The Center of Historical and Traditional Technologies in Russian Research Institute for Cultural and Natural Heritage

The analysis of natural factors capable of modifying the radiocarbon age of the Turin Shroud

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Introduction

The Turin Shroud is one of the major objects of Christian worship and one of the greatest monuments of world culture.

However, many aspects of the Turin Shroud origin and history have defied explanation, like, for instance, the radiocarbon dating of the Shroud fabric carried out in 1998.

Parallel measurements performed by three leading world laboratories have resulted in a paradoxically recent dating of the fabric, i.e., 13th-14th centuries instead of the expected 1st century! The expertness of the said laboratories and the correctness of determining the C14 isotope content in the Shroud sample are beyond doubt. However, the chronological interpretation of the radiocarbon data should not necessarily be so straightforward.

The unexpectedly recent radiocarbon age of the Shroud fabric can be accounted for by two possibilities:

1. The fabric was actually manufactured in the 13th-14th centuries and the radiocarbon dating testifies to its real age.

2. The Shroud was produced in the 1st century A.D. In the course of time, however, it has incorporated various more recent carbonaceous organic substances. Given their considerable amount, the C14 analysis is likely to produce a more recent dating of the fabric indicative not of the actual age of the Shroud, but of the "mean" age of the object consisting of The Shroud fabric + recent carbonaceous pollutions.

This paper deals with the second of the above-mentioned possiblities.

The present author has for some 25 years carried out experimental studies of heterochronous textiles from various regions, including the Bronze Age, classical and early medieval European and oriental fabrics. He has dealt specially with the nature and degree of pollution of museum and archaeological textiles, first at the Physical-Chemical Laboratory of the State Research Institute of Restoration and then at the Centre for Historical and Cultural Technologies of the Russian Research Institute of Cultural and Natural Heritage.

The Turin Shroud is obviously a textile. Therefore, its fabric, like any other textile on earth, could have been affected by various natural processes. Moreover, the Shroud could have been put through certain "artificial" processes essential for the keeping of textiles, like washing.

Owing to both natural and artificial factors at work throughout the existence of the Shroud it could have incorporated and/or lost various carbonaceous substances.

The author makes an attempt to elucidate, on the basis of earlier studies, ***recent carbonaceous organic and non-organic compounds*** that could be incorporated into the Shroud fabric, thus making its C14 dating more recent.

1. Pollutants modifying the fabric age

This part examines certain rules regulating the modification of the Shroud fabric age due to the sorption of various pollutants.

***The relevant pollutants can be divided into two major groups*,** depending on their spacial distribution within a fabric and the nature of their interaction with its fibres:

*1. **Particles of solid substances** incorporated between the fibres and filaments of a fabric;*

*2. **Gaseous and liquid organic pollutants** chemically bound to the functional groups of the fabric fibres.*

***The influence of pollutants on the C14 dating, regardless of their nature, depends on the following factors**:*

1. If the carbonaceous pollutants are unevenly distributed over the Shroud the effect depends on ***their local content at the place of withdrawing the microsample for the C14 analysis*** rather than on their overall content in the fabric.

2. The age-modifying influence of purely organic "recent" carbonaceous pollutants is defined by the following factors:

- *The content of a given pollutant with regard to the volume of the fabric;*
- *The content of carbon in an organic pollutant;*
- *The presence of a pollutant within fibres and filaments or only in between them;*
- *The dry or wet means of cleansing the fabric and the degree of the natural destruction of the pollutants;*
- *The time of pollution; the more recent the pollutant is and the later it was introduced into the fabric the higher is the degree of its modifying effect.*

3. The modifying factors characteristic of mineral carbonaceous substances and heterochronous organic pollutants being admixtures to various incorporated mineral materials are dealt with separately in parts 2 and 3.

The paper does not deal with modifying factors ***from the quantitative point of view***, since detailed information on the assortment and quantity of alleged carbonaceous pollutants in the Turin Shroud is lacking.

Neither has *the hypothetical influence of periods of higher C14 atmospheric activity* throughout the existence of the Shroud been taken into account. The content of the radio-active C14 isotope in carbonaceous pollutants can become higher in such periods resulting in an additional modification of the fabric age.

2. Solid substances incorporated

between the fibres and/or filaments

No information on the assortment of solid pollutants of the Turin Shroud is available to the present author. Therefore the paper deals only with the influence of the most widely distributed solid substances characteristic of the so-called “everyday dust”. Particles of everyday dust are most likely to be incorporated into the Shroud fabric owing to the air flow.

2.1. Mineral pollutants

Mineral components of everyday dust are made up of minerals with the following properties:

- *They are the most widely distributed minerals in relevant areas;*
- *They exist as finely dispersed particles capable of reacting with air to produce stable aerosoles;*
- *They should be capable of sedimentation on the cellulose fibres of the fabric.*

The following minerals show such characteristics.

2.1.1. Carbonates

Anion -Co_3^{2-}-derived carbonates are worth special attention, since they are the only minerals with a carbon-containing lattice.

It stands to reason that the influence of carbonates on the fabric dating ***depends on the age of the carbonates contained in mineral dust.***

1. A fabric may incorporate “fresh” carbonates with the composition of carbon isotopes akin to that of present-day atmosphere. ***In this case the dating will be on the recent side***. It should be noted, however, that the probability of the Shroud fabric being polluted by “fresh” carbonate dust is fairly low.

2. It seems more likely that the Shroud fabric incorporated *prehistoric carbonates*. Such carbonate rocks as chalk, chemogeneous limestone or coquina often crop out onto the earth surface and are in the course of erosion destroyed to form microscopic particles. ***Naturally enough, the dust of pre-historic carbonates, unlike that of the “fresh” ones, will make the radiocarbon dating earlier.***

2.1.2. Other minerals

Other minerals present in everyday dust do not contain carbon, at least as the main lattice atoms. Among the most common finely dispersed “carbonless” mineral components of everyday dust are primarily clays as well as other silicates and aluminum silicates, e.g., quartz and feldspars.

Such mineral pollutants might produce the following effect on the radiocarbon dating of a fabric*:*

1. ***Direct influence****. Aluminum silicate clay minerals of sediment rocks may contain organic admixtures. Naturally enough, in this case the age estimates will be modified by these admixtures rather than by minerals proper (see below, part 2.1.3).*

2. ***Indirect influence****. The presence of mineral pollutants increases the amount of ash produced by the burning of the fabric, which is necessary for the radiocarbon analysis. Therefore the presence of minerals in the sample impairs the accuracy of the dating.*

2.1.3. Organic admixtures to mineral dust

A specific influence of such admixtures depends on the age of the organic admixtures and their ratio in mineral dust.

Evidently, organic admixtures of pre-historic sediment rocks may ***make the dating earlier.***

2.2. Recent solid organic pollutants

Solid organic pollutants may be brought to the fabric by the air flow. Such heterogeneous pollutants are dealt with below.

2.2.1. Carbon particles

"Recent" carbon particles emerge from organic materials in the course of combustion.

2.2.1.1. Carbon particles from organic sources of heating and light

Effective oxidizing combustion of organic sources produces a thermal destruction of organic substances down to the oxides of their main atoms, namely CO_2, H_2O, NO, and No_2***. If the speed of the heat influx on the periphery of the burning source is higher than that of the oxygen inflow organic substances are but partially burned.***

Therefore, only a certain part of a given substance burns down completely to form gaseous oxides in organic burning sources.

The rest undergoes a kind of anaerobic pyrolysis resulting in:

- *Black particles of pure carbon being the products of the most complete pyrolysis;*
- *Dark-brown and brown products of incomplete pyrolysis, containing other atoms besides carbon.*

The products of pyrolysis in the form of finely dispersed soot particles show the following characteristics:

- *Even the soot of the products of incomplete pyrolysis, not to mention that consisting of pure carbon, is considerably enriched with carbon;*

- *The form and dimensions of soot particles depend on the nature of a given organic material, e.g., wood, coal, wax, paraffine, kerosene and others;*
- *Soot particles tend to form aerosoles and be absorbed by fibres, especially if lipid pollutants had been bound with the surface of the fibres.*

Previous studies of textiles have shown that a fabric can absorb a considerable amount of soot particles if kept in a room heated and lighted with the aid of organic substances for a long time.

In this case, the radiocarbon age of soot would be akin to that of its organic source. It is likely to be considerably younger than that of the Shroud. ***Evidently, the absorption of such soot would make a conventional radiocarbon age deviate from the real age of the fabric towards modern times (see above, part 1.2)***

2.2.1.2. Carbonaceous particles emerged as a result of fire

If there are conflagrations in the rooms where fabrics are kept, ***intensive combustion of a large quantity of foreign organic materials can occur.*** Processes of soot formation and its interaction with fabrics in the course of conflagrations ***do not differ fundamentally*** from the corresponding processes occuring in the course of heating and lighting the rooms in question.

However, if it is the fabric itself that burns in the fire, the probability that soot will enter the fabric surface, unaffected by the fire, by absorption may become higher.

Evidently, the absorption of soot from the Shroud fabric itself is not likely to modify considerably the estimate of its radiocarbon age.

2.2.2. Finely dispersed solid biological pollutants

Besides minerals, everyday dust can contain large quantities of organic components.

Such components in the form of microscopic solid particles may produce various recent biological products, i.e.:

1. ***Various living micro-organisms***, e.g., bacteria, algae, protozoa, etc., may use a fabric as a solid substrate as well as the food source.
2. ***Parts of living macro-organisms***, e.g., seeds and pollen of plants, can be brought by the wind onto the surface of a fabric.
3. As a result of vital activity and the subsequent death of animals, plants and micro-organisms, ***the accumulation of biomass of the "dead" organic substance occurs on the Earth***. Then "dead organic matter" becomes subject to physical chemical, chemical and biological destruction. Its biodestruction is particularly effective in soil.

The comminution of "dead organic matter" to microscopic particles is an important by-product of any destruction. ***The atmosphere may accumulate particles of destructed "dead organic matter"*** from various sources, including soil.

All the above-mentioned organic sources react with air producing stable aerosoles and may be included into everyday dust.

The Shroud fabric enveloped in the atmosphere may absorb organic components of everyday dust and thus become considerably enriched with heterogeneous fresh miscroscopic organic matter of biological origin.

Previous studies of museum and excavated textiles have shown that particles of this organic matter were most effectively accumulated in hollows between filaments and/or fibres of a fabric.

The accumulation of solid particles of recent microscopic organic matter is conducive to ***the deviation of radiocarbon dating of a fabric from its actual age.***

2.2.3. Microscopic biodestructors

The Shroud fabric can be polluted with biodestructors capable of ***reproducing in culture media present on the surface of fibres:***

- ***The cellulose of fibres*** may serve as a nutrient for micro-organisms ***possessing of glucolitic ferments, for instance, microscopic fungi.*** Biodestructors grown at the fabric own cellulose ***practically do not modify its radiocarbon age.***
- ***Particles of foreign dustlike microscopic recent organic matter*** accumulated in hollows between fibres become propitious culture medium for many kinds of micro-organisms. Evidently, both ***fresh organic matter and micro-organisms grown on it will make the radiocarbon age of the Shroud "younger".***

Under favourable conditions various ***long-lived successions of different micro-organisms*** may emerge on the surface of fibres, in which the preceding kinds of micro-organisms would serve as substratum and nutrient for the following ones.

If ***autotrophic kinds*** occur in such successions, they will ***produce fresh organic matter***, capable of making the Shroud fabric "younger".

3. Liquid and gaseous carbonaceous pollutants capable of binding to the fabric fibres

The Shroud fabric throughout its existence could have incorporated, besides organic everyday dust, relatively low-molecular "fresh" carbonaceous substances, capable of firmly binding to the fibres, thus making the radiocarbon age of the fabric younger.

Such substances can be related to the following groups, depending on their nature and the mechanism of their interaction with fibres of the fabric:

1. *Gaseous carbon oxides CO and CO_2*
2. *Liquid organic substances, i.e.:*

- *Natural liquid materials incorporated into fabrics without direct human interference.*
- *"Artificial" materials deliberately introduced into fabrics/*

3.1. Gaseous carbon oxides CO and CO_2

Gaseous CO and CO_2 may be produced not only by organic sources of combustion but also by micro-organisms in the course of biochemical decomposition of organic pollutions.

This paper deals merely with general, potential aspects of interaction between a fabric and carbon oxides. Therefore actual mechanisms of interaction between CO and CO_2 with cellulose within flax fibres of the Shroud are not analyzed below.

CO and CO_2 originating from different souces will evidently interact differently with cellulose of fibres.

1. ***In the course of the emission of such gases at the time of fires***, especially if the fabric itself burns, as it was the case in the 16th century, they can interact perceptibly with cellulose. ***The fact is due to the following reasons:***

- ***A high local concentration of gases.***
- ***A high temperature*** *conducive to the diffusion of gases into the fabric and fibres as well as to the acceleration of chemical reactions.*

2. ***In the course of biodestruction*** the efficiency of interavtion of emitted gases depends on the following factors:

- ***The concentration of gases*** *determined by the biological productivity of biodestructors, the properties of the culture medium, and the presence of relevant successions* ***is the key factor of their efficiency.***
- ***If sufficiently long-lived radical derivatives CO_2*** *emerge in the process of biodestruction, their activity grows drastically in the interaction with cellulose.*

3. The interaction of such gases emitted from the organic sources of heating and lighting would be ***the least noticeable***, since their local concentrations near the fibres would be relatively low. An excess of "fresh" carbon oxides CO and CO_2 emerging in the fire and actively interacting with cellulose fibres of the fabric ***can, however, make the radiocarbon dating of the Shroud "younger".***

3.2. Liquid organic matters

incorporated into a fabric due to ‘natural causes’

The group includes matters that could have been incorporated into the Shroud fabric without human interference. At the time of contact with the fabric they are either liquid or gaseous and therefore capable of penetrating into the fabric and be bound to the functional groups both on the surface and/or within the fibres of the fabric.

3.2.1. Lipid products of incomplete combustion sources used for heating and lighting

In the process of combustion of organic sources liquid carbonaceous products *being usually hydrophobic lipid substances may emerge besides carbon oxides and the products of pyrolysis. They emerge as side effects of combustion of organic materials,* are volatile and capable of binding to the fibres of the fabric.

Various processes conducive to the emergence of volatile “recent” lipid compounds can be observed in organic matters.

The evaporation of volatile lipid components

The evaporation of volatile monomeric or oligomeric organic components takes place on the periphery of organic sources of heating and lighting in a zone relatively distant from that of burning. The temperature in such a zone is considerably lower than that of oxidazing combustion yet sufficiently high for an efficient evaporation of volatile components.

1. ***The following volatile compounds can be emitted in the course of combustion as a result of their evaporation from various matters:***

- *Terpene resins evaporate from wood, especially from that of coniferous trees.*
- ***Whole oils as well as free fatty acids*** *being the products of oil destruction evaporate from burning liquid oils and solid animal fats.*
- ***Destructed wax acids*** *containing a hydrocarbon frame bound to the -COOH and -OH groups evaporate from wax.*
- ***Free hydrocarbons*** *evaporate from paraffine and kerosene.*

Dry distillation

Volatile carbonaceous components do not emerge exclusively in the course of lipid evaporation during combustion. Such components may emerge owing to the so-called ***dry distillation*** as well. The products of dry distillation also belong to the class of lipids and emerge in certain zones of a burning organic matter.

These zones should comply with the following conditions:

- ***The temperature*** *should be higher than that of evaporation of volatile components yet lower than that of burning.*
- ***The rate of oxygen supply*** *there should be the maximum low in order to prevent oxidizing pyrolysis.*

Dry distillation is the most efficient in the following kinds of solid organic fuel:

- *In hard kinds of wood.*
- *In bituminous coal.*

Volatile lipid compounds emerging in the process of ***evaporation and dry distillation*** of organic sources can be efficiently adsorbed on the surface of the Shroud fibres.

The absorption of such compounds may result in the following after-effects for the shroud:

1. ***The modification of the fabric age*** *due to "recent" lipid compounds.*
2. ***Hydrophobization*** *of the surface of filaments and fibres due to the absorption of lipids.*

As a result, an explosive increase of the rate of absorption of "recent" hydrophobic compounds, i.e. lipids and soot, takes place on the surface of the fabric.

- *A single* ***hydrophobization of the surface*** *through the first portions of volatile lipids* ***increases the efficiency*** *of its interaction* ***with the next portions of volatile lipids.***
- ***The increase of the degree of hydrophobization*** *of the fabric surface increases, in its turn,* ***the degree of absorption of hydrophobic particles of soot.***

Given a repeated successive character of the said processes, the surface of the fabric fibres may become covered with a relatively deep bed of "recent" hydrophobic products of incomplete combustion.

This process may be highly efficient under the following conditions:

- *The fabric is kept for a long time in a closed room with regular lighting and heating through organic sources.*
- *The fibre surface is accesible to the absorption of volatile products of incomplete combustion and soot.*

The present author has observed on the surface of fibres and filaments of a number of uncleansed museum textiles relatively deep beds of lipid pollutants formed by volatile products of incomplete combustion mixed with soot particles.

As a result of such a 'natural' covering of the surface with 'recent' hydrophobic carbonaceous compounds ***the radiocarbon dating of the Shroud fabric may be modified.***

In Oxford Laboratory a microsample of the Shroud fabric was treated with hydrophobic organic solvents capable of getting rid of lipids. As a result, the estimate of the radiocarbon age of so treated sample in the said laboratory is some 100 years older than in other laboratories that did not use such treatment. ***The author holds that such an 'ageing' effect of hydrophobic cleansing is due to the elimination of 'recent' lipid pollutions in Oxford laboratory.***

3.2.2. Low-molecular products of biodestructors' vital activity

If there is ***a sufficient amount of 'recent' solid organic pollutants*** in hollows between filaments and fibres of the Shroud fabric, they can become ***an efficient culture medium for the vital activity of microscopic biodestructors.***

The activity of exoferments produced by aerobic and anaerobic micro-organisms triggers the hydrolysis of high-molecular organic compounds with the emergence of ***lower-molecular organic compounds, i.e. sugars, amino acids, oligopeptones, fatty acids, etc*** . Some of these compounds can penetrate into the fabric fibres and bind there to the functional groups of cellulose.

It is only natural that the set of these hydrolysis products as well as their relation to cellulose depends on the composition of original organic pollutions and the assortment of micro-organisms feeding themselves on these pollutions. If a fabric is abundantly covered with the said pollutions and at the same time highly contaminated with micro-organisms, ***it can be enriched with 'recent' low-molecular organic products, which fact, in its turn, can modify the radiocarbon dating of the Shroud fabric.***

3.3 ‘Artificial’ organic substances deliberately introduced into fabrics

The Shroud of Turin, like any textile, could be subject, throughout its lifetime, to various ‘liquid’ treatments necessary for its maintenance. In the course of such treatment ‘recent’ carbonaceous components capable of modifying the actual radiocarbon age of the fabric could be introduced into it. The most important of these components are dealt with below.

3.3.1. Detergents

We lack the information on washing the Shroud with detergents, if any. At least, one can safely assume that after the fire in the 16^{th} century it was washed. Therefore we cannot estimate correctly the amount of detergents that could penetrate into the fibres and will restrict ourselves to the theoretical analysis of the influence of detergents.

3.3.1.1. Classical and medieval detergents

Surface-active substances used to wash textiles are called detergents.

Throughout the most part of the Shroud lifetime, i.e. in classical and medieval times, such specific natural substances as ***soaps, i.e. potassic or sodium salts of fatty aliphatic acids,*** were practically sole detergents.

Soaps were obtained through the treatment of oils and/or animal fats with alkaline agents, i.e.:

- ***<u>potash</u>*** *K_2CO_3 for potassic soaps.*
- ***<u>soda</u>*** *Na_2CO_3 or $NaHCO_3$ for sodium soaps.*

Both solid and liquid soaps were used.

1. ***<u>Liquid soaps</u>*** were obtained from oils containing ***unsaturated fatty acids:***

- *linseed oil*
- *nut oil*
- *poppy-seed oil*

2. ***<u>Solid soaps</u>*** were manufactured of ols or animal fats containing ***only saturated fatty acids.***

3.3.1.2. Possible influence of detergent on the age estimate

In the process of washing or wet cleaning in solutions of soaps potassic and sodium salts of fatty acids can penetrate into fibres and interact differently with their functional groups:

- ***Saturated acids*** can be bonded to cellulose ***through relatively weak intermolecular interaction.*** For instance, carboxyl groups of fatty acids can form hydrogen bonds with hydroxyl groups of cellulose. As a result they can be eliminated from the fibres in the course of the subsequent rinsing.
- ***Unsaturated acids can form, through double bonds,*** firm covalent bonds with cellulose that neither rinsing nor other treatments can eliminate.

The degree of 'infiltration' of 'fresh' fatty acids and of the elimination of 'recent' carbonaceous pollutions depends on a number of factors, i.e.:

1. ***How often was the Shroud washed throughout its lifetime?***
2. ***The nature and ratio*** *of organic and mineral carbonaceous pollutants*.
3. ***The firmness*** *of their interaction with fibres*.
4. *The kinds of soaps*.
5. *The conditions of the washing*.
6. *The efficience of the rinsing after the washing*.
7. *Intervals between the washing*.

It is worth noting that the influence of fatty acids of natural soaps will be twofold:

- ***On the one hand,*** the binding of 'fresh' fatty acids of soap with fibres will modify the age of the fabric on the recent side during the washing.
- ***On the other hand, soaps*** will eliminate other 'recent' organic poollutants from the surface of the fabric and/or fibres, thus eliminating the deviation from the real radiocarbon age.

3.3.2. The introduction of liquid oils into the fabric

Besides the 'natural' treatment with detergents in the process of the washing, the Shroud fabric could be subject to the influence of other 'recent' specific liquid organic substances.

<u>Oil</u> introduced into the Shroud fabric under various circumstances could be one of these substances.

<u>Oil solutions of fragrances</u>

1. ***Solutions*** are the most convenient form of the use of ***fragrances in perfumery.***
2. ***Both early and the majority of modern fragrances*** are usually ***hydrophobic and slightly polarized substances.***
3. ***In modern perfumery the weakly polarized ethanol or alcohol*** is a practically universal solvent.
4. In classical and early medieval times the range of organic solvents capable of solving ***hydrophobic fragrances*** was very restricted. ***Liquid oil was one of few available***

hydrophobic solvents. It was, therefore, most often used for the preparation of fragrance solutions.

It stands to reason that throughout the Shroud lifetime fragrance solutions prepared with the aid of liquid oils could be deliberately introduced into its fabric.

If oils in fragrances and fragrances themselves contained ***unsaturated fatty acids*** (see above), they coud be ***firmly bonded to cellulose fibres through covalent bonds.***

Through 'anointment' and firm binding of 'recent' oil and fragrance to cellulose the Shroud fabric could become considerably 'younger'.

Oil as a cleansing and conservation substance

Oil and its partially polymerized derivative, i.e. drying oil were used in certain periods for the restoration of artefacts made of organic materials.

They were used for the following purposes:

1. *To prevent the infiltration and reproduction of insects and other biodestructors.*
2. *To eliminate hydrophobic pollutants, e.g. soot.*

4. Can the Shroud age be adequately estimated without regard for carbonaceous pollutants?

The results of a qualitative theoretical analysis dealt with in part 3 show that throughout the Shroud lifetime its fabric could accumulate various 'recent' carbonaceous pollutants ***capable of deviating the radiocarbon estimate of the Shroud age from its actual dating.***

Let us turn to the set of conditions under which a considerable modification of the fabric age due to various kinds of 'recent' pollutants is possible.

Solid mineral pollutants

1. **No ancient carbonates** *form part of mineral components of everyday dust.*
2. **No ancient organic substances** *form part of organic admixtures to the other mineral components of everyday dust.*

Solid organic pollutants

1. ***There are soot particles resulted from 'recent' organic sources, i.e.:***

- *Fires*
- *Heating*
- *Lighting*

2. ***There are natural 'recent' organic pollutants of different kinds, i.e.:***

- **Micro-organisms** *and/or their spores.*
- *Parts of* **microorganisms,** *e.g., plant pollen.*

- *Microscopic remains of the destructed '**dead organics'.***

Gaseous oxides of 'recent' CO and CO_2 carbon,

chemically bonded to cellulose

'Recent" carbon oxides emerged under extreme thermal conditions became chemically bonded to cellulose.

'Recent' liquid organic pollutants

chemically bonded to the fabric

1. ***Volatile hydrophobic (lipid) products, e.g. resins, hydrocarbons, oils, and soot*** emerged at incomplete combustion of substances used for heating and lighting covered the fabric surface and were not eliminated in the course of the washing.
2. ***Low-molecular products of vital activity*** of micro-organisms became chemically bonded to the fibre cellulose.
3. ***The remains of fatty acids being the main components of ancient detergents*** were incorporated in the fabric:

- *Owing to the regular and protracted washing.*
- *Owing to short-time rinsing.*
- *In the case of liquid soaps with unsaturated fatty acids.*
- *In the case of the pollutants being firmly bonded to the fibre.*

4. ***Liquid oils and fragrances*** that could be introduced into the fabric ***as solutions of ancient fragrances*** *became chemically bonded to the fibre cellulose.*
5. *Oils could also became fixed in the fabric as materials for cleansing and/or strengthening in the course of early restorative interventions.*

The above-described combination of 'recent' carbonaceous pollutants present and the ancient ones absent can sufficiently modify the radiocarbon age of the Shroud fabric on the recent side.

5. How can the real age of the Shroud fabric be estimated with modifying pollutants present?

If the fabric contains a large amount of carbonaceous pollutants, the estimate of the actual age of the Shroud on the basis of C^{14} analysis comes up against serious problems.

There are two ways of dealing with them.

The successive elimination of various pollutants

This method is efficient, at least potentially, in the case of solid pollutants not bonded to the fibres.

The method, however, suffers from serious drawbacks related to the elimination of carbonaceous pollutants chemically bonded to the fibres:

- *The Shroud fabric can be destroyed.*
- *'Recent' carbonaceous agents can be introduced into the fabric.*

Taking into account the nature and content of various pollutions

In the course of such a study it is necessary to carry out *both qualitative and quantitative analysis of all kinds of carbonaceous* in a fabric sample. It would enable one, at least in theory, to calculate a correction factor while estimating the age of the polluted fabric.

This approach also has its drawbacks:

- *It is impossible to carry out the qualitative and quantitative analusis of all kinds of carbonaceous pollutions, especially those chemically bonded to the fibres.*
- *It is impossible to carry out the necessary analyses by non-destructive methods only.*
- *For the analysis of certain kinds of pollutions one has to take a microsample with its subsequent destruction.*

Nevertheless, the author holds that for an adequate estimate of the Shroud real age a preliminary qualitative and quantitative, or at least semi-quantitative estimate of all the kinds of 'recent' carbonaceous pollutions is indispensable. This can be done by carrying out a complex experimental study of the very sample of the fabric, which will be used for C^{14} analysis.

The author as a member of the Russian Committee for the Study of the Turin Shroud. is willing to participate in the study of ***'recent' carbonaceous pollutions*** in the Shroud fabric with the use of the most delicate experimental methods.

Conclusions

1. The present paper has demonstrated, from the qualitative if not quantitative point of view, a possible influence of organic and mineral carbonaceous pollutions on the estimate of the age of the Turin Shroud by C^{14} analysis.
2. It has been shown that carbonaceous pollutants are capable of making the radiocarbon dating both older and younger than the actual age of the fabric.
3. An estimate of the modifying effect of various carbonaceous compounds capable of influencing the mean radiocarbon age of the Shroud through forming a new object consisting of The Shroud fabric + recent carbonaceous pollutions has been made.
4. The conditions under which the radiocarbon dating of the 'fabric - pollutions' system can deviate significantly towards present time from the real age of the Shroud have been found.

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