Zhong-Nian He,[1] *Ph.D.*

Application of Trace Evidence in the Forensic Medical Examination

REFERENCE: He, Z.-N., "**Application of Trace Evidence in the Forensic Medical Examination,**" *Journal of Forensic Sciences,* JFSCA, Vol. 34, No. 2, March 1989, pp. 391-398.

ABSTRACT: The statistics in this paper were based on the classification, lifting, general detection, and results of instrument analysis of trace evidence (354 samples) in 211 cases involving homicide, suicide, rape, and traffic accidents which were handled in our institute since 1982. The study showed that trace evidence plays a critical role in crime investigation. We expect the application of trace evidence to be further developed and more widely used by our colleagues in the forensic science community.

KEYWORDS: forensic science, criminalistics, trace evidence, statistical analysis

The use of trace evidence (TE) in forensic medical examination has progressed along with the development of society and with scientific advancements. With an increase in crime in our society, however, the number of cases in which there has been destruction of evidence and of the body has also increased: thus there is less forensic science evidence available, whereas the number of crimes demanding such evidence has increased. This greater demand for technical operation methods (and for greater volume) has created a new task for forensic medical examiners. Methods used in the past for examination of bloodstains, semen stains, skeletons, and hair do not provide information sufficient for the current demand, which is growing. We emphasize here the use of modern detection and the application of TE in forensic medical examination in order to meet this new need. Experiences in recent years have shown that as long as special attention is paid to the five main points of TE, it can continue to play an important role in exposing and confirming crime:

- discovery
- lifting
- packaging
- general detection
- application of conclusion

Material Source

The study described herein examined 211 practical cases involving homicide, suicide, rape, traffic accidents, and so forth, all of which concerned the application of TE in the forensic medical examination handled by the Forensic Physical and Chemical Laboratory and the Forensic Medical Laboratory in our institute since 1982. A statistical analysis was

Received for publication 25 March 1988; accepted for publication 22 June 1988.
[1]Chief legal medical expert, Liaoning Criminal Scientific and Technical Research Institute, Shenyang, Liaoning, People's Republic of China.

made from these cases, and the discoveries, gathering (lifting) of TE, and results of instrument analysis in each case were observed.

Results

Classification of the Cases

The 211 practical cases included 151 cases of homicide, in the majority of which (109 cases) blunt objects were used. Of the cases 7 involved sharp tools, 12 cases shooting, 23 cases explosion, 3 cases suicide, 9 cases rape. Thirty-eight were cases of traffic accidents, of which thirty-six involved motor vehicles, one a train, and one an airliner. Table 1 gives these numbers and the percentages they yield.

Classification of Trace Evidence

Because of the ongoing development of new techniques, the constant appearance of new products, and the increasing use of natural materials, there are many types of TE to be found. (See the subsection on *Skillful Use of Trace Evidence* for discussion of what constitutes TE.) Because of these facts, we cannot completely summarize TE at the scene of the crime, nor can we fix the investigative scope. This paper develops statistics and analyses from only 354 samples (30 different types) taken from the 211 cases (Table 2). The most

TABLE 1—*Crime classification of 211 cases.*

Crime Classification	Number of Cases	Percent
Homicide	151	71.6
Suicide	3	1.4
Rape	19	9.0
Traffic accident	38	18.0

TABLE 2—*Types of evidence.*

Types	Number of Cases	Percent
Paint	61	17.2
Fiber	59	16.7
Residue of explosion	39	11
Powder	8	2.3
Broken bits of metal	37	10.5
Soil	45	12.7
Mineral oil	27	7.6
Pitch, paraffin	5	1.4
Vegetable oil	6	1.7
Body fat	9	2.5
Human skin	6	1.7
Brick, stone, coal, glass bits	15	4.2
Ink, dyestuff	7	2.0
Wood, paper scraps	6	1.7
Plastic, rubber, and polymer	16	4.5
Animal hair	2	0.6
Ashes	6	1.7

frequent examinations were of 61 samples of paint, followed by 59 samples of fibers; the least frequently occurring were of animal hair (2 samples). Any TE, however, regardless of frequency, can play an important role in exposing and confirming crimes.

Case Report 1—On 13 Oct. 1986, a woman was killed in a field, after which it rained heavily. The case was reported the following day, but no TE was gathered from the scene of the crime. Later, a set of worn clothing was found about a mile away from where the corpse had been discovered. On one cuff was a small bloodstain, which later proved to have been made by human blood. Two white fibers were later discovered in the coat pocket and were positively identified as rabbit hair. This last finding provided an investigative direction which led to the theory that the killer had some connection with rabbits. A man who feeds rabbits was suspected, and a comparison of his rabbits' hair with the fibers found in the coat pocket showed them to be the same. By this trace evidence, we had solved the criminal case.

Location and Gathering of Trace Evidence

The discovery and gathering of physical evidence are difficult, requiring good light and a diligent search with a magnifying glass of the crime scene as well as of the entrances and exits of the criminals and victims. The discovery of extraneous hair or fibers on the body or clothing of either the victim or the suspect is critical. In cases of homicide and rape, for example, the criminal is likely to unwittingly leave at the scene or take away TE in the form of valuable fibers, soil, adhesives on the wound, fibers in strangulation mark, metal residues on electrical burn marks, or gunpowder residues. In motor vehicle accidents, it is important to gather any paints, oilstains, dust, bloodstains, hair, skin, tissues, fibers, plastic, and metal marks on the body or bike of the victim or on the motor vehicles. Table 3 lists various gathering sites for TE and their incidence rates for this study.

Detection and Role of Trace Evidence

The most common examination method of TE is to observe its physical form, color, odor, density, hardness, and magnetism. This report, however, primarily describes methods using the modern instruments listed in Table 4.

The examination of about 30 different kinds of samples of TE such as paint, fibers, soil, metal bits, polymer, grease, and biological tissue has been helpful in all but about 20% of the cases in which it was used. Table 5 breaks down the function of TE to 3 possible classifications: key role, general role, and role failure.

TABLE 3—*Location of sample gathering.*

Location	Number of Cases	Percent
Central crime scene	120	33.9
Exits and entrances of crime scene	7	2.0
Dead bodies	55	15.5
Living bodies	13	3.7
Wounds	18	5.1
Victims	22	6.2
Suspected sites	56	15.8
Suspected bodies	31	8.8
Suspected tools	32	9.0

TABLE 4—*Classification of instrument analysis.*

Instrument	Number of Cases	Percent
Scanning electron microscope	110	31.1
Emission spectrograph	53	15
Atomic absorption spectrophotometer	12	3.4
IR spectrophotometer	40	11.3
Gas chromatographer	16	4.5
Liquid chromatograph	1	0.3
Fluorescence spectrometer	5	1.4
Thin-layer scanner	102	28.8
XF spectrometer	13	3.7
Mass spectrometer	2	0.6

TABLE 5—*Function of trace evidence in 211 cases.*

Role	Number of Cases	Percent
Key	62	29.4
General	107	50.7
Role failure	42	19.9

Discussion

Skillful Use of Trace Evidence

As stated earlier in this paper, destruction by the criminal of the crime scene and evidence seems to be becoming more frequent. This challenges forensic medical examiners to expand the scope of examination with modern instruments and to exploit fully what little TE is available.

The term *trace evidence* itself is rather difficult to define completely. In effect, TE can be innumerable types of materials which are very common in daily life, so its investigative scope is very wide. This author approaches TE from two directions: First is a gathering of already apparent physical evidence, such as materials left on the victim's body or at the crime scene by the criminal. The second is a close scrutiny of samples from the locale likely to yield trace substances, even at the parts-per-million level. This examination can be accomplished only with instrument analysis, which can yield exact results specific to the case. Both types of samples can be called trace evidence.

It is impossible for forensic medical examiners to examine all the potential TE because of the range of samples which can be considered and impossible for them to do every available test, given the range of methods using modern instrument analysis. It is necessary, however, for examiners to master discovering, gathering, and packaging skills, to take advantage of forensic physical and chemical examination approaches, to distinguish accurately the results of instrument analysis, and to use these techniques correctly in the forensic medical examination.

Role of Instrument Analysis

In the past 20 years, instruments such as the thin-layer scanner, gas chromatographer, ultraviolet (UV) visible spectrophotometer, and infrared (IR) spectrophotometer have been more commonly applied in forensic medical examination. We have used such instruments in our field since the early 1980s, but it is still not common practice in the province to do so. There is a growing need to develop modern instruments for specific application in forensic medical examination, and examiners should do their best to exploit them even further. This paper discusses the use of several of these modern instruments in the forensic science examination of trace evidence, in an effort to do so.

The scanning electron microscope (SEM) which we used is fitted with an energy spectrometer. This setup is widely used, does not damage samples, and provides accurate, fast results. Emission spectrographs (ES) and atomic absorption spectrophotometers (AAS) are used in inorganic quantitative and qualitative analyses; the AAS is more sensitive than the ES. The IR spectrophotometer and the UV-visible spectrophotometer are used in organic quantitative and qualitative analyses. The thin-layer scanner is used to detect animal and vegetable oils, mineral oils, dyestuffs, and other organic matter. The gas chromatographer is used primarily to examine volatile mineral oils, powders, explosives, plastics, rubbers, and so forth. The liquid chromatograph and fluorescent spectrometer are seldom used in the application of TE examination. Following are descriptions of actual cases at our institute in which instrument analysis proved helpful in examining TE.

Soil—Soil is the material that remains after rocks have eroded and weathered away. Because of the influence of the specific natural condition in different areas, soil samples collected in a definite area are also different in their chemical components and physical nature. These differences may be used in the forensic medical examination of trace evidence.

On 26 March 1986, a worker in a city was reported missing. On 26 April, the body was found in the dirty water of a culvert. After 35 days, the body had become badly decomposed, and no trace evidence proving a crime could be found at the site. The investigators at the scene thought that although nothing could be found at the crime scene, the perpetrator might well have unwittingly taken away some trace materials while committing the crime. After careful investigation of the crime scene, the investigators discovered that the dirty water flowed into the culvert from an oil chemistry factory and thus had very specific characteristics. At the same time, they found the culvert to be so small and narrow that the perpetrator would have had to bend down to negotiate it. When he put the body into the culvert, some mud on the wall probably came away on his clothes. Following this clue, they searched the suspect's house and discovered two mud marks on the back and the shoulder of his coat. An SEM comparison of the mud lifted from about 20 places of the wall with the mud on the suspect's coat revealed that the components were the same. In light of the evidence, the criminal admitted his guilt.

Fiber—When there is a struggle between criminal and victim in cases of rape or homicide, TE in the form of fibers on the victim's or criminal's body or clothes is almost certain to be present.

On 8 Sept. 1984, Hu, a female employee of the hospital, was killed. After careful research, we determined that two dirt stains on her white shirt were pressure marks made by the perpetrator's knees. Under observation with a stereomicroscope, three blue fibers of 2.8-, 1.25-, and 0.25-mm length were found. The SEM identified the blue fibers as having the same characteristics as cotton. The results of face scanning, point scanning, and semi-quantitative analysis by the SEM indicated that the fibers contained seven inorganic elements: aluminum, silicon, sulfur, chlorine, potassium, calcium, and iron. It was determined that the fibers' colors, forms, and inorganic elements matched those of the suspect's blue trousers. This provided the conclusive evidence we needed to crack the case.

Paint—People come into daily contact with protective or decorative paints on furniture, motor vehicles, and many other objects. In cases of homicide, rape, and traffic accident, paint is one TE which is often discovered, thus becoming important as evidence in many cases.

Pan, a city resident, was raped at her home. Red and green paints were discovered on the suspect's socks. We lifted paints from the headboard of the victim's bed and the wall of her home and compared these paints with the paints on the socks of the suspect by TR-spectrophotometer and by the SEM with energy spectrometer. The inorganic elements shown in the IR spectrometer's pattern by the SEM with energy spectrometer were the same as the elements of comparative samples. It provided enough evidence to solve the case.

In cases in which criminals flee after a traffic accident, paints are commonly found on the corpse, on the bike of the victim, or at the crime scene. In the 36 cases of motor-vehicle accidents discussed in this report, paint-lifting was a factor in 30 cases, or 83.3%. Therefore, paint becomes the most visible TE in traffic accidents.

On 15 Oct. 1985, the perpetrator escaped after a fatal traffic accident. On 2 December, the deceased's coat, which had marks of paint, was sent to our institute. The paint was compared by means of the IR spectrophotometer/energy spectrometer with ten paint samples lifted from the suspect's motor vehicle. It was determined that the color of the marks and the organic and inorganic components of the paints on the victim's coat were the same as those of the paint gathered from the vehicle and that their percentages were similar. These provided the evidence which solved the traffic-accident case.

Body Fat—Cases of murder in which the victim's body is dissected, followed by transporting and cremation are increasing in number. In such cases, investigators at the crime scene must carefully search for body fat TE on the tool or the package.

In April 1986, Lu, a woman, was killed by her husband, who cut her body into 14 parts in the bathroom, washed and dried the body parts, and then put them into a plastic bag. He then washed the crime scene thoroughly. During a chance business travel, he threw the body parts into the sea. Investigators combed the scene 3 times, and finally, about 0.6-mm brownish-yellow, glutinous material was recovered from a crack in the cement floor of the bathroom. The thin-layer scanning spectrometer was able to identify the material as body fat; the blood group, B, was the same as the victim's. In light of the evidence, the husband admitted to the murder, and he was put to death.

Tissue—In forensic science examination, we sometimes come across a case which raises a question of whether or not the deceased was poisoned. Now in all poisoning cases caused by mercury, both mercury and arsenic can be detected in pathological tissue by the super-trace method of analysis, the sensitivity of which can reach the parts-per-billion level.

On 24 March 1985, Chang, a factory worker, twice used an ointment (produced by an unknown person) for a skin problem, after which he became seriously ill and died. After the family had his body cremated, they raised the question of whether or not he had been poisoned. For this reason, we took a lump of the liver and of the kidney tissue stored in the hospital and used the AAS to compare them with common liver and kidney tissues. The result indicated that the mercury content of common tissue was obviously different from the mercury content of the sample and thus that Chang had been poisoned by mercury (see Table 6).

Powder—In shooting cases, gunpowder residues are lifted from the hand, wrist, and cuff of the suspect or victim by adhesive tape. The AAS is then used to detect inorganic elements in the residues of the gunpowder, which is regarded as evidence to distinguish the homicide

TABLE 6—*Results of the Chang examination.*

	Hg Contents in Liver, μg/g	Hg Contents in Kidney, μg/g
Examination	11.75	112.50
Comparison	0.037	0.75

or suicide. In explosion cases, residues on the palm, under the fingernails, on the clothes, or in the pocket of the suspect may be lifted and the powder elements analyzed. If the suspect's hands were washed, the powder can still be detected.

On 26 April 1984, the house of Zhang was blown up. A handkerchief and fingernails were gathered from the crime scene, and the components of TNT explosive were detected.

Rubber Particles—Rubber products are widely used in daily life. In the examination of cases, we often encounter scrape marks left by the perpetrator at the crime scene, adhesive rubber marks on the tools of the crime, brake marks of motor vehicles, and so on. As long as the trace rubber particles of those marks can be observed under the stereomicroscope, the same kind of identification can be done when the visible particles are compared with the samples taken from the suspect by pyrolysis gas chromatography.

Estimation of Lethal Weapons Using Trace Evidence

Forensic science examiners for a long time have been identifying lethal weapons used in crimes, commonly according to the forms of wound and to the adhesive substances on the lethal weapons, but mainly according to examination of the wound forms. In recent years, we have combined the methods of analyzing trace material components and sometimes come to conclusions about lethal weapons on the basis of characteristics of wound forms. We examined nine samples of pure iron from wounded skin, one sample of galvanized iron, one of brick, one of rock, one of wood bits, and two samples of fibers from the lethal weapon of the suspect. These samples provided the evidence to estimate the crime.

In 1984, Cen was stabbed. A knife was taken from the suspect, and fiber was lifted from the knife. The fiber was similar to that taken from the victim's red vest; their organic elements were the same when compared by the State Detector.

Examination of Trace Metal Elements in Electrical Burns

TE from electrical burns is formed by electric sparks and trace metal elements depositing on the skin of the electrically injured victim when the metal wire contacts skin. Satisfactory results which detected trace metal elements of electrical burns or questioned electrical burns on the skin have been obtained by the AAS and the ES. This provides scientific evidence for cracking the electrical homicide case.

Chen, a villager, died suddenly. Her husband claimed that "she was struck by lightning." The investigators from the Electrical Bureau examined the scene and concluded that she had received an electric shock of "indirect lightning." Her family did not agree with the husband or the Bureau's findings and went to the police. Public Security Bureau investigators opened the coffin to examine the corpse and gathered pieces of electrically burned skin from her right cheek, the back of her left hand, and the right knee, as well as an unburned, common piece of skin, then sent these over to our institute. The results are given in Table 7.

TABLE 7—*Results of the Chen examination.*

Samples	Content Iron, $\mu g/g$	Content Copper, $\mu g/g$	Content Zinc, $\mu g/g$
Skin of right cheek	100	trace	100
Skin of back of left hand	2000	69	30
Skin of left knee	100	1	10
Control sample	5	0.3-1.0	0

By instrument analysis, the content of iron and zinc on the electrically burned skin was very different from that of the control samples, so the electrically burned injuries were finally identified as such; what had been called "indirect lightning" was exposed. The TE and instrument analysis provided the scientific evidence for cracking the case.

Conclusion

In recent years, the use of modern instruments which examine about 30 types of trace evidence such as paint, rubber, and body fat has played a certain distinctive role in confirming crime. Our experiences have proven that trace evidence, despite its small size, can provide valuable information concerning the crime and crime clues, can narrow the investigative scopes, and can be used in court testimony. With the development of modern scientific instruments and the increasing variety of the forensic physical and chemical contents, trace evidence is sure to become one of the most valuable types of evidence to help detect and solve crimes in the future. Especially with spectacular and difficult cases and in situations in which there is no visible evidence, we must concentrate on discovering and examining trace evidence. This is the direction that examination identification must take. We expect the application of trace evidence to be further developed and widely used by our colleagues in the forensic science community.

Address requests for reprints or additional information to
Dr. He Zhong-Nian
No. 2 Sec. 2 Beiling Street
Huanggu District
Shenyang, Liaoning
People's Republic of China