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Diatoms and Drowning

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Summary. An examination is made of the applicability of quantitative and qualitative diatom analysis to the diagnosis of death by drowning, definition of the environment in which drowning occurred, and delimitation of the area where it occurred. The material comprises 107 bodies of subjects known or suspected to have died by drowning together with a control series of 15 bodies of subjects over 30 years of age who had died of various diseases on land.

Whenever diatoms were found in the greater circulatory organs they were also found in the lungs, and when none were present in the lungs none were found in the other organs either. No diatoms or fragments of diatoms were found in the samples from the control subjects. All the fresh, well-preserved bodies for which death by drowning could be regarded as certain from the macroscopic autopsy findings and police reports, the cases used to test the method, gave quantitative diatom results that supported a diagnosis of water aspiration.

The diatoms identified in the qualitative analyses served well to describe the ecological properties of the environments in which death had taken place, and the site of drowning could be defined by means of comparative water samples provided that sufficient diatoms were present, the local environment was not too homogeneous or the diatoms were not of quite different species due to a completely unknown location of death.

Key words: Diatoms – Drowning – Diagnosis of death

Zusammenfassung. Es wird über Untersuchungen berichtet, die zum Ziel hatten, die Anwendbarkeit der quantitativen und qualitativen Diatomeenanalyse zur Diagnose des Ertrinkungstodes, der Feststellung des Ortes oder der Eingrenzung der Gegend, wo das tödliche Ereignis sich abspielte, zu prüfen. Das Untersuchungsmaterial bestand aus 107 Leichen, bei denen die Todesursache Ertrinken durch Autopsie festgestellt worden war; als Kon-

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trolle dienten 15 Leichen von Personen, die über 30 Jahre alt geworden waren und die an verschiedenen Erkrankungen gestorben waren.

Wenn Diatomeen in den Hauptorganen gefunden wurden, so waren sie auch in den Lungen nachweisbar. Waren sie nicht in den Lungen vorhanden, verlief der Nachweis in den anderen Organen ebenfalls negativ. Keine Diatomeen oder deren Bruchstücke wurden in den Organen der Kontrollgruppe gefunden. In allen Fällen, in denen frische Leichen, bei denen Ertrinken als Todesursache durch den makroskopischen Befund und den Polizeibericht als sicher diagnostiziert worden war, der Untersuchung zugrunde lagen, unterstützte der quantitative Diatomeenbefund die Diagnose einer Wasseraspiration.

Die Identifizierung der Diatomeen erlaubte eine Charakterisierung der ökologischen Gegebenheiten des Ortes, in welchem das tödliche Ereignis sich abspielte. Durch gleichzeitige Untersuchung von Wasserproben konnte der Ort des Geschehens näher eingegrenzt werden. Voraussetzung war jedoch, daß genügend Diatomeen vorhanden waren, die örtlichen Verhältnisse nicht zu einförmig oder bei unbekannter Lokalität die Diatomeen-Arten nicht völlig verschieden waren.

Schlüsselwörter: Diatomeen – Ertrinken – Diagnose der Todesursache

Introduction

A diagnosis of death by drowning is normally based on findings from external examination of the body and autopsy together with laboratory investigations, but the degree to which such a diagnosis can be demonstrated with certainty depends essentially upon whether or not decomposition has set in. The best indicators of death by drowning are the "drowned lung" sign typical of bodies feshly recovered from water and the presence of fine froth at the mouth and nostrils [1]. Such macroscopic autopsy findings are usually regarded as sufficient for a diagnosis of death by drowning, especially when clear account of the event has been submitted by the police. It is possible, however, to come to false conclusions on the grounds of macroscopic pulmonary findings alone, since there are some diseases, such as pronounced fibrosis or past pleurisy with extensive pleural thickening, or accidents, such as vomit aspiration and other forms of suffocation, which can cause difficulties in the interpretation of such findings [2]. On the other hand, the above mentioned froth is found in only about half of all cases and disappears rapidly upon contact with air or upon decomposition [1].

These possible sources of error make it essential in dubious cases for the diagnosis to be based on laboratory tests, the most important and most widely used of which is quantitative diatom analysis, i.e., identification of the presence of diatoms in the body tissues. At our present state of knowledge this is also the only reliable diagnostic approach for cases of a decomposed body recovered from water in which the macroscopic findings typical of drowning can no longer be assessed.

A further refinement to this method is the use of qualitative diatom analysis, involving determination of the diatoms to species, to define the general environmental conditions under which drowning occurred, thus enabling the site to be delimited by reference to comparative water samples. This is possible because diatoms reflect fairly accurately the water quality at the site at which they grow, each species having typical site requirements in terms of salinity, pH range, water depth, bottom conditions, aquatic vegetation, etc. Although individual species may be able to survive at a variety of sites, each set of species with similar environmental requirements forms a closely definable diatom community of its own.

Apart from the extensive shallow dea area around the islands off Finlands' coasts, it also has many tens of thousands of lakes, with a mean depth of only 7m, covering almost 10% of the country's surface area, probably a higher proportion than in any other country in the world. Thus, it is only to be expected that ecologic conditions should vary markedly even within small geographic areas. This variability in environmental conditions provides much better opportunities for using qualitative diatom analysis than are to be found in Central Europe, e.g., where the physical environment is more homogeneous.

There is nevertheless some research to suggest that algae with cell walls of silica are to be found to some extent independently of death by drowning. This has led to much debate over the reliability of the method and the significance of diatom findings, which continues up to the present day.

Among the most recent investigators to consider this problem, Gylseth and Mowé [3], Schellmann and Sperl [4], Schneider [5] and Foged [6] are of the opinion that since diatoms can be found at autopsy in other subjects, they cannot be used as evidence of drowning. It is even suggested in the literature that the diversity of the diatom flora in water systems detracts from the usefulness of the method [7]. On the other hand, Udermann and Schuhmann [8], Goontilleke [9], Ranner et al. [10], and Calder [11] regard the method, when performed by the correct techniques, as appropriate for the diagnosis of death by drowning.

To look into this matter further, a project leading to a doctoral dissertation was set up at the Department of Forensic Medicine, University of Helsinki [2], to determine the relevance of quantitative diatom analysis to the diagnosis of death by drowning, the applicability of qualitative analysis based on species identification to the determination of the general environmental conditions at the site of drowning and the chances of delimiting the site of the death by reference to diatom ecology.

Material and Methods

The material comprised 107 subjects who had died by drowning or were suspected to have died in this manner. All of them were autopsied at the Department of Forensic Medicine, University of Helsinki, together with a control series of 15 subjects over 30 years of age who had died suddenly of various diseases on dry land.

The following samples were taken for diatom analysis:

a) at least 100 g strips of surface tissue (in situ) selected so as to avoid where possible emphysematous areas of the lung with poor circulation,
b) one half of a kidney, or in cases of marked nephrosclerosis, a whole kidney,

c) a wedged-shaped liver sample (in situ) extending deep into the tissue,
d) a brain sample (in situ) including part of the plethoric arachnoid membrane.

The samples were taken in as sterile a manner as possible to avoid contamination. All the instruments and unchalked gloves were changed as the investigation proceeded from the skin to the body cavities, and also when proceeding from one organ to another. The use of all forms of paper was avoided, especially cellulose wadding, which has been shown to contain surprisingly high numbers of diatoms.

Water samples from the assumed place of drowning and/or place where the body was found were taken as soon as possible after discovery. One half to one liter of water was taken into a pre-washed bottle which had been rinsed in water from the sampling site prior to filling.

The following chemical method was developed for extracting diatoms from the organ samples. The samples were first cut into thin strips under sterile conditions, placed in a 500-ml Kjeldahl flask and boiled for 10–15 min in distilled water tested for freedom from diatoms by the Millipore filter method prior to use. About 10 ml nitric acid was carefully added to the boiling sample, followed by the same quantity of 30% hydrogen peroxide, again both tested to ensure freedom from diatoms. Further additions of nitric acid and hydroperoxide were made as boiling continued, until the tissue had dissolved entirely. A final addition of hydrogen peroxide was made to the lung samples since this appeared to be capable of binding carbon dust to some extent. If excess frothing was encountered in the course of boiling, further distilled water was added. After disintegration the samples were centrifuged at 3000 rpm and the precipitate transferred to a cover glass with a disposable micropipette. The slides were coated with Canada balsam and bromnaphthalene. The diatoms were counted both quantitatively and qualitatively and the results compared with those obtained from the water sample from the known or suspected site of drowning whenever such a sample was available.

The above method avoids the exceedingly low pH encountered in ordinary acid digestion, which is thought to damage certain species of diatom, nor does it lead to the formation of crystals which may interfere with diatom counting.

The water samples were processed in the same manner to ensure maximum comparability with the organ samples.

The chemicals and instruments were checked regularly for contamination. Since diatoms are said to dissolve in highly alkaline substances [12], the equipment was cleaned by immersion in 2-N NaOH for 24 h immediately after each process, followed by washing in a machine and rinsing with diatom-free distilled water.

The results were grouped for ease of interpretation on the basis of the site of investigation (A = lungs, B = liver, kidneys, and brain), and the diatom findings (+ = positive finding, − = negative finding), yielding the following three combinations:

1. A+B+ = positive diatom findings in the lungs (A+) and other organs (B+).
2. A+B− = a positive diatom finding in the lungs (A+) but negative in the other organs (B−).
3. A−B− = negative diatom findings in the lungs (A−) and other organs (B−).

The results were then tabulated in the above groups in the order of known or estimated date of death, the first two groups being further subdivided according to the presence or absence of decomposition at the time of recovery. The former subgroup was intended for practical application of the method and the latter for testing its usefulness, being composed of cases, which could be taken as definite deaths by drowning on the basis of both police reports and macroscopic findings at autopsy.

Qualitative analysis of the diatoms led to identification of the more typical species and interpretation of the prevailing water conditions by reference to the ecology of these.

Results and Discussion

No sample from any of the 15 autopsies of subjects aged over 30 years who had died suddenly of various diseases on dry land contained any diatoms or diatom fragments.

All cases in which a positive diatom finding was recorded in the major circulatory organs also had diatoms present in the lungs, and, conversely, if no diatoms were to be found in the lungs, there were none in the other organs either.

Group A+B+

There were 62 cases in which diatoms were noted in both the lungs (A+) and the greater circulatory organs (B+), comprising 30 fresh bodies and 32 decomposed ones. This group accounted for 57.9% of the total material. The quantitative diatom analysis gave the same results in all the fresh, certain cases of death by drowning, i.e., indicating aspiration of water into the lungs. In both the fresh and the decomposed cases the results of the qualitative analysis reflected well the conditions at the site of death where these were known. Water samples were available for comparison in 28 cases (45.2%) and the site of drowning could be delimited by reference in these in 18 cases (64.3%).

Case Report

Case 5 (8a)

A 52-year-old man had been found dead and almost naked in a brook about 3.5 m within the city of Helsinki. Death was estimated to have occurred 7–13 h earlier. He had many minor bruises on his body suggestive of violence but no injury or organic disease which would explain his death. His blood alcohol content (ADH method) was 1.3‰. Police investigation raised the suspicion that he may have been drowned in the nearby small pond, not connected with the brook, and then carried the distance of about 5 m overland to the site where his body was found. Water samples were taken for further investigation. Diatom analysis showed the water of the brook to contain large numbers of diatoms, with *Surirella ovata* and *Meridion circulare* the dominant species, pointing to a flowing freshwater environment *(Meridion)*, whereas the pond had species of the genera *Gomphonema* and *Navicula predominant*, i.e., quite different ones from those in the brook. The lungs of the deceased were found to contain over 100 diatoms on the sample slide among which the dominant species proved to be *Surirella ovata* and *Meridion circulare*, and some examples of the same taxa were also identified in the other organs examined. The results thus strongly point to aspiration of water from the brook and were interpreted as excluding the possibility of drowning in the nearby pond.

Case 6 (8a)

A 48-year-old woman was found dead in a small ditch, a water sample from which contained *Meridion circulare, Tabellaria flocculata*, numerous species of the genus *Nitzschia, Pinnularia* sp., *Navicula* sp., *Campylodiscus echeneis, Grammatophora marina,* and Amphora holsatica. This diatom analysis is thus suggestive of flowing fresh water, perhaps with some pollution (*Meridion* and the nitrogen-heterotrophic *Nitzschia* species), which had at one time been associated with a brackish water environment *(Campylodiscus, Grammatophora, Amphora)*. The lung sample from the deceased contained about 40 diatom frustules representing the same species as in the water sample, and the other organs had just under 20 specimens, also of the same taxa. The results thus point to aspiration of water either at the site from which the water sample was taken or in an ecologically comparable body of water. Diagnosis: Aspiratio diatomarum.

Case 31 (8b)

The decomposing body of a 31-year-old woman was found in a small bay on the coast. Several hundred diatoms were found in the lung sample, including *Navicula pusilla, N. peregrina, N. oblonga, Coscinodiscus* sp., *Nitzschia tryblionella, Eunotia praerupta, Thalassiosira baltica, Synedra pulchella, Gyrosigma attenuatum,* and *Cymbella ventricosa*, while those from the other organs contained only a few examples of the same species. The findings suggest aspiration of water, the differences in proportion between the findings apparently indicating aspiration of a large quantity of water into the lungs followed by a rapid cessation of circulation and onset of death. In diatom terms the site concerned is shallow brackish water representing a mixed environment typical of the coastal areas of Finland, in which the local shallow brackish water species, such as *Synedra pulchella* and *Navicula peregrina*, are found in conjunction with plankton species which have drifted in from the open sea, e.g., *Thalassiosira* and *Coscinodiscus*, and freshwater species washed out from inland waters, e.g., *Eunotia praerupta* and *Gyrosigma attenuatum*. Diagnosis: Aspiratio diatomarum.

Group A+B−

There were 33 cases, 21 fresh corpses and 12 in the process of decomposition, in which a positive diatom finding was recorded in the lungs (A+) but a negative finding in the other organs studied (B−). The group accounted for 30.8% of the total material.

As in the previous group, the fresh cases, known to be the result of death by drowning, were used to test the method and the decomposed ones as practical applications. Again the quantitative diatom analyses gave similar results for all the certain cases, just as the qualitative analyses reflected well the conditions found at the known sites of drowning. Comparative water samples were taken in 12 cases (36.4%), and these enabled the site of drowning to be delimited in 5 (41.7%).

Case Report

Case 1 (9b)

A 67-year-old man committed suicide by jumping into the rapids of a river flowing into the Gulf of Finland in October, at the autumn peak in diatom production. His body was then carried about 10 km downstream and was found in a decomposed state in a sound of flowing brackish water between islands some 4 km from the mouth of the river after the winter ice had melted almost six months later, at the time of the spring peak in diatom production. No signs of organic disease or injury that could have explained the death could be found. The very high number of diatoms found in the lung sample were distributed in percentage terms as follows:

- Purely freshwater species 71.3% (e.g. *Meridion circulare* var. *constricta, Melosira distans, M. granulata* var. *angustissima, M. italica, M. islandica* ssp. *helvetica, Synedra ulna, Navicula radiosa*)
- Facultative freshwater or brackish water forms 23.2% *(Melosira varians, Navicula rhynchocephala, Cocconeis placentula, Tabellaria fenestrata)*
- Purely brackis water species 5.5% *(Achnanthes taeniata)*

In diatom terms, the death could be put down to drowning in flowing fresh water, the brackish water species being attributable either to erosion caused by the current or to post-mortem contamination. Diagnosis: Apiratio diatomarum.

Case 11 (9a)

A boat being used by a 52-year-old professional fisherman to move house capsized about 100 m from the shore during the spring peak in diatom production. The victim went under almost immediately. Serious heart disease was revealed at autopsy, but no alcohol in the blood. The lung sample contained only about 30 diatoms, with *Thalassiosira baltica* dominant, even though there was known to be a very high incidence of diatoms in the water at the time. The result is suggestive of a very sudden death, probably with very little aspiration of water. Death may well have been brought about by the patient's serious heart condition, which was indicated as a contributory factor on the death certificate. In diatom terms the accident occurred under brackish open water conditions. Diagnosis: Aspiratio diatomarum.

Case 15 (9a)

A 33-year-old man had been diving repeatedly into a lake from a jetty at the height of summer, when diatom production was at its minimum. Suddenly, when pushed from the jetty, he plunged rapidly to the bottom. Autopsy revealed no organic disease or injury which could have led to the death. His blood alcohol at the time was 2.87‰ (ADH method). Several hundred diatoms were counted in the lung sample, including the species *Gomphonema acuminatum, Cyclotella ocellata, Cocconeis* sp., *Tetracyclus lacustris, Synedra tenera, Pinnularia borealis, P. nodosa* and *Surirella angustata*. The findings suggest rapid death and cessation of circulation upon entry into the water, since if his bodily functions had continued for longer, diatoms or fragments of diatoms would have been found in the greater circulatory organs. Experience suggests that the sizes or shapes of the species identified would not pose any barrier to transport from the lungs into other organs. On the other hand, the exceptionally high concentration of diatoms on the lungs at a time when production was at its summer minimum would suggest aspiration of a very large quantity of water. The accident took place in a shallow freshwater environment in diatom terms. Diagnosis: Aspiratio diatomarum.

Group A-B

Twelve cases were found in which neither the lungs (A−) nor any other organ contained diatoms. This group comprised 11.2% of the total material.

Case Report

Case 4 [10]

A 16-year-old schoolboy was found dead lying on his back in a shallow reed bed on the sea shore, with his head partly under water. Extremely high numbers of diatoms were found in the water at the site, but none at all in the organs of the deceased upon autopsy, even though lung changes suggestive of drowning were noted. His blood alcohol level was 1.73‰. Drowning was regared preliminarily as the cause of death, but the negative diatom findings and the detailed accounts of the contents of the stomach and airways given in the autopsy records led to an eventual verdict of death by vomit aspiration rather than drowning, in accordance with the original lung findings.

Case 19 [10]

A 72-year-old man was found dead in shallow water at the shore near his summer cottage, with his face partly under water. No macroscopic lung changes indicative of drowning were found, nor was there any alcohol in his blood. Although a water sample from the site contained large numbers of diatoms, none were found in the organs of the deceased. Autopsy also revealed evidence of coronary artery disease, and this was taken to be the cause of death.

Case 1, 8, 9, and 12 [10]

In all these cases drowning was regarded as the cause of death on the basis of macroscopic findings at autopsy. Three of them involved tapwater (drowning in a bath or swimming pools), which has not been found to contain diatoms in Finland, and one occurred in a well, a water sample from which similarly yielded no diatoms.

Discussion

All the cases in the A+B+ group were regarded as carrying evidence of death by drowning, since the same diatom species were identified both in the lungs and in the major circulatory organs examined, the latter occurrence serving to exclude the possibility of post-mortem contamination. This view is supported by earlier research performed in Finland [13].

As far as the A+B− cases, those in which diatoms were found only in the lungs, were concerned, both numerous and moderate occurrences of diatoms were regarded as denoting drowning, whereas lower numbers were thought to be insufficient to permit reliable conclusions to be drawn. Thus, a limit of 20 diatoms per lung sample was set for a finding of death by drowning, a figure based on long-term experience in Finland that a high or moderate number of diatoms in a lung surface sample is suggestive of aspiration of water [13] and also to an essential degree the author's own observation over the course of time that findings of this order of magnitude regularly emerge from deaths taken as well-established cases of drowning.

One good example of the applicability of the above limit value to the determination of drowning in an A+B− case is that of case 1 (9b) above, in which drowning in a rapid stream of fresh water was confirmed by witnesses, the diatoms identified, in the lung samples only, comprising 71.3% exclusively freshwater species, 23.2% species typical of both freshwater and brackish water environments, and 5.5% purely brackish water species.

If this last mentioned figure is taken to represent the proportion of diatoms likely to enter the lungs post mortem if the body remains immersed in water, this would imply one diatom frustule of the 20 required as a minimum for a diagnosis of death by drowning, i.e., a contamination vs. original diatom influx ratio of 1:19. If, on the other hand, we assume, as an extreme case, that all the facultative freshwater and brackish water species (23.2%) had also entered the victim's lungs post mortem, we obtain a total of 28.7% of the diatoms attributable to contamination. This implies that about 6 of every 20 diatoms recovered in a lung sample are of this origin, and gives a contamination vs. original ratio of 6:14.

For an experienced diatomologist even the latter figure may be regarded as adequate to eliminate the possibility of error, and thus Hendey [14] believes the weak point in the diatom analysis method to lie in the fact that most investigators are unable to distinguish the diatom species originating from the environment in which drowning occurred from those derived from contamination sources. Analysis of the case discussed above points to the fact that the figure of 20 diatoms per microscope slide set for lung sample findings does allow a sufficient margin for the exclusion of sources of error for analysis possessing at least a basic acquaintance with diatoms and willing to bear in mind the possibility of contamination.

Among those who have applied this method in practice, Thomas et al. [15] are of the opinion that a finding of diatoms in the lungs alone is strongly suggestive of only a few breaths taken during the agony period, while Timperman [16] claims that excluding situations in which the water at the site of recovery of the body contains a few diatoms, the finding of relatively low numbers of diatoms indicates sudden death in water, death from hypothermia caused by cold water or cases in which the agony period is foreshortened for some reason.

The cases in which all the diatom analyses at autopsy were negative (A-B-) serve to show that the method can also be used under certain conditions to exclude drowning as a cause of death.

The relevance of the diatom method was tested here on the set of fresh, well-preserved bodies recovered from water which gave diatom findings of A+B+ or A+B− and involved macroscopic autopsy findings and police observations that pointed to a very high probability of death by drowning which bordered on certainty. These cases numbered 51 in all, comprising 47.7% of the total material. Since the quantitative diatom analyses in these cases also confirmed the impression of death due to water aspiration, the method may be deemed suitable for the diagnosis of drowning, at least under Finnish conditions.

On the other hand, the method cannot be used reliably to establish a positive diagnosis in cases in which there are only a small number of diatoms present (less than 20 per microscope slide) and only in the lung sample.

A further obvious restriction is placed on the use of the method by bodies of water which contain few or no diatoms, as is generally the case at the winter minimum in the annual diatom cycle, expecially when the water is covered by ice, thus allowing a diagnosis to be reached at that season of the year only at places with rapidly flowing open water or in habor basins or shipping lanes.

The 44 bodies in the A+B+ and A+B− groups which were in a decomposed state upon recovery from the water, comprising 41% of the total material, provided an opportunity for practical application of the method. In these cases the diagnosis was based to a substantial degree on quantitative diatom analysis, since, as mentioned above, this offers the only practicable means of establishing death by drowning at our present level of knowledge in the case of a decomposed corpse.

A further aspect in addition to establishing a diagnosis of death by drowning was naturally also the testing of the qualitative diatom analysis method, for which purpose at least one water sample, and in many cases several, must be obtained for comparison with the organ samples to determine the actual site or environment in which death occurred. In the present instances a total of 58 water samples were taken in connection with 40 cases to be investigated. Qualitative analysis enabled the site of drowning to be defined in 23 of these cases, 57.5%.

In those cases where the site of drowning could not be determined the sample had often been taken from the place where the corpse had been found, usually in shallow water by the shore, whereas the diatom taxonomy of the organ findings pointed to deeper water or a quite different environment. This was especially common in cases where the actual site of drowning was entirely unknown. There were other instances, however, in which the numbers of diatoms present were too limited for any reliable conclusions to be reached, and others in which the water and organ samples pointed to water bodies of the same kind (e.g., open water conditions) but the species differences suggested that the event had not actually occurred at the spot represented by the water sample. Finally, there were also cases in which a homogeneous environment, such as a river estuary, meant that water samples taken from several places all contained virtually the same diatom species as did the organ sample and in similar proportions, so that the site of drowning could not be determined any more accurately. Similarly, the site could not be pinpointed accurately if aspiration of water had taken place near the bottom and the sample had been taken from the surface water, or if the water sample had been taken too long after the event so that there was a possibility that the flora at the site had altered in the meantime.

It is quite obvious that one cannot determine the site of drowning entirely accurately by this method, unless it happens to be a small lake, pit, or ditch, and where large bodies of water are concerned one must inevitably attempt merely to delimit a certain area defined in terms of variations in diatom ecology. One good point as far as conditions in Finland are concerned is that the shallowness of the waters gives rise to a substantial site variation in this respect.

Although limits exit upon the degree to which the site of drowning may be determined, the ecologic properties of diatoms do provide important information on the general water conditions at the site (e.g., shallow, flowing fresh water, etc.) and the qualitative diatom findings coincided well with the prevailing environmental conditions in the cases studied here in which the site of drowning was known for certain. Thus, this method can also be regarded as useful under Finnish conditions, even though it requires special training of a kind which lies well outside medicine as such.

Sources of Error and their Evaluation

The principal reason for the criticism leveled at the diatom analysis method evidently lies in the fact that diatoms have been found in the bodies of persons who have died other than by drowning, a fact which is largely explicable by sources or error introduced by contamination. The control corpses used in research carried out in Finland have not been found to contain diatoms or diatom fragments [2], and neither did the 15 control corpses examined at Rochester in the United States [17].

The danger of contamination is particularly great in connection with the autopsy itself. A body recovered from water will have large numbers of diatoms attached to its clothes and skin, which could prove misleading if allowed to affect the samples taken. Mention was made above when explaining the method of the need for absolutely sterile conditions, for routine checks on the instruments and distilled water used and the chemicals employed in dissolving away the tissues and for the avoidance of all paper products, especially cellulose wadding.

A memorandum on this subject prepared by the Department of Forest Technology at the University of Helsinki includes the following observations: „The manufacture of all paper products, no matter from what raw materials, always requires the use of large amounts of water, which is usually obtained from the surface water of lakes and rivers. Such surface water has a mean silica (SiO2) content of 1–10 mg/l and typically contains microscopic plants and animals, mostly of the kind referred to as plankton. The pumps of one particular sulfate pulp mill alone have a water intake of 2781 l/min. Thus, one can appreciate that impurities carried in the water will be absorbed and incorporated in the products in spite of the fact that the water is purified for many purposes. As for cellulose wadding and filter papers, the former is manufactured from bleached cellulose and the latter from paper containing virtually pure cellulose so that both processes will have involved the use of considerable quantities of water" [18].

In summary, it may be stated that the threat of contamination from many quarters can be regarded as the main reason for criticizing the diatom analysis method. Since such a source of error can affect the results both qualitatively and quantitatively, it can easily lead to false conclusions in either the diagnosis of death by drowning or the definition of the site or environment in which the event occurred.

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