drug within some finite time frame before the collection. The time frame can be described in general terms based on previous research on the excretion patterns of known amounts of drug in the urine of human subjects. Principal among the problems with urine is that it is an excretion product and that target analytes may still appear for some time (days or even weeks) after last use, and that analyte concentrations are often easily affected by pH and the flow rate of urine. Tremendous variations of urinary concentration are possible because of fluid intake even when the supply of the drug to the kidney is relatively constant. Like the other specimen types, interpretations of urine results are made more complicated because it is sometimes impossible to be absolutely certain of the source of a positive test without substantiating information.[28]

Urine results are rarely useful in the determination of per se drug impairment and intoxication.[29] Very occasionally, the concentration in the urine is sufficiently high that some scientists may be willing to suggest a possible link to impairment based on urine results obtained in direct impairment studies.[30] It is sometimes slightly easier to relate concentration of certain target analytes in urine to dose and time intervals, and once this is done certain guarded statements might be made by a qualified expert.[31] But this can be dangerous ground given the current state of knowledge, and extreme caution with such interpretations is usually the most scientifically sound position.

Even the results of urine alcohol tests, where alcohol does have an impairment index (blood alcohol concentration equivalent), must be closely scrutinized based on the pooling of excreted alcohol in the bladder since the donor's last void. Unless precautions are taken, individual variations may give a slightly elevated

reading.[32]

Breath

The principal application of breath testing has been in the identification and quantification of ethyl alcohol for the determination of blood alcohol concentration (BAC) equivalency. There is a substantial body of experimental and epidemiological research which has validated breath-alcohol testing with driver performance, impairment, and crash involvement.[33]

Like all indirect tests of blood alcohol concentration (BAC), breath testing relies on the principle of equilibrium between the concentration of alcohol in the blood and in the lung. The equilibrium between blood and breath occurs in the deepest part of the lung tissue (the alveoli) and the breath sample must be taken from this alveolar breath. For many years there has been an established blood/breath alcohol concentration ratio range in both the scientific and the forensic literature which defines the necessary equilibrium.[34] In addition, there has been some interest among forensic scientists in establishing a separate breath-alcohol concentration standard (BAC_{br}). A breath sample is considered to be a generally non-invasive test and has a significant on-site detection capacity.[35]

Of the common drugs of abuse, marijuana has been mentioned as having potential for breath detection,[36] but little research has been completed. Because of the expected low levels involved, it is not expected that breath cannabinoid analysis will be of much interest in the future.

Saliva

Saliva has been proposed as a suitable specimen for the detection of drugs of abuse since the 1970s and for ethyl alcohol since the 1930s. Today, saliva is seen as having good potential and value as a specimen in the detection of ethyl alcohol and many of the other drugs of abuse.[37] The physiological source of analytes detected in saliva varies depending on the drug. Although most drugs appear to be transferred to saliva by the blood, marijuana metabolites, for example, do not.[38] Instead, marijuana and its metabolites appear to be sequestered in the buccal cavity during smoking and can be detected directly.[39] Saliva has therefore been suggested as a valuable medium for the detection of very recent marijuana use in reasonable suspicion or post-accident situations.

There are noticeable between-drug variations in the length of time parent and/or metabolites are present in saliva and in the relative amounts of drug present in blood and/or urine.[40] To date, most drugs do not yet appear to be candidates for reasonable suspicion and post-accident impairment determinations even though saliva is an ultrafiltrate of interstitial fluid and often will contain the free component of drugs.[41] However, because in some cases saliva analyte concentrations seem to correlate with levels in the blood, the result might be helpful in determining that use was recent.

One of the other advantages of saliva for the drugs of abuse is that it is a noninvasive and private collection, and it is a sample less vulnerable to adulteration. At the present time, use of saliva in a drug testing program is limited by our incomplete knowledge of the concentrations and length of time analytes remain in detectable amounts and the necessity to determine individual analytical laboratory protocols and cutoffs for the various drugs of interest.[42]

Saliva alcohol determinations have been given commercial application for a number of years. Although blood, breath, and urine are the most popular for alcohol analysis, saliva has been occasionally used as an alternative specimen. Unlike blood, saliva is considered noninvasive for alcohol testing. Saliva appears to have reasonable correlation with blood values for purposes of blood alcohol concentration estimations,[43] and the blood/saliva alcohol ratio may remain stable for many hours after last use.[44]

Hair

Hair analysis has proven to be a useful tool with varying degrees of success in forensic toxicology, environmental toxicology, clinical pathology, and nutrition. There is little still known about the mechanisms by which drugs gain entry into the hair. It is known that drugs and other substances can obtain access both through absorption from the outside environment and through incorporation into the hair shaft from the blood supply. Drugs can enter the hair from outside exposure by way of aerosols, smoke, shampoos, cosmetics, dust, fumes, vapors, or from secretions from the two hair glands.

There are currently a number of analytical methods capable of detecting drugs of abuse in hair.[45] Analytical sample preparation practices, such as washing steps, have occasionally been found to lower drug concentration in a hair sample. Also, washing procedures may not remove all of the drug from environmentally contaminated hair, suggesting the possibility of false positives.[46] Preliminary research on drugs of abuse in hair has also demonstrated that there is generally a significant variance in concentration found in the various hair locations of an individual. Research has indicated that at least some hair samples (i.e., beard) may be capable of dose-related evidence of time and degree of exposure.[47]

Because of its vulnerability to outside contamination

and the variable concentrations found in different body locations, hair analysis may be of little use in telling the amount of drug used. However, research indicates that concentrations of some drugs can be found in hair after only one use, although the minimum dose that will produce a positive result is still unknown. There are some indicators that hair analysis techniques may eventually prove to be extremely sensitive to the presence of drugs in hair. At the present time, however, the application of hair analysis in any situation other than an experimental setting should be closely considered.[48]

The Search for Analyte Markers for Identifying the Impaired Operator

It would be clearly impossible for employers to defend against the universe of possible substances of abuse through chemical detection means. There are simply too many drugs and too many possibilities, with science developing more abusable compounds every day. Therefore, chemical methods of detection and deterrence must target certain drug groups and certain specific drugs within that group in order to attempt to cover the most likely possibilities.

The two most important issues for the future, however, may be to hopefully determine the presence (or absence) of unchanged drug and/or metabolites which appear for only a short period after use, and to determine ratios of drug and/or metabolites which can only be reflective of very recent use. If the identification of such markers are possible, it would work towards assuring a scientifically credible chemical means to detect the impaired operator. Of the major drugs of abuse, the most research in these particular areas has been with marijuana and cocaine.[49] Based on the research literature, although there is reason to remain hopeful, data is insufficient at this time to establish clear predictors of recent use or impairment.

Ethyl alcohol has the capability of blood alcohol concentration (BAC), and has an extensive body of research literature which supports it as a determination of recency of use and for an "under the influence" determination.

Recommendations for Future Research: Over the next decade, continued research should support the existing drugs where potential still exists to establish analyte markers or ratios indicative of recent use (such as marijuana and cocaine), and to initiate study with the other principal drugs of abuse to determine if any real potential exists.

Future Challenges to Detecting the Impaired Operator: New Potential Abused Substances

Ethyl alcohol and the current drugs of abuse (marijuana, cocaine, opiates, phencyclidine, amphetamines, barbiturates, benzodiazepines, and hallucinogens) are generally conceded to cover the most likely substances to be found in impairment situations. However, over the next decade, there may be a number of substances which may need to be addressed in order to protect the public from the impaired worker.

Anabolic Steroids

Use of anabolic steroids and related compounds, once only popular with body-builders, are reported to have become increasingly popular among a wide range of athletes of varying ages. Anabolic steroids are derivatives of testosterone, the natural male hormone. One of their first applications was an experimental use by Germans in World War II to increase aggressiveness in its troops. Since then they have been abused by world-class athletes in a number of countries in order to attempt to enhance performance. Recent media reports have indicated substantial abuse among high school and college age men and women athletes. Anecdotal reports have placed abuse in the transportation workplace among weight-lifters and other part-time athletes.[50]

Recommendations for Future Research: Over the next decade, rates of use of anabolic steroids and other related compounds in the workplace should be carefully observed. The development of a rapid and sensitive screening capability which covers a broad number of these substances might prove to be an excellent proactive detection and deterrence step.

Designer Drugs and the Opioid Peptides

Although rates of use of some of the more esoteric and "designer"-type drugs are not high, attention should be kept on epidemiological trends. Certainly, the capability for abuse is significant,[51] and they pose problems in detection given current analytical strategies. Several drug families evoke special concern, including the phenylethylamines and various synthetic narcotics including the meperidine derivatives.[52]

The identification of opiate receptors in the early 1970s helped trigger the search for endogenous opiate-like substances found in the brain. In this early work, pentapeptides with morphine-like activity called enkephlans were isolated.[53] This was soon followed by the identification and isolation of larger polypeptides with greater activity (endorphins). At various times,

interest has been triggered in these compounds as agents to help resolve opiate addiction, to assist with problems of stress, to treat certain mental illnesses and disorders, and to remedy pain.

Certainly, the potential of this field will continue to be extraordinary. The principal scientific interest has been to find orally administered, stable opioid peptides of long duration which are going to be non-addicting. To date, it is probable that several thousand analogs have been synthesized. As yet, the hunt for a non-addicting opioid has been unsuccessful.[54] Instead, if these mistakes catch the interest of the drug use underground, we have created a whole generation of compounds which may contribute to the world's drug abuse problem and which may overwhelm our capability to rapidly and flexibly detect them. Areas of concern would be both in the misuse and abuse of the growing list of addicting synthetic compounds, but also in the development of triggering mechanisms which may cause the release and/or manipulation of the endogenous opioids already in the brain.

Recommendations for Future Research: Current chemical detection and confirmatory strategies reasonably target a limited number of specific drugs which are those most likely to be found in the target population. This approach will remain acceptable until drug using populations choose to select substances which avoid current chemical means of screening and confirmation. Some thought should be given to innovative and creative strategies of chemical detection which may allow better flexibility without sacrificing our current detection capability.

Defending Against Sample Dilution, Adulteration, and Substitution

The validity of urine drug testing results is necessarily predicated on the quality of the collection process, since the best opportunity for the impaired operator to defeat the test is at the point of sample collection. Because of issues of privacy, the majority of urine drug test collections today are monitored collections and are not directly observed, except under very specific circumstances. Even under close monitoring, there can be ample opportunity for the prepared donor to purposely dilute or to adulterate their samples and to defeat the test.

In general, methods have been classified as "in vivo" and as "in vitro" approaches.[55] With in vivo approaches, methods of masking drug use by purposely ingesting certain vitamins, herbs, special fluids (i.e., vinegar), or special masking "potions" have proven generally unsuccessful.[56] Nonetheless, underground sources still persist in at least suggesting or advertising them.[57] Other in vivo approaches can be more successful.[58]

In vitro approaches offer the donor the most assured means to defeat a drug or alcohol urine test. The purposeful placement of various materials and fluids directly into the voided sample itself can have varying degrees of success and can be the most productive means to produce a negative test.[59]

Recommendations for Future Research: Future research needs in this area principally revolve around the need for better detection of sample adulteration and dilution. Current methods of detection are problematic and rely to some degree on luck. Extensive effort seems to be warranted to discover markers for adulteration or dilution which are not assay or method specific, but which can be used to routinely and accurately defeat attempts to compromise test program integrity. An inexpensive laboratory test which could detect a broad range of adulterating substances in urine and which is suitable for application in mass urine drug screening programs, would be an outstanding asset. Greater use of administrative sanctions applied by the employer and/or the appropriate legal system for the purposeful use of adulterants and diluents, are also strongly encouraged.

METHODS OF DETECTION AND DETERRENCE: NON-CHEMICAL BASED

The use of chemical means of detection and deterrence is seen to have value because it can sometimes provide objective, scientific measures of drug and alcohol use, and in some cases, of impairment. Reliance on only chemical means of detection can be dangerous, however, because no chemical detection method is invulnerable to being defeated by a knowledgeable employee wishing to escape detection. The use of non-chemical means of detection and deterrence have extreme value to employers, especially to supplement and/or compliment drug and alcohol testing programs.

Education and Prevention Programs

There are two general types of drug and alcohol abuse prevention programs: primary and secondary. In this context, primary prevention programs are those usually implemented before the onset of any problems and principally revolve around basic education on drugs and alcohol and on positive measures designed to enhance interpersonal relations, self-esteem, self-concept, values clarification, decision-making skills, and personal and social development as they relate to drug and alcohol abuse.

Theoretically, primary prevention programs are often

too late for implementation in today's workplace. In fact, primary drug and alcohol prevention programs seem to be best suited for children at the elementary school level where drugs and alcohol first start becoming prevalent.[60] It is the consensus of prevention professionals that basic drug and alcohol education alone is generally ineffective as a sole prevention strategy.

Secondary prevention programs usually focus on specific skills and strategies for employees and supervisors to deal with drugs and alcohol in the workplace. These programs often include a component on drug and alcohol behavioral indicators and training on recognizing signs and symptoms of use and abuse. However, basic education on drugs and alcohol and the development of interpersonal and decision-making skills may also have significant value in secondary workplace prevention programs.

The problem with implementing education and prevention programs in the workplace is that it is often difficult to gain a true evaluation of their long-term effectiveness. Certainly, pre and post testing can indicate what has been immediately learned. But whether an education or prevention program has any long-term impact or deterrent effect on a particular workplace is extremely difficult to quantify. Comparative evaluations or research on prevention strategies may never be of significant practical use because of the complexities of a specific workplace environment, changing personnel mixes, and evolving company cultures. The fact is, it may be sufficient to say that education and prevention programs can be effective if only because they call attention to the problem and management's interest in a drug-free workplace.[61]

Supervisor Training and Identification Programs

Supervisor training programs are often an important part of good workplace secondary prevention programs. The typical supervisor training program today is intended to provide basic information on drug and alcohol abuse, to equip supervisors to recognize performance and behavioral indicators of employee problems in both an acute (crisis) situation and over a longer term degradation of performance, and to assist supervisors to act appropriately when confronted with an employee whose job performance or overt behavior may indicate use of alcohol or drugs.

A typical supervisor training package should at a minimum cover alcohol and drug information, including definitions, drug classifications, modes of administration, observable effects, and material indicators of the use of particular drugs. The package would also ordinarily include specific signs and symptoms of drug and alcohol use, as well as impairment indicators. This information is usually presented in a didactic fashion and is designed to give supervisors specific knowledge which will contribute to a determination that reasonable cause testing or a fitness for duty examination is necessary.

For some employers, supervisor training is more advanced and will also teach skills on how to directly handle both the crisis intervention and the long-term degradation of performance situations. These knowledge and skills would ordinarily include training on how to handle the intervention/confrontation, as well as the process of problem identification and resolution (problem recognition, how to conduct the confrontation, supervisor do's and don'ts, recommended action, and proper documentation). Just as importantly, the supervisor could also be trained in how to directly handle the early identification of work performance problems, before an acute situation can build. This level of training requires an experiential, hands-on practicum where these skills can be practiced and refined. This level of supervisor training, when properly organized and competently taught, has been shown to be an effective detection and deterrent tool for the employer.

Although effective, these types of supervisor training programs have intentionally removed the supervisor from the role of diagnostician in the acute or reasonable suspicion situation. Instead, the supervisor is encouraged to leave every aspect of the impairment determination or the fitness for duty examination to an outside medical or diagnostic professional, such as found in an Employee Assistance Program.

Over the past decade, supervisor program content and training strategies have not changed much. The recent evolvement of the DRE (Drug Recognition Expert) program in the law enforcement community, however, lends itself to a re-evaluation of current supervisor training methods to determine if parts of the DRE program could improve and upgrade existing training strategies. The DRE program, originally pioneered by the Los Angeles Police Department, has evolved into a product which has caught the interest of the National Highway Traffic Safety Administration (NHTSA). Its stated purpose is to apprehend and convict persons operating motor vehicles under the influence of drugs other than alcohol.[62] The program has quickly expanded by popular demand to other law enforcement jurisdictions throughout the country.

The DRE's Drug Evaluation and Classification Process is a standardized, systematic method of examining an individual. It is not a field test, but must be conducted in a controlled environment. The examination is broken down into twelve separate components.[63] The DRE program trains personnel in a

little over 110 hours[64] to determine whether a suspect is impaired; and, if so, whether the impairment is drug or medically related (illness or injury). If drug related, the DRE will then further determine what drug class category or combination of categories is the most likely cause(s) of the impairment.

Research results indicate that DREs, when properly trained, are often successful in correctly identifying drugs other than alcohol (94 percent of the time), identifying the proper drug class category when one drug was involved (79 percent of the time), and identifying all of the drug categories when multiple drugs were involved (50 percent of the time).[65] Part of the value of this examination is that once it is completed, toxicological tests can focus in on just one or more blood tests, with good specificity in which drugs are probably involved. Research indicates that the determinations are accurate even when alcohol has also been used by the suspect.

Recommendations for Future Research: It is clear that the use of a law enforcement tool like the Drug Recognition Expert (DRE) program could not be unilaterally applied to the training of workplace supervisors. The training is too long, requires too much practicum, and is far more indepth and technical then is reasonable to train supervisors. But the success of the DRE program gives evidence that perhaps existing supervisor training program content has been unnecessarily limited by a fear of supervisors fulfilling a diagnostic role. The DRE program should be looked at carefully over the next few years for several possible applications. First, what can be learned from the program which will reasonably improve the capability of the supervisor without over training him/her? Or, more likely, what can be learned from this program which can give occupational health clinics a better fitness-for-duty capacity. This would allow supervisors to fulfill their existing role but dramatically expand the quality of the medical fitness for duty determination, which now is inconsistent and often valueless.

Employee Assistance and Peer Intervention Programs

One of the most valuable tools available to the employer to assist the impaired operator is an Employee Assistance Program (EAP). At its simplest, an EAP is a screening and referral program which can have a dramatic impact on the identification and resolution of employee and employee family problems. There are a number of ways in which an employee can access a company EAP: as a self-referral, as a medical referral, as a union referral, or as a supervisory referral. In most organizations employees are referred, directly or indirectly, by supervisors.[66] EAPs have consistently demonstrated their value by assisting companies with the identification of drug and alcohol using employees, by providing cost-containment of employee benefits, and by facilitating the successful return of the rehabilitated employee back to the job. The EAP also has a role in monitoring the employee in aftercare programs and assisting with problems of relapse. EAPs are designed to determine the level of education, counseling, treatment, or rehabilitation needed, and make a referral into the proper program as necessary. Often EAPs are also significantly involved with company education and prevention efforts.

Another valuable detection and deterrence tool for employers are peer identification and intervention programs. Often these programs are organized by labor organizations to impact their fellow workers before they are intercepted by chemical tests or by supervisor intervention.[67] Usually these programs are designed to encourage anyone with a drug or alcohol problem to voluntarily seek help. The employee is then provided with EAP assistance or treatment and will not be fired. Whenever possible, the individual remains in service and is treated on an outpatient basis. Normally, the employee is confronted by a "team" consisting of two or more labor members, who will intervene with the individual who arrives at work under the influence or who consumes while on the job. The individual is counseled to stop using and to seek immediate assistance at the EAP. Discipline may be possible if the individual refuses to volunteer for help and is considered a safety problem. Discipline is not seen as punishment, but as a training and education process. Every effort is made by the company to accommodate the rehabilitation and return to work of the successfully rehabilitated employee.

Peer intervention programs are difficult to evaluate or duplicate identically in other locations, because they rely to no small degree on the corporate culture and the dedication of individual members. Nonetheless they can be extremely effective and are to be encouraged with resources and assets.

Performance Testing Strategies

Chemical testing alone is not intended to provide daily protection against the employee who may not be fit-for-duty due to the effects of drugs or alcohol, or because of other factors (stress, fatigue, illness, etc.), alone or in combination. Historically, employers have had to rely on supervisory personnel to identify and confront employees who may not be capable of performing safety-sensitive functions at the required level of performance.

Supervisors usually have received only a few hours

of training in the recognition of signs and symptoms of impaired functioning and are often ill-prepared to identify impacted employees. The lack of indepth training may lead too often to a subjective determination, with no consistency between supervisors. Supervisors are also often poorly equipped to confront employees who may be defensive or argumentative, or might accuse the supervisor of discrimination or harassment because of the perceived subjectiveness of the determination. To that end, the concept of a daily objective performance test to determine fitness-for-duty has great appeal to employers.[68]

The determination of fitness-for-duty through some level of performance testing has proven to be an interesting scientific problem, and proposed or suggested approaches and systems have encompassed a most diverse set of test types.[69]

Certainly, there have been identified a wide variety of components of human performance from which to draw test types, including physical strength, sensory/perceptual ability, motor ability, psychomotor skills, learning, memory, and decision-making, among others. Fitness-for-duty tests must be sensitive to job performance impairment in one or preferably more of these components. Additionally, they must also involve a detection strategy that minimizes rejection of acceptable performance and maximizes rejection of unacceptable performance.[70] This detection strategy can be inherently complex, for example, due to individual variability and the fact that not all potential impairing factors impact performance in the same consistent downward direction (i.e., small amounts of cocaine or other stimulants may actually enhance performance).

One technology which may hold some promise for the identification and recognition of impairment of operators in the transportation workplace is critical tracking task (CTT), a test of visual-motor performance.[71] The science of CTT was developed in the early sixties to evaluate pilot and astronaut visual motor performance. Extensive research on humans and operator impairment has been completed over the last three decades in a number of areas, including measuring the effects of various environmental stressors (noise, space station confinement, ship motion, spacecraft re-entry, fatigue), other workload factors, and drugs and alcohol. Its principal capability appears to be in the evaluation of any effect which is related to the manner in which visually perceived information is reacted to by motor (eye, hand) actions.

Other promising products currently being marketed include those which use a computer software shell to embed two or more tests challenging cognitive and perceptual motor function. The tests are run singly but are integrated together within the software presentation structure. Tests are selected based on the type of workplace or job type being screened, and should have a strong scientific background in discriminating levels of impairment in these kinds of job functions.

Interesting new work is also being conducted under the guidance of the U.S. Army Office of Military Performance Assessment Technology. These various studies, which essentially are precursors to more complex simulations of workplace performance measurement, have now become a tri-services project.[72] The work, which has been going on since 1983, attempts to model "real-world" military workplace environments in order to be better able to measure factors which affect performance. It is essentially synthetic work, with one or more carefully selected assessment instruments presented to the subject in sequence or simultaneously on a computer screen. The tasks may provide measures of time deadlines, divided attention functions, or other similar activities which taken together can provide a more accurate representation of real-world performance.[73] Although not intended to be directly applicable to fitness-for-duty, there may be lessons learned which could apply to various of the fitness-for-duty testing approaches. Even seemingly peripheral test batteries, such as those which constitute the Los Angeles Police Department's drug evaluation and classification program (see Section 4.2), may prove useful in evaluating future needs for fitness-for-duty test structures.

Recommendations for Future Research: Of course, the Army/tri-services project is not directly intended for commercial application and is still in its relative infancy. Still, impressive progress has been made to date with preliminary studies and computer software engineering. There may be a later application of some part of this technology as the next generation of performance testing available in the commercial marketplace. In the interim, studies should be undertaken which assess existing commercial and noncommercial performance testing methods for possible practical application in the transportation industry. At a minimum, criteria should be established and an evaluation made to assess test accuracy, consistency, and sensitivity to specific transportation industry job-performance impairment.

METHODS OF DETECTION AND DETERRENCE: MISCELLANEOUS PROPOSED RESEARCH

In the previous sections, chemical and non-chemical based methods of detection and deterrence have been seen as somewhat distinct from each other. However, there are several areas where the information required for employers to reinforce a safe, drug and alcohol free

workplace seem to apply to the development of strategies in both categories.

Use of Random Testing as Deterrence

No chemical test type has engendered more controversy then random testing. Labor unions, employee groups, and the public may in certain circumstances be willing to accept pre-employment, reasonable suspicion, and post-accident testing as necessary to maintain a drug and alcohol-free transportation workplace. Random testing, on the other hand, generates a significant amount of emotion and genuine concern about its purpose and effect on drug and alcohol use prevalence rates. Random testing manages the selection of employees for testing based on a certain pre-determined percentage of the target workforce, where testing is spread throughout a year and each member of the target population has a theoretically equal chance of being selected each time.

It has been forcefully argued by opponents that random testing is simply not necessary, since the specter of reasonable suspicion and post-accident chemical testing should by itself successfully deter employees who are continuing to use. That argument has tended to be more successful when applied against employees not performing safety-sensitive jobs. However, political and public opinion has often affirmed the need for random testing of employees performing safety-sensitive functions, such as is often the case in the transportation industry.

It is the argument of proponents that random testing is successful because each employee never knows if and when he/she will be tested, and for how many times during the year. The deterrent effect is then internally calculated by each employee based on their personal concern in being caught and thereby jeopardizing their employment.

With as much controversy as it generates, there has been almost no formal research either evaluating random testing as a deterrent for employees or establishing which rate of testing provides the maximum deterrent value. Random testing is simply assumed to be a deterrent, and random rates are often set arbitrarily by employers or by regulators.[74] Data that are generated usually come directly from workplace random testing programs already in place, without baseline or control data to establish deterrent effect. Proponents of current random testing programs point to low positive rates as evidence of deterrence (generally 1-3 percent in federally regulated transportation industries).[75] Opponents use that same data to claim that random testing is unnecessary because only such a small percentage of employees apparently use drugs.

Because of the costs involved, employers want to know if random testing is providing any real cost-benefit to them and employees are wondering if this strategy is actually contributing to a drug and alcohol free workplace.

Recommendations For Future Research: Over the next decade, research in this area should focus on verifying the efficacy of random testing as a deterrent to drug and alcohol use by employees in the transportation industry. Controlled or quasi-experimental studies should be conducted which evaluate whether random testing has any direct effect on rates of use in an industry. Among the other questions which need to be answered are those relating to the direct effect of random rate on deterrent effect, on the real opportunity versus the perception of being caught on a random test, and whether a minimum/maximum effective random rate can be scientifically established.

Prevalence Rates of Drug and Alcohol Abuse in the Transportation Workplace

statements regarding the prevalence of drug and alcohol use in the transportation industry have traditionally been speculative or based on educated guesses. Companies have historically resisted scrutiny by researchers for a variety of reasons, including because of the direct and indirect impact on employees and on company operations. Instead, industry has traditionally relied on drug test statistics, anecdotal and case study data, self report data, and information extrapolated from other industries or sources. Accurate prevalence rates for the transportation industry, especially when done by category (maritime, aviation, rail, pipeline, ground transport, etc.), would be of tremendous importance in the design and structure of future transportation workplace programs.

Recommendations for Future Research: Over the next decade, attempts should be made to establish "real-world" drug and alcohol prevalence rates for transportation modes based on scientifically credible research designs utilizing multiple measures.

NOTES AND REFERENCES

1. (Cited by Sweedler 1991)
2. National Transportation Safety Board (NTSB) 1989.
3. (NTSB 1988)
4. (NTSB 1990)
5. In this paper, impairment is described as any process which adversely affects reasoning and judgement, mental performance (involving clarity and acuity), and/or physical performance (involving dexterity, reaction, and strength).
6. Most companies conduct tests in urine. Current

federal regulations and most knowledgeable company drug testing policies forbid the presence in urine of an illicit drug, an unauthorized controlled substance, and in some cases, ethyl alcohol above an established threshold. Use of the term "presence" purposefully avoids the complicated issue of on-the-job impairment determinations based on a urine test result. Correlation of urine test results with "under the influence" is considered a difficult scientific task by most experts (Baselt 1989).

7. Shaw and Ellis 1993; Shaw and Ellis 1985; Hawks 1986.

8. U.S. Department of Health and Human Services, 1988; U.S. Department of Transportation 1989.

9. Hoyt et al. 1987.

10. Immunoassays are based on the principle of competition between labeled and unlabeled antigen (drug) for binding sites on the antibody. Antibodies are substances that react with the drugs or drug metabolites that are being tested. The difference between the RIA, EIA and FPIA immunoassays is mainly in the indicator (label) that is used. EIA (or its most common commercial application, EMIT™) utilizes an enzyme as the label while RIA uses a radioactive material. FPIA (or its most common commercial application, TDx™) uses a fluorescein labeled ligand.

11. The Roche Abuscreen™ RIA amphetamine specific assay is essentially insensitive to d-methamphetamine and the Roche RIA methamphetamine assay is insensitive to d-amphetamine (Package Inserts, Roche Abuscreen RIA™, 1989 and 1992). Both are excellent assays, but if not run in tandem, each assay could miss certain illicit drugs and licit medications which may be contributing to a reasonable suspicion or post-accident situation. Theoretically, very recent methamphetamine use to the point of severe intoxication might go undetected by the RIA amphetamine assay if there was still insufficient metabolized amphetamine available in the sample (under 1,000 ng/ml in federal testing programs). In this hypothetical case, an employer would receive an RIA amphetamine result of negative, but a large concentration of methamphetamine would have been missed. That same sample analyzed by EIA or FPIA would likely have been strongly positive.

12. For all of the immunoassays, the opiate assay is based on any of the narcotic drugs in the phenanthrene series. The assays do not react or react to only a slight degree with any of the mentioned synthetic narcotics. These drugs are highly prescribed, and can be factors in reasonable suspicion and post-accident determinations.

13. The barbiturate assay is built around secobarbital for EIA, RIA, and FPIA. Secobarbital is rarely seen anymore as a prescription (Simonsen 1991) or as an abused drug, and consequently using it as the target analyte appears increasingly less valuable since other far more common barbiturates do not cross-react well with this assay. Two commonly prescribed barbiturates, butalbital and phenobarbital, are noticeably less sensitive to EIA and RIA then to FPIA analysis. The relative lack of sensitivity is not as important when high doses of these drugs are present. However, in cases of multiple drug impairment or where a disease state (i.e., migraine or epilepsy) may have effected performance, failure to detect these drugs may be significant.

14. An illustration, the benzodiazepine assay is often constructed around oxazepam as the "anchor" analyte. Oxazepam is still a valuable base analyte since at least eight benzodiazepines, including diazepam, metabolize to this substance (Baselt 1984). However, identification of the source(s) of a benzodiazepine positive can become somewhat clouded. More importantly, various of the immunoassays have little sensitivity to the parent drug and/or major metabolites for several of the very potent short or intermediate acting benzodiazepines, including alprazolam, triazolam, and lorazepam (Jones and Singer 1989; Fraser et al. 1991; Fraser 1987; others). These drugs are prominently prescribed and have extensive potential for impairment (Simonsen 1991; Jones and Singer 1989). Yet they may go undetected in many reasonable suspicion or post-accident standard chemical tests.

15. Gas liquid chromatography (interchangeably referred to as gas chromatography or GC) is a form of chromatography which utilizes an inert gas, such as nitrogen or helium, as the moving phase to transport a vaporized sample of a drug through a glass or metal column (usually 10-15 meters in length and a few millimeters in diameter) containing specific packing material. Individual compounds are separated on the column according to their physical and/or chemical properties. The drug is identified and the concentration quantified by a detector as the analytes appear at the far end of the column.

The mass spectrometer is a highly sensitive and specific detector. When coupled with a gas chromatograph (GC/MS), it is capable of providing the most accurate procedure for the identification of drugs commercially available (Shaw and Ellis 1993; Hawks 1986; Shaw and Ellis 1985; Hoyt et al. 1987). Components separated by a gas chromatograph are introduced into the mass spectrometer where fragmentation of the chemical bonds of the molecule takes place. These electrically charged fragments (ions) differ from one another in intensity and result in fragmentation patterns which have specific characteristics for identification.

16. Perspectives of Dr. R. Foltz, personal

communication 1992.

17. Tandem mass spectrometry (MS/MS) couples two mass spectrometers together, so that one acts as a sample cleanup and the other as the analyzer. A sample can be directly introduced into the first MS, eliminating the sometimes lengthy chromatography step. While at the same time providing increased sensitivity, there appears to be some sacrifice of specificity. Generally, MS/MS doesn't appear to do as well at low end concentrations requiring good quantitative accuracy.

Another interesting use of MS as a mass analyzer occurs when a GC is coupled with two MS stages (GC/MS-MS). With this combination, the first MS acts to isolate the ions of the analyte(s) of interest from all others coeluting at the same time. The second MS then performs the more normal MS function of producing the "fingerprint" mass spectra for evaluation. GC/MS-MS seems to provide a noticeable improvement where it is necessary to demonstrate a better sensitivity with less interference (such as analyses required in the low picogram range). However, MS-MS does not guarantee better sensitivity for all drugs of interest. The combination is expensive and more complex to operate then standard GC/MS.

There has been increased scientific interest in the combination of gas chromatography and the ion trap mass spectrometer (GC/Ion Trap MS). The standard MS detector separates the ion beams into groups of ions based on the mass-to-charge ratio by means of a quadrapole filter, but in SIM mode discards much of the analytical signal. With the ion trap, all of the ions are retained and the ions are then selectively ejected in the detector during the mass scanning process. Compared with the quadrapole MS, the Ion Trap MS appears to have a slightly greater sensitivity, especially in full scan mode, but it does not have a strong advantage at this time over traditional GC/MS quadrapoles. The technology is advancing rapidly, however. With this approach, there are currently some very interesting developments coming from research laboratories that may have future commercial application.

High pressure liquid chromatography (HPLC) is a highly competent alternative to gas chromatography (GC) analysis. This technique is non-destructive and easily handles substances difficult to assay by GC because of sample destruction or decomposition at high temperatures. HPLC coupled with MS as its detector is currently undergoing a rapid development. With the success of the electrospray interface as its connector, it shows increasingly better promise as an analytical match for GC/MS.

18. U.S. Department of Health and Human Services, 1988; U.S. Department of Transportation 1989.

19. The National Laboratory Certification Program (NLCP) was established in 1988.

20. Historically, the earliest saliva alcohol measurement methods had some problems when used in the field. Large volumes of saliva and the complete cooperation of the subject were needed. Enthusiasm for breath alcohol testing procedures, an equally noninvasive approach, relegated saliva testing to a back burner in the research community for many years. Commercial applications using saliva testing reappeared in the mid 1980's with the development of a dry reagent test strip technology using alcohol oxidase and with the field tests of commercially available versions. These commercial technologies were based often on the enzymatic oxidation method. With this relatively simple technology, color changes in the visible spectrum on a solid-state test strip could be compared against pre-determined color/saliva alcohol standards. These particular applications were hampered by a number of identified problems, including a high proportion of false positives in certain temperature conditions (NHTSA, 1986).

21. Schramm et al. 1992.

22. U.S. Department of Transportation, 1992. The special requirements of the proposed regulations will probably mandate a whole new generation of breath-alcohol testing devices.

23. Discussed in Sweedler, 1991; in Barnett and Willette 1989; and many others.

24. Barnett and Willette 1989. See also earlier work by Willette (NHTSA 1985).

25. For marijuana, diazepam, and secobarbital, Barnett and Willette relied heavily on the work of Chiang and Barnett 1984; Perez-Reyes 1982; Perez-Reyes personal communication; Peat and Jones, personal communication 1985; Moskowitz and Sharma 1979; and many others.

26. There are a number of questions which need to be discussed in the debate over future research in this area. Some of these are:

- Current laboratory models do not often capably represent the transportation workplace, and rarely measure performance in a number of factors at the same time, such as reasoning and judgement, mental performance (clarity and acuity), and physical performance (dexterity, reaction time, and strength). How many of these factors are really necessary in determining true performance impairment? Is a more complex model better or even necessary to judge impairment of safety sensitive functions?
- Additionally, it would also seem important to know what the effect is of multiple drug use and tolerance on impairment and detection capability? What is the effect of multiple dose use and tolerance (a more realistic scenario) as opposed to the typical existing single dose studies?
- Blood is normally the specimen of choice for

impairment and/or recency of use determinations (see Section 3.4.1). Since blood is usually not going to be available as a specimen for analysis because of its intrusiveness, can other types of specimens prove valuable to identify the impaired operator and under what conditions?

- It would seem necessary to correlate the pharmacokinetics of a drug (absorption, distribution, metabolism, and elimination/excretion) with the pharmacodynamics (the effect of the drug on the individual) in order to determine impairment. When will research data be available to make this possible for all of the drugs of interest? In the interim, are there dangers inherent in extrapolation and/or interpolation of existing data to the workplace population? How much data is necessary to collaborate impairment and generalize findings across workplace populations?

27. (Described in Caplan 1988, among others)

28. (Baselt 1984)

29. The best example is of the opiates, where the standard urine assay is specific only for codeine and morphine. A quantitative result of 300 ng/mL of morphine, for example, may be reflective of previous use of either codeine or morphine based drugs, heroin, or poppy seeds.

30. (Barnett and Willette 1989)

31. (Baselt 1989)

32. Baselt and Danhof 1988. As an example, collectors are recommended to have the suspected alcohol user completely void his/her bladder and provide an additional (second) sample 20-30 minutes later. The second specimen is probably a better sample to link to blood alcohol concentration equivalent. Examples of such a protocol may be found in Shaw and Ellis 1985; and in Caplan 1988.

33. For example, Borkenstein et al. 1972; Turner et al. 1985. Cited in Dubowski 1991.

34. Reviewed very capably by Mason and Dubowski 1988; and in Dubowski 1991.

35. There are five major techniques commonly employed to determine blood alcohol concentration (BAC) from the analysis of breath samples. They are the oxidation/photometric (color change), gas chromatography, infrared absorption, electrochemical oxidation (fuel cell), and semi-conductor technologies. Each of these techniques is capable of producing highly accurate measurements of BAC, and each has its own particular advantages and disadvantages (Mason and Dubowski 1988; Dubowski 1991). Since the early 1970's, the National Highway Traffic Safety Administration (NHTSA) has established standards for devices that purport to measure breath alcohol. In support of these standards, NHTSA started regularly publishing lists of qualified products which meet federal standards as evidential-level devices. However, there is a great variety of non-evidential level devices which vary significantly in quality and accuracy.

36. (Hawks 1982)

37. A most comprehensive review has been provided by Schramm et al. 1992. See also an earlier review by Caddy 1984. Besides ethyl alcohol and the cannabinoids, research on saliva concentrations of drugs has been conducted at least to some degree in cocaine, phencyclidine, morphine, codeine, hydromorphone, methadone, amobarbital, hexobarbital, phenobarbital, methaqualone, diazepam, nordiazepam, and amphetamine.

38. Cited in Hawks 1982, based on personal communications with Perez-Reyes.

39. Although urine tests find principally the carboxyl metabolite (THC-COOH), research in saliva reveals at least three metabolites (THC, CBD, and hydroxy-THC) not normally found in substantial amounts in urine (Schramm et al. 1992). These may therefore appear directly either from marijuana smoke or from metabolism of the drug in the mouth. Importantly, it has been reported that ingestion of normal foods and liquids does not appear to impact the detection of marijuana metabolites in saliva (Thompson and Cone 1987; among others), although an alcohol rinse may be a risk.

40. (Schramm et al. 1992)

41. (Schramm et al. 1992)

42. (Schramm et al. 1992)

43. (See Coldwell and Smith 1959; and others)

44. (See Jones 1980; and others)

45. The most common commercially available test for the analysis of hair for drugs of abuse utilizes radioimmunoassay (RIA). TDx™, another immunoassay technique, has also been used. High performance liquid chromatography, gas chromatography, and gas chromatography/mass spectrometry have been successful for both screening and confirmatory procedures. Opiates, cocaine, PCP, marijuana, methamphetamine, and amphetamine have all been detected.

46. (Cone et al. 1991; Goldberger et al. 1991)

47. (Cone 1990)

48. Society of Forensic Toxicologists (SOFT), Proposed Revised Consensus Opinion, 1992. There has been previous criticism of hair analysis for drugs of abuse because of the lack of effective quality control procedures, limiting confidence in analytical findings. Even more significantly, because of the relative newness of this type of analysis, the most common evaluative techniques available commercially to employers are only now being be linked to reliable confirmatory procedures.

Besides those previously mentioned, other limitations of hair analysis are that studies have involved a limited number of subjects, were not controlled, and relied too heavily on self-report data; there is little data available on the precision and accuracy of hair analysis; and there is relatively little clinical experience with hair analysis for the drugs of abuse (Harkey and Henderson, 1989, who provide a comprehensive overall review).

According to some reviewers, hair analysis may eventually prove useful to verify a history of drug use, to reaffirm past use beyond the window of urine or blood detection, to identify use of those drugs not normally tested for, to provide a "safety net" to guard against an error in testing, and to monitor compliance with an abatement program (Harkey and Henderson 1989). One of the exciting scientific possibilities of hair analysis is its potential to evaluate windows of use for a drug taken days and months previous since drugs in theory are retained "permanently" in the hair shaft as it grows out. However, many scientific issues still need resolution. A number of these issues were drawn directly from the consensus statement by a scientific committee brought together by the National Institute on Drug Abuse and the Society of Forensic Toxicologist's (SOFT) in May 1990. They include:

- What are the mechanisms of which drugs are incorporated into hair and what;
- Is the minimum dose required to produce a positive result?;
- To what degree does outside contaminants (i.e., marijuana, PCP, methamphetamine, or cocaine smoke) bind to the hair, thereby creating a situation equivalent to passive inhalation?;
- To what extent does hair treatments, shampoos, or analytical washing procedures remove already bound drug from a hair segment?
- To what degree does nutritional changes, disease, and other factors play a role in increased or decreased hair growth, thereby hurting the ability to "zero-in" on a targeted time-segment?
- To what degree does the various drugs diffuse or migrate along the hair shaft, thereby weakening the targeting capability?
- How much drug incorporation and retention in hair based on individual factors, including race, sex, age, or other differences?

49. Marijuana tests routinely can detect use of the drug, since the target analyte in urine, 11-nor-delta-9-tetrahydrocannabinol-9-carboxylic acid (THC-COOH), is easily identified by most chemical methods and usually exists in sufficient quantities after relatively recent use. It can also be detected in urine for many weeks after last use especially if the donor is a regular or frequent user (Ellis et al. 1985; Wall et al. 1983; Dackis et al. 1982). The presence of THC-COOH alone, then, is not of much use in detecting either the impaired worker or establishing recency of use with certainty. The metabolic parent, delta-9-tetrahydrocannabinol (THC), is responsible for the primary psychoactivity of the drug, but because it is so rapidly metabolized, it rarely is present for long in the urine. Presence of the parent THC in the blood of the infrequent user is usually reflective of recent use (Hunt and Jones 1980; Peat et al unpublished, cited in Peat 1989). Somewhat surprisingly for infrequent users, levels of THC-COOH may actually exceed that of THC for the first half-hour or so after last use (Hanson et al. 1987; Peat et al. unpublished, cited in Peat. 1989). The presence (or absence) of other metabolites (notably 11-hydroxy-THC) can be important in result interpretation especially if the history of marijuana use by the donor is known (Heustis et al. 1992A). Some research has suggested differences in the type of metabolites found in frequent users compared to light or infrequent users (Peat et al. unpublished, cited in Peat 1989; Alburges and Peat 1986). Other research has suggested that THC-COOH/THC ratios in plasma or blood may be useful in estimating time since last use (Hanson et al. 1983; Huestis et al. 1992B), but it is clear that a significant amount of information is necessary about the user (route of administration, analytical procedure used, type of user) before the ratios could be judged important (Wall et al. 1983; Peat, personal communication 1992).

Additionally, the concentrations and timing of various metabolites appears somewhat different than from smoking or intravenously administered doses (Wall et al. 1983). Neither passive inhalation or oral administration seems to cause either unique metabolites or metabolite ratios.

Most current cocaine use will involve one of two versions, either cocaine hydrochloride (the usual powder form which is most often snorted or injected) or crack cocaine (which is smoked). Current methods of chemical detection can choose to focus in on the presence of parent cocaine and two of its major metabolites, benzoylecgonine (BE) and ecgonine methyl ester (EME). To date, at least eleven metabolites of cocaine have been identified in the urine of a cocaine user (Zhang and Foltz 1990). One additional metabolite, cocaethylene, may be present when alcohol is used with cocaine (Hime et al. 1991; Hearn et al. 1991). This suggests that the metabolism of cocaine is more complex than previously suspected. In addition, there are questions about the stability of cocaine and its metabolites in vivo and in vitro, which appear dependent also on specimen pH (Baselt 1983; Levine and Smith 1990).

Research has generally suggested that use of cocaine

by any of the three principal administration methods (insufflation, injection, or smoking) produces drug and main metabolites (BE, EME) in roughly the same proportions. There is also data which suggests that additional metabolites may be present in the urine of smokers, perhaps due to the intake of cocaine pyrolysis products and their metabolism and/or excretion (Reported in Cook et al. 1985). Although cocaine metabolites are usually excreted out in detectable amounts up to 72 hours after last use, there are at least several cases where cocaine and/or BE positives have been reported in urine from 4-10 days (Cone and Weddington 1989; Hamilton et al. 1977). This last data suggests possible accumulation of the drug in body tissue after chronic use. The presence of parent cocaine in urine, therefore, may not necessarily be as useful as once thought to suggest very recent use of cocaine products.

Attempts have been made to prepare a predictive model of the excretion of cocaine and the principal cocaine metabolites in urine (Ambre 1985; Ambre et al. 1988; Ambre et al. 1991). Urine concentration ratios were preliminarily suggested as potentially useful predictors of time since last use. More recent kinetic models of cocaine and BE disposition continue to suggest that this may continue to be a productive avenue of research in both blood and urine, but more research is necessary.

Of the other drugs surveyed (amphetamines, barbiturates, benzodiazepines, the opiates, the hallucinogens, and PCP), there is little evidence yet available which would suggest strong markers helpful for identifying recent use. The only exception, of course, is that the presence of 6-monoacetylmorphine (6-MAM) in the opiate determination is an absolute indicator of recent heroin use. Unfortunately, the metabolite's absence in a suspect specimen does not rule out heroin. Interestingly, the apparent retention of 6-MAM in hair may make a verification of heroin use a much greater possibility.

50. Steroids can have a number of significant physiological and behavioral side effects. Adverse medical side effects include liver function damage and tumors, reproductive system problems, and possibly cancer (Strauss 1987; Haupt and Rovere 1984). People who take high doses of anabolic steroids may exhibit a variety of psychological and emotional changes. These range from feelings of well-being and euphoria to lack of energy, irritability and aggressiveness, manic behavior, symptoms of major depression, hallucinations, and paranoia (Strauss 1987; Haupt and Rovere 1984; Lamb 1984; Pope and Katz 1988). Fights and problems with interpersonal relations have been noted. Because of the large number of steroid compounds and similarity between the compounds, detection and accurate identification is not a trivial problem (Chiong et al. 1992; Gaskell 1983).

51. Capable reviews of so-called "designer-drugs" and drug trends of the future have been provided by many, including Buchanan and Brown 1988; Shulgin 1975; and others.

52. Among the drugs that continue to be of potential interest to abusers include the phenylethylamines. These include derivatives of amphetamine and methamphetamine, as well as 3, 4 methylenedioxyamphetamine (MDA), and 3, 4 methylenedioxymethamphetamine (MDMA; Ecstasy). All of these drugs have significant abuse potential, cause impairment, and in excessive dose or overdose situations, cause significant behavioral and medical problems. Most of these drugs may be picked up by current screening technologies, but because current confirmatory strategies generally ignore them, use of these drugs is generally going to be missed.

A number of synthetic narcotics substances appear to be of some concern because of their impairment capability and their difficulties for routine detection. As an example, the fentanyl derivatives have approximately 1,000 times the potency of heroin (Henderson et al. 1990). Their abuse potential is high among medical personnel (fentanyl is a commonly used general anesthesia) and among heroin-user type populations. The fentanyl family is a large and seemingly limitless one, possessing all of the pharmacological actions and effects of the better known narcotics. Because their chemical structures are quite different from the common narcotics, their ease of synthesis, and their ready availability, they are illustrative of the potential problems if drug use trends change to avoid routine detection strategies.

Another similar example can be found in the analogs of synthetic narcotic, meperidine. The meperidine derivatives are best known for the rash of moderate to severe Parkinsonism among addicts over a decade ago attributed to a batch of drugs contaminated with MPTP (1-methyl-4-phenyl-4-phenyl-1, 2, 3, 6–tetrahydropyridine; summarized in Buchanan and Brown 1988). However, as long ago as the mid-1970s, there were thousands of chemically modified meperidine structures available, some with potencies thousands of times that of morphine which could serve for heroin substitution and illicit drug usage (Shulgin 1975). Neither meperidine or any one of its analogs will screen positive on any of the assays in federal drug testing programs.

53. (Hughes et al. 1975)

54. (Rapaka et al. 1986)

55. (A comprehensive review is provided by Cody

1990)

56. (Cody 1990; Manno 1986; Schwartz et al. 1987; and others)

57. High Times Magazine (many issues); Hoffman 1987. Golden seal, cranberry juice, vinegar, and some specially manufactured commercial products have all been mentioned or advertised. Interestingly, the commercial products often offer a warranty of sorts—your money back if you offer proof that the product didn't work. Many of the underground commercial preparations are touted as necessary to protect against the specter of a false positive from over-the-counter products, although there is certainly no real illusion as to their real purpose.

58. A second in vivo approach focuses on flushing the system of drugs and/or metabolites through the use of some of the commercial masking products mentioned above or through the purposeful use of diuretics. At least one author has suggested that diuretics may have the capability to dilute the concentration of the analytes below the cutoff so that they are not detectable. Although prescription diuretics will clearly be the most effective, over-the-counter water loss pills or the simple ingestion of large amounts of fluid can have a mild diuretic effect. The best internal masking agent appears to be the ingestion of liquid, any liquid, in sufficient quantities to physiologically dilute the drug or alcohol concentration in the urine. This is best achieved when the concentration of the analyte of interest is going to be relatively close to the cutoff, although impressive dilution results have been reported from the ingestion of a liter of water (Laboratory of Pathology, unpublished).

A third in vivo-related approach may be direct sample substitution, where "clean" urine is intruded into the collection process by way of concealed sample bottle or bladder device such as a condom. This is a very common means to defeat a drug or alcohol test, and collections that are not directly observed are the most vulnerable to this approach. This approach is virtually undetectable by a laboratory if the replacement sample escapes the scrutiny of the collection agent.

59. Some of the common "household" materials used and for which there is research data include table salt, vinegar, ammonia, ascorbic acid, soap, detergent, bleach, Drano™, Vanish™, Visine™, Lime-a-Way™, and lemon juice (see Cody and Schwarzoff 1989; Kim and Cerceo 1976; Vu Duc 1985; Warner 1989; Pearson et al. 1989; Mikkelsen and Ash 1988; and others). There are a number of underground commercial products becoming available which are advertised to defeat one or more of the immunoassays. These substances are often very toxic and are usually advertised in underground press or passed on by word of mouth. In some cases, they have a characteristic odor and can be detected upon collection. In others, they can be detected upon analysis if the laboratory is using a screening method other than the assay the product is designed to defeat (one well known product, for example, appears to contain a corrosive, likely butyraldehyde (butanol) or a similar substance. It also has a very characteristic odor in urine. The product clearly defeats EIA, but appears to cause multiple false positives with RIA). If the donor has judged the test requirements correctly, and the collection site and the laboratory are not vigilant, the adulterants can produce the desired false negative result.

60. U.S. Department of Education 1988; State of California Attorney General's Office 1991.

61. Naturally, this assumes a quality program which is developmentally appropriate, is of sound content, is employee-focused and relevant to the workplace, utilizes a broad methodology for teaching knowledge, skills, and concepts, and involves teachers or trainers who are knowledgeable and experienced.

62. (NHTSA 1989; U.S. Department of Justice 1989)

63. NHTSA 1989. The DRE examination includes the following components:

a. A breath alcohol test. This is done to determine whether alcohol is involved.

b. The interview of the arresting officer. Information is gathered from the arresting officer which may be used to craft the DRE's own interviews.

c. The preliminary examination. This is a structured series of questions, specific observations, and simple tests to help rule out injury or another condition not related to drugs. If injury or disease is suspected, the evaluation may be terminated here and professional medical attention sought.

d. The examination of the eyes. This examination looks for horizontal and vertical nystagmus, and includes a check for lack of visual convergence.

e. The divided attention psychophysical tests. These include classic roadside "drunk" tests including the walk and turn, the one leg stand, the Rumberg Balance test, and the finger to nose test.

f. The dark room examinations. These tests involve systematic checks of the size of the pupils, the reaction of the pupils to light, and evidence of ingestion of drugs by nose or mouth.

g. The vital signs examination. These are designed to be systematic tests of an individual's blood pressure, pulse rate, and temperature.

h. Examination of muscle rigidity. This test is a physical check of whether the muscles are hypertense.

i. Examination for injection sites.

j. Suspect's statements and other observations. At this point, the DRE will ask the suspect specific questions which have been derived from the preliminary determinations made from the previous examinations.

k. Opinions of the DRE. Based on what has been learned up to this point, the DRE will be prepared to make and document his/her determinations.

l. The toxicological examination. The results of any chemical tests (preferably blood) that were administered are applied to the DRE's findings.

64. Officer T. Page, Los Angeles Police Department, personnel communication, 1992.

65. (NHTSA 1989)

66. (Scanlon 1986)

67. In this discussion, Operation Red Block, a successful peer intervention program in the railroad industry is used as the model. There are many other excellent examples.

68. To be useful, such an objective measure of impaired functioning would at least:

a. Provide an immediate and consistent measure of job performance capability before an employee goes on duty, not just subsequent to an incident or accident.

b. Be able to consistently measure impairment at expected thresholds.

c. Help identify more subtle forms of impairment where combinations of factors (i.e., an alcohol or drug induced hangover effect plus stress or fatigue) may produce additive of supra-additive impact on job performance, and which may be missed by routine chemical testing.

d. Be cost effective and cost beneficial and not detract from the effective and efficient operations of the company.

e. May be conducted with a minimum intrusiveness and impact on the rights of the individual employee.

f. May be conducted with a minimum capability of an impact by the test administrator on the results.

69. Two of the most common approaches are as follows:

a. Test Driven. A test or battery of tests which already has been developed for other purposes and which may be capable of discriminating fitness-for-duty, are applied to various workplace settings and job types.

b. Job Task Driven. An evaluation of a work function or job type is conducted and tasks associated with the performance of a job are identified. A test or test battery is then devised to discriminate impaired performance in a fitness-for-duty determination.

70. (Allen at al. 1990)

71. As it is currently implemented as a commercial performance impairment testing device, an operator manipulates a control knob to correct increasingly unstable movement of a pointer on a computer screen. Eventually, the pointer becomes impossible to control and the operator fails. Success on the test is measured by the length of time the operator is able to retain control of the pointer compared against the operator's own pre-established baseline performance on the task. The operator is given several attempts (or trials) to pass the test.

72. Dr. Hegge, Office of Military Performance Assessment Technology, Walter Reed Army Institute of Research, personal communication, 1992.

73. To the person participating, the test(s) will ideally appear as a unified, integrated operating experience. This may include graphical displays such as maps and operating instruments. Depending on the type of work to be modeled, families of tasks can be constructed which are directly traceable back to the actual workplace. From the data gathered, risk assessment statements can be generated.

74. In the transportation industry, rates have generally ranged from 50 percent to 10 percent in past years, with 50 percent the current federal requirement for most Department of Transportation regulated employees.

75. Various reports have been generated which show some support for the suggested range of 1-3 percent positive tests. Among these are data provided by the American Trucking Association (Davis et al. 1991) of 1.95 percent random positives for its industry in 1990; by the Federal Railroad Administration of 0.9 percent positives among employees of Class I carriers in 1990–1991; and by the Federal Aviation Administration of 0.8 percent positives of its regulated employees in 1991. Some data also exists for the maritime industry of a 1.5 percent random positive rate in 1991-1992 (Ellis unpublished). The National Institute on Drug Abuse (NIDA) has also published data covering a broad range of industries in 1991-1992 consistent with a general range of 2-3 percent positives (NIDA 1992).