FORENSIC EXAMINATION OF SOIL EVIDENCE

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INTRODUCTION

It was more than a hundred years ago that soil evidence was effectively used for criminal investigation. But it was in a fictional literature of Sherlock Holmes series written by Sir Arthur Conan Doyle. At almost the same time Hans Gross of Austria wrote in his Handbook for climinalistics that dirt on shoes probably can tell useful information for criminal investigation, but it did not include any actual case study in which soil could be physical evidence. According to the report by Murray (1), Georg Popp of Germany might be the first scientist who examined soil evidence and led the solution of the murder case in 1904. Recently several interesting articles describing the importance of soil evidence and contribution of geologists to criminal investigation with many historical case studies (1-4). Soil evidence further can contribute to drug intelligence development, for instance, soil taken from containers, ships, or trucks is useful to identify drug shipment pathway (5). Using air photo, satellite imagery enabled to locate underground bunkers which were built to grow cannabis by map interpretation techniques (6).

The monumental work was publishing the textbook entitled “Forensic Geology: Earth Science and Criminal Investigation” by Murray and Tedrow (7) in 1975. It has now revised as “Forensic Geology” (8) along with the change of quality of examination.

Soil can provide useful information about link of persons to crime senes because of its nature as the surface of the ground. The evidential value of soil stands on large variation in its characteristics. Soil has extreme complexity not only in components such as minerals, oxides, organic matter, microorganisms and their materials but also physical nature such as particle sizes and densities. Considering the granite rock alone, for instance, there is an almost unlimited number of kind. They are easily recognized according to difference of color, mineralogy, texture and a lot of other characteristics. Diversity of soil is the results of many kind of soil forming process on diverse kind of parent materials, that strongly depends on topography, climate, course of years, botanical and microbiological functions, conditions of watering, and even human activities. Moreover, there are millions of fossils, external matters such as pollen and spores and even artificial materials. Forensic soil examination has been believed to be very complicated because of complexity of soil, but such diversity and complexity enable us to discriminate soil samplers with high discriminating power. The biggest problem in forensic soil examination is shortage of well-trained staffs and expertise for soil in crime laboratories. Especially mineralogical identification using polarized microscope requires sophisticated and experienced skill, and it also forces examiners to work patiently for many hours. Although considering complexity of soil a variety of methods have been proposed for many years, recent trend of reports has become simplification of procedures and methods. However, still standardization of forensic soil examination is difficult because of diversity of soil samples. Methods sometimes must be changed to optimize for conditions of soil samples.

This paper is summarizing reports about soil evidence, which have appeared for recent three years since 1998, but some important reports written before 1998 are included. As soil evidence has very close relation with dust and other materials, this paper includes dust, diatoms, pollen and botanical materials.

HANDBOOK AND SAMPLING

Training program of forensic soil examination is needed for examiners who are in charge of soil evidence and crime scene investigators. An adequate handbook for forensic soil examiners was written by Mazurek (9). It is effectively used for training program in Eastern Europe. Outstanding point of this handbook is that it includes pedological description about soil and those about soil taxonomy without ending up with technological description alone.

Alertness of those who collect samples, and quality and collection is critical to success of forensic soil examination. According to R. Murray's experience, there was a case where 30 soil samples arrive that have been systematically collected but are useless because they do not represent the exact original location of the questioned sample (4). A report written by Munroe (10) is an excellent guideline for forensic soil examination. It is focusing on sampling horizontally and also vertically from soil. These sampling methods are written from the viewpoint of pedology, especially sampling from each soil horizons in soil profile is outstanding. There is also detailed description about sampling from a vehicle. Standard sample section points includes: (1) the exterior of the front bumper and grill; (2) inner surface of the front bumper and grill; (3) all wheel wells and tires; (4) engine compartment including carburetor housing and air filter; (5) rock panels; (6) control arms/A-frames and leaf springs; (7) tops of mufflers and condensers; (8) interior of passenger compartment and trunk; (9) inner and outer surfaces of rear bumper: (10) rain gutter paths and windshield trim, and (11) Q-Tip or gauze swabs on the exterior painted body surface. The author noted these points are not limited, these are just some suggested selection sites for a vehicle and the investigator should make use of any other possible sites of value. This notice can be applied all crime scene investigation. A lot of important things are written there, but the most important concept in sampling is that soil should not be mixed even they locate in the proximate sites, and the texture should be kept unbroken as possible.

UNUSUAL MATTER

Macroscopic observation and low-power stereomicroscopic observation is important at the initial step of forensic soil examination. It will be lucky for examiners if unique particles such as paint chips, fibers with distinctive color, glass fragments can be found both in a questioned soil sample and a control one. The examination can be focused on these unusual matter in soil, and at this step soil is only background of evidence.

In some articles described interesting cases in which unusual matter could be the key to identify soil evidence and related materials. In a murder case in California, victim's body was dropped at a oil well apron where gravel which was transported from 300 mile south was used. Soil material found in the suspect's car was compared with those around the oil well apron. The questioned sample from the car contained rock fragments which were the same with the imported gravel (1, 4).

Blue thread gave key information in a rape case in Upper Michigan. Three flower pots had been tipped over and spilled on the floor in the struggle. Potting soil on the suspect's shoe was compared with one of those flower pot spillings. Small clipping of blue thread existed both in that flower pot sample and on the shoe of the suspect (1).

In another rape case in New Jersey, that happened at a vacant lot in back of a bar, coal fragments was important. The suspect had soil samples in the cuffs of his pants that were typical glacial sand of northern New Jersey. In addition, the soil contained fragments of clean Pennsylvania anthracite coal. In this sample there was too much coal when compared with samples in the surrounding area. Further investigation showed that some 60 years ago, the vacant lot was the coal pile of a coal burning laundry (1, 2).

A police officer happened to look at a man arrested on a minor crime. He observed "that's the worst case of dandruff I have ever seen." It was not dandruff but diatomaceous earth that compared species-to-species with the insulation materials of a safe that had been ripped the previous day (1, 4).

There was a murder case in Hiroshima, Japan, in which the body of victim, who was a professor of the university, was found in his office with sand on his body. The reason why sand was put on the body was not clear, but the sample collected from sand storage for a sand bath in a laboratory where the suspect was working was compared with that on the body. Cell fragments with unique shape existed both in the sand on the body and that in the sand storage (11).

A woman who lived in Yokohama in Japan killed her husband. She and her daughter carried the body 100 km to the west, and abandoned the body in forest where lava from volcano Mt. Fuji distributed. This lava has distinctive characteristics that are black porous baslt with strong magnetic force and white phenocrysts of bytownite (calcium rich plagioclase). Soil material was collected from floor mat and trunk of suspect's vehicle. In these samples black rock fragments were found. But the area of Yokohama, where the suspect was living, is widely covered with loamy soil developed from thick sediment of fine volcanic ash, and rock does not originally exist. The rock fragments were identified as the lava originated from Mt. Fuji on the basis of the distinctive characteristics (12).

In a murder case in Iwate prefecture, Japan, victim's body was buried in a beach. Soil material collected from the suspect's car and sand of the beach were compared. There were unusually significant number of augite both in the evidence from the car and the beach sand. Additionally, most of these augute particles were large (1-2 mm) indomorphic crystals and had distinctive inclusion. These distinctive augite crystals could link the suspect and the victim (13).

SCREENING METHOD

The forensic soil comparison stands on considerable variation among soil. The significance of match between questioned samples and control ones must be interpreted in consideration of the intra-sample variation within questioned samples and control samples. As it is needed to demonstrate the range of local difference of soil for interpretation, the number of soil samples collected for comparison inevitably increase. Simple and rapid screening methods, therefore, are required for successful identification from a large number of soil samples. Color comparison and determination of particle size distribution for soil samples can be carried out quite easily, and the combined data can be quite useful for discriminating among similar samples. Junger (14) has examined discriminating power of air-dried soil color and particle size distribution on soil samples, which had been collected systematically.

Color comparison on air-dried soil alone is insufficient for discrimination of samples. In order to increase discriminating power Sugita and Marumo (15) studied multiple color observation on soil samples. This method composed of color observation on air-dried soil, moistened soil, the soil after decomposition of organic matter using hydrogen peroxide, the soil after removal of iron oxides using sodium dithionite, and the soil ignited at 850 °C in an electric furnace. For the soil after decomposition of organic matter and after removal of iron oxides, finer particle fraction will be preferable color observation. Namely, the surface of dried deposit by centrifuging after these treatments, because it is more homogeneous than the bulk sample.

Sugita and Marumo (16,17) examined the validity of the determination of particle size distribution for forensic soil discrimination. As fur as reproducibility is concerned, wet sieving is preferable, but the procedure which have been proposed for forensic soil comparison is complicated and a lot of water is required for sieving into several particle size classes. To simplify the procedure, wet sieving was used only to separate a fine particle fraction less than 0.05 mm in diameter and a coarser particle fraction using a sieve with a 0.05-mm aperture size. Then dry sieving, which is easier to perform, was applied to the coarser particle fraction. Generally, particle size was divided into four to nine classes. But when particle size classes with narrow ranges were used for small amount of soil samples, reproducibility came to decrease. In order to obtain better reproducibility and to achieve high discriminating power, the particle size classes were reduced to three: <0.05, 0.05-0.2, and 0.2-2 mm. Discriminating power examined using 73 soil samples collected systematically on the basis of a geologic map and a topography map. Among all the pair of samples, 88% could be discriminated by this sieving method. Additionally, a particle size distribution in the fine particle fraction (<0.05 mm) was determined using particle size analyzer, Horiba model CAP A-300. However, it did not show such remarkable discriminating power; nearly 40 % of pairs of samples remained indistinguishable. Application of particle size analysis together with the multiple color measurement could significantly raise discriminating power, resulting in only 0.5 % of sample pairs being indistinguishable. The addition of particle size analysis of the fine particle fraction does not greatly improve discriminating power.

Coarse particle examination with a binocular microscope is under studying as one of the screening methods.

DENSITY GRADIENT DISTRIBUTION

An improved density gradient technique was reported by Petraco (18). A density gradient column has been prepared using bromoform/bromobenzene (BF/BB) or bromoform/absolute alcohol (BF/AA). But its density (2.89-1.50 g/mL) can not cover whole density range of soil minerals. Probably it is one of the major problems that makes density gradient examination less valuable. The problems of this technique are not only in reproducing the analysis, but provides the same observation on two totally different minerals simply because they happen to have the same density. Problems with the density gradient column were summarized by Murray and Tedrow (8). In the imprived method, density gradient is prepared with mixture of Clerici's solution (CS, saturated solution of thallium malonate-formate in distilled water) and distilled water (DS) in a density range of 4.24-1.00 g/mL with 11 layers of the subsequent mixtures. After allowing the gradients to stand overnight to equilibrate, 5 to 10 mg of dry soil sample (120-140 mesh sieve) is placed into the gradient column. Again after allow the column to stand for 24 h comparison and evaluations are made. Using this gradient column (CS/DS) enable to observe heavy minerals distribution in the column, though they fall past the gradient liquid to the bottom when organic gradient (BF/BB or BF/AA) is used.

PRIMARY MINERALS

Optical examination of primary minerals using a polarized microscope requires expertise and a lot of experience. It can frequently be distress in many forensic science laboratories because of lack of geologist, mineralogist or soil scientist. However, examination of primary minerals, which consist of sand fraction, is essential in forensic soil identification, because sand is one of the major constituents of soil, and mineralogical information of sand can interpret reasonable relationship between a questioned soil samples and control ones. A lot of reports describing simplification of mineralogical examination have been presented to solve this problem.

There was an attempt to use identification chart for mineralogical examination by a polarized microscope. Ishiwatari (19) proposed useful identification chart including 200 minerals. Minerals can be identified according to the position in rectangular coordinates, that is determined by the optical characteristics under the polarized microscope. The ordinate presents color under the plane polarized light, refractive index and cleavage, and the abscissa presents optic axial angle 2Vz and conoscopic figure. Additionally extinction angle, elongate sign, twinning, double refraction and anomalous interference color observed between cross polars are shown by marks and frames. This identification chart is aiming to use rock-forming minerals. If this chart is simplified for soil minerals, it can be very useful for forensic soil examination.

Application of a scanning electron microscope equipped with an energy dispersive x-ray spectrometer (SEM-EDX) to mineralogical examination is the most prospective approach for the future. McVicar and Graves (20) developed a particle search and analysis technique using an automated SEM-EDX system. The first key point of this method is how sand particles can be separately arranged on an adhesive tape placed on a stub (a sample holder of SEM), because SEM regards two or more adjacent particles as single particle. The taped surface of the stub was pressed firmly onto the bottom surface of a 150 mesh stainless steel sieve. Sample particles were poured onto the grid atop the center of the stub, forming a small mound of sample particles. The sieve was gently tapped and rotated to distribute the particles onto the exposed adhesive patches between the grid wires. After particles were firmly presses into the adhesive, the stub was removed from the grid. This particle placement allowed the examination of more than five thousand particles per one inch diameter stub. The "Zeppelin" software was used in two steps. First, percentage compositions of elements were recorded and then mineral particles were classified. Each particles are identified according to the mineral classification rules which had been build up beforehand on the basis of analysis on known minerals by this method. Even though results of identification by this method were not necessarily correspond to those by optical examination, sand particles could be identified with the precision of <10% (CV) for components more than 5% in soil. Based on differences in composition, as measured by means of Chi-Square test, the four soil samples of the same color from different locations in the Province of Ontario were clearly discriminated.

There was another interesting report by Sungwoo Park and co-workers (21) about evaluation of mineralogical composition in soil samples. It was an attempt to application of image processing to pictures taken on sand particles under a polarized microscope. Color distribution calculated from the picture was subjected to soil comparison. It does not completely correspond to mineralogical composition, but it can provide useful information of sand fraction of soil to forensic soil identification. They also reported the use of SEM-EDX.

CLAY MINERALS

Since clay minerals are secondary produced in soil pedon from parent materials during soil forming process, clay mineralogical composition reflects pedogenic variation in addition to that of parent materials such as sediment and metamorphic rocks. Clay minerals are so small that optical microscopy can not be applied. X-ray diffraction (XRD), transmittance electron microscopy (TEM), differential thermal analysis or infrared spectroscopy is used for identification of clay minerals.

McAlister and Smith (22) proposed a rapid preparation technique for XRD analysis of clay minerals. As crystals of most clay minerals have platy structure, basal spacings have to be recorded by XRD. For this purpose orientation of clay minerals is needed. Sedimentation of clay suspension onto glass slides, suction onto unglazed ceramic tiles, smearing clay pastes onto glass slides, and suction onto membrane filters have utilized to prepare oriented clay mounts. However, each of these techniques is known to have drawbacks. They proposed a refined technique, whereby clay suspensions were precipitated onto membrane filter discs under pressure given by syringe injection. The membranes were dried and mounted using a water-soluble polyvinyl alcohol adhesive onto glass slides, and subjected to XRD. Solvation of the clay could also be carried out by placing one drop of ethylene glycol at the center of these mounts and leaving to disperse throughout the specimen layers. The strength of this technique is that it can reduce preparation time and enhance detection of clay minerals presenting in low concentrations in samples.

Righi and Elsass (23) reported usefulness of mathematical treatment of the XRD diagrams named "a curve decomposition program" (24) for identification of complex mixtures of clay. Because in temperate soil the clay fractions are complex mixtures of numerous clay minerals, including mixed-layer minerals of different types, their characterization is generally a difficult task. These mixtures exhibit complex XRD bands combining several poorly individualized peaks. By this mathematical treatment, the complex mixture band could be reasonably resoluved.

ORGANIC MATTER

There has been woeful number of reports about soil organic matter. The most important as soil material is humic substances. Since it is derived from decomposition of plant materials by micro-organisms, humic substances are surprisingly complex mixture of organic substances in which unlimited type of organic substances with different molecular structure can exist. Therefore analytical methods utilized for humic substance in soil science is complex and time consuming. It is important for soil survey investigation to analyze organic matter, but it does not show remarkable variation among soil samples for forensic soil comparison like minerals. Because of thise complexity forensic scientists have not been paying much attention to organic matter in soil.

Cox and co-workers (25) recently developed an excellent method for analysis of soil organic matter using Fourier transform infrared absorption spectrometry (FTIR) tecnique. The spectrum obtained after pyrolysis subtracted from the one measured on the same sample before pyrolysis left a spectrum which presented soil organic matter. This method was applied to four soil samples collected from different geographic province, which had not been discriminated by means of color comparison and organic content (weight loss by ignition) among 100 samples. These four soil samples could be clearly differentiated.

MICROBIOLOGY

Application of soil micro-organisms and their activity to forensic soil comparison has been vary rare. The report by Thornton, Crim and McLaren (26) was the only one realistically useful approach in which activities of phosphatase, arylsulfatase, urease, tripsin and invertase in soil were measured.

Omelyanyuk and co-workers (27) proposed a multisubstrate testing method (MT) for forensic soil comparison, as traditional method of microflora investigation is rather complicated because separation of pure cultures is needed. MT was based on complete functional characterization of complex natural microbial communities using intensity of assimilation of different sources of organic carbon while observing the change of color of tetrazolium salt. In this method 11 carbon sources was used: loctose, acetate, sodium, arabinose, lysine, serine, valine, cysteine, thymidine, sorbitol, starch and tween. Soil samples were extracted in water by sonic treatment for 30 sec. The water suspensions were put into microtiter plate with a set of substrates (11 types) and tetrazolium violet as an indicator of growth microorganisms. Incubation was carried out over 72 h at 27 °C. Change of color was observed and recorded using microplate scanner attached to the MT-system. This method was effectively applied to actual case study.

INORGANIC ANALYSIS

Microscopically, soil is heterogeneous mixture consist of organic matter, rock fragments, mineral grains, clay, oxides etc. Therefore unique particles can be of important to characterize soil evidence. A small crumb is much more important, and bulk analysis frequently gives poor results for forensic soil examination (28). Some particular fractions of soil can be useful for forensic soil discrimination rather than the bulk analysis. Some analytical methods such as x-ray fluorescence spectrometric analysis of free oxides, high performance liquid chromatographic analysis of polycyclic aromatic hydrocarbons had been proposed.

Recently, Cave and Wragg (29) proppposed to analyze soluble elements obtained by sequential leaching. A series of leachate solution containing varying proportion of different physico-chemical components of soil allowed the chemometric procedure to identify and quantify each component. In this report the method was still trial for NIST certified soil (SRM 2710). Attempt to use this method for forensic soil discrimination can probably be valuable in the future.

Cengiz and Sakul (30) reported application of anion analysis for forensic soil discrimination. Capillary electrophoresis was applied to soil extract obtained by shaking 10 g of soil sample with 10 mL of distilled water. Chlorite, nitrate, sulfate and phosphate contents were compared among soils.

POLLEN AND OTHER BOTANICAL MATERIALS

Forensic interest in soil evidence is to establish the link between two objects including a suspect, a victim, a crime scene, and often a tool or a vehicle. Therefore, what criminal investigation requires to forensic pollen analysis is to establish presence or absence of localized pollen species in soil evidence. For this purpose, generally insect pollinated species can provide useful information. These pollen usually remain near the site of deposition of their flowers, while wind pollinated species disperse long distance and distribute over extensive area, though they can provide negative result by the presence and absence that two samples have not originated from the same site. Useful protocol was provided by Eyring (31), in which some modifications of traditional method were made. The author was describing detailed procedure of pollen specimen preparation for microscopic observation:

4# **Cleaning up: All apparatus should be well cleaned, to avoid sample contamination, and free of surface films that might hold small particles.**

4# **Sample disruption: Materials that are agglomerated with the pollen should be disrupted. Soaking followed by gently stirring with a small amount of density separation liquid suffices to separate the pollen. Occasionally, a bit of ultrasonic agitation will be helpful.**

4# **Soil size fraction: Pollen is generally less than 100 µm in diameter. A sieve with openings of 250 µm is adequate for pollen search and can reduce the volume of sample.**

- **4# Density separation: A concentrated solution of zinc bromide (1.81 g of $ZnBr_2$ in each mL of acidified distilled water, 2 g/mL) is commonly used. For forensic purpose, heavy organic liquids (2 g/mL) such as trichloroethylene/bromoform are used, because the zinc bromide solution affects crystal of calcite.**
- **4# Heavy fraction preservation: a few acetone rinses and short centrifuge spins will free the heavy fraction obtained by the density separation from halogenated liquids.**
- **4# Digestion of humic materials: Gentle boiling the separated pollen fraction with 10% (w/w) potassium or sodium hydroxide for a minute or two in a centrifuge tube.**
- **4# Dissolution of silicates: If the fraction include substantial amounts of fine clay and other mineral particles, those should be dissolved with 35 to48% hydrofluoric acid, but frequently this treatment is not necessary.**
- **4# Hydrolysis and acetolysis: This reaction involves the conversion of cellulose using a solution of acetic anhydride (G=1.08) and remove fibrous materials.**
- **4# Gentle bleaching of acetylated pollen: Recently deposited pollen and fresh pollen recovered from blossoms can be stained a dark brown by the acetylation, and may need destaining or bleaching before selective staining. A sodium hypochlorite solution (5.25 to 10%) can be used to remove acetylation stains.**
- **4# Removing large contaminants: If any clumps of dark black carbonatious material in the 200+ µm exist in the sample, these must be removed using a sieve with 200 µm openings. These large particles can interfere with mounting cover slips on slide preparation.**
- **4# Staining: At least three types of basic stains have proven suitable for pollen. They are 1. Safranin O, 2. Calberla's solution, and 3. Carbol fuchsin.**
- **4# Sample mounting: Pollen extracts are normally mounted on slides in glycerin. Cover slips are applied and the mounts are stabilized by applying nitrocellulose adhesive (nail polish) at a few spots around the cover slips.**

Useful literatures for pollen extraction and identification and method for preparation of SEM reference samples were also described in this report.

Horrocks and co-workers (32) verified forensic pollen analysis. Samples from within the same localized area showed a high degree of similarity. On the other hand, pollen assemblages from different places with the similar vegetation showed significant difference even within the same geographic region. They examined soil samples from shoes and those from places where shoeprints were impressed by the shoes before (33). Pollen assemblages in the sample from the shoes showed significant similarity with those the shoeprints made by those shoes. They applied pollen analysis to a rape case (34). A victim tried to leave a suspect's car which parked at a driveway, but she was caught and raped on a alleyway 7 m away from the car. But the suspect insisted that he only got out of his car, but stopped and stay there just the side of the car without running after her. Soil samples taken from the jacket and pants of the suspect were compared with the soil samples from the alleyway and the driveway by means of pollen analysis. The results strongly supported the allegation by the fact that pollen assemblages in the samples from the suspect strongly correlated with the soil from the alleyway that was the actual crime scene.

All these results are suggesting that pollen analysis of soil samples is valuable for forensic science investigation.

Bock and Norris (35) described contribution of plant anatomy as a part of forensic botany. The authors have utilized characteristic features of epidermis cells of plants, especially from food plants to identify the stomach contents of homicide victims. They had already published a guide to plant food cells for the use of criminal investigation and pathology (36). Examples of some other botanical evidence useful for criminal investigation were written in this report.

DIATOMS

Diatoms frequently observed in soil, since they can rapidly propagate in various environments even during short temporary wet conditions. Because of distinctive diversity of their species and assemblage diatoms can play an important role in forensic soil identification.

Pollanen (37), who has been studying diatom test for postmortem diagnosis diagnosis of drowning, published a text book for the diatom test. The book is copiously illustrated with black-and-white photographs, among these are a number of illustrations of some of the commoner fresh-water diatoms. This compilation of photographs may be of valuable to potential readers. Some of practical examples of utilizing diatom studies cited in this book will be useful for forensic science.

Pollanen (38) reported six drowning cases in which diatoms were extracted from bone marrow showing usefulness of the diatom test as an important adjunct to the medicolegal investigation of homicidal drowning, particularly in those cases where autopsy and scene findings did not imply drowning as a cause of death.

Gruspier and Pollanen (39) also reported application of the diatom test to limbs in dismembered cases. In all these cases diatoms were recovered from marrow extracts, indicating that drowning was the cause of death or at least a significant contributing factor in the cause of death and dismembering happened after the death.

Caution when the Soluene-350 is used for solubilization of organ samples was reported by Sidari et al (40). It was appearent that Soluene-350 treatment was excessively destructive for sea water diatoms, while it has been effectively used for fresh water diatoms. It was probably due to less silicized frustule of sea water diatoms than that of fresh water diatoms. As a result the Soluene-350 treatment should be replaced by the Proteinase K method for sea water diatoms.

Li Yange and cowoekers (41) proposed the use of pressure resistant double capped Teflon bottle for extraction of diatoms from human tissues. Three grams of organic tissue could be digested using the bottle with 4 mL of nitric acid by heating at 120 °C for 100 min. Diatoms were separated by centrifuging the residue.

There were serial articles about diatoms entitled "diatoms: diatom microscopy" in the Microscopy until 1995 (42). These will be helpful for forensic scientists who are interested in diatoms as trace evidence.

DUST

As dust is complex mixture of distinctively various types of particles and fibers, it might have rich information for criminal investigation. If particular combination of some unique components in dust is established, it can be a strong proof of contact with a particular place. A lot of interesting issues are still remained untouched in forensic dust evidence.

Millette and Few (43) described five basic dust sampling method suitable for microscopic analysis. It included illustrations of each of the samplers and a list of 30 useful literatures about dust sampling.

4# **Brush sampling: This procedure is used for loose or lightly attached particles. Synthetic bristle brushes work best because it is difficult to remove some particles from hair scales as camel hair. Glassine envelope or resealable plastic bag is used for preservation of samples.**

4# **Scrape sampling: Razor blades or scalpels are preferred for particles or stains that tightly held on surfaces. But caution have to be taken because razor blade can damage some surfaces. Push the scrapings together with the blade and scoop them into a plastic container.**

4# **Adhesive tape sampling: Clear cellophane tape attached to a glass microscope slide is the most common of the adhesive tape sampling. Check whether the adhesive tape can damage the surface or not before sampling.**

4# **Wipe sampling: A variety of wiping materials including cloths, swabs and filter papers have been used to sample surfaces for contamination. Recently, a plastic bag wipe sampler was reported (44). Gauze pads impregnated with a solvent often used, but dry wipe is preferred for microscopic particle identification. A resealable plastic bag is used for preservation.**

4# **Vacuum sampling: Both a full size modified vacuum cleaner and a smaller size modified hand-held vacuum system have been used to collect dust. But these vacuum samples can collect only particles greater than 5 µm and therefore may not include all the particles of interest to a microscopist. Air sampling pump with a flow rate between 1 and 15 L/min is used for vacuum.**

Millette and Few (45) reported their study on indoor carbon soot particles using transmittance electron microscopy (TEM). The authors classified carbon soot into four groups.

The group with the largest particles is the char fragments, which are carbonized wood or cellulosic materials ranging from micrometers to millimeters often retaining some of the features of the original materials.

4# **Carbon cenospheres are hard shiny, porous or hollow carbon spheres, typically of 10-100 µm and are formed when liquid drops undergo carbonization without substantial change in shape.**

4# **The smallest soot particles are formed through the deposition from the gas phase. These particles are spherical or near-spherical with mean diameters around 20 to 30 nm. They adhere to each other to form straight or branched chains, and designated as aciniform.**

4# **A fourth group of particles consists of material composed of microscopic entities in which spheroidal carbon particles of colloidal dimensions embedded in carbon or carbonaceous material. This category was designated as carbonaceous microgel.**

Benko (46) described polarized microscopic observation and application of FTIR to dust examination. Dust samples were extracted by solvent and evaporated residues were analyzed by micro-FTIR. Cooking grease, vegetable oils, some candle wax formulation, and certain semi-volatiles may provide definitive spectra. Residues from cleaning/polishing products can also give unique IR spectra.

CASE STUDY

On march 16, 1978, the Prime Minister of Italy, Mr. Aldo Moro was kidnapped on his way to the Parliament House. In the morning on 8 may 1978, Mr. Moro's body was found in a trunk of a car. The results of this forensic investigation were disclosed after 20 years. Lombardi (47) discussed the findings by the forensic investigation conducted on the evidence found on Mr. Moro's clothes, shoes (beach sand, bitumen, vegetable materials and polyester fragments), and on the car. The study of the vegetable materials suggested that they had been picked up in a period of time close to the killing. Thermosetting polyester, of the type used in boat manufacturing, was found under the fenders, in the tires and inside the car, as well as under Mr. Moro's shoes, supporting proximity of a beach. Pollen analysis showed that adhesion of volcanic soil to the car fenders antedated adhesion of the sand.

In November 1989, an aircraft flew from San Diego, California toward Ruidoso, New Mexico. The aircraft crashed a few moments before a scheduled landing near Ruidoso in Lincoln County, New Mexico. Contribution of soil evidence to the investigation of this case was reported by Daugherty (48). The main issue was that which could be the cause of crash, in-flight accumulation of the soil or the soil accumulated after the crash while the debris was in a storage yard. The plane was exposed to intense fire after the crash. Change of soil color by heating was examined by redness rating test, which can illustrate relation between reddening and heating on soil samples. As the results, no evidence was found for the presence of soil in a pre-crash period that would have interfered with the operation of the airplane.

SOCIETY OF FORENSIC SOIL INVESTIGATION

American Society of Forensic Geologists Inc. was established in 1999, 620 Bridlewood Dr. Culpeper, VA. 22701, USA. The society is a non-profit scientific organization whose purpose is the enrichment of the forensic geology discipline and its expanded utilization in criminal and civil investigation. The membership is composed of geologists, mineralogists, forensic scientists, geophysicists, archaeologists, educators, investigators and all other who share the common goals and interests. Publishing of a newsletter is under preparation.

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