



# World Scientific News

An International Scientific Journal

WSN 162 (2021) 102-119

EISSN 2392-2192

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## Could an anomaly in Turin Shroud blood reopen the 1988-radiocarbon-dating result?

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### ABSTRACT

This work proposes an explanation for a blood anomaly found in the Turin Shroud (TS). Unlike common human blood which contains significant levels of nitrogen (weight percentages of the order of 10%), TS blood shows levels of nitrogen which are lower than the background noise produced by the measuring instrument (about 1%). It is not easy to find an explanation for this result, but if we refer to the hypothesis formulated by T.J. Phillips who first proposed that neutron radiation had acted on the TS and therefore on the blood analyzed, it is possible to qualitatively understand what may have altered the observed nitrogen levels. The hypothesis of T.J. Phillips proposes that neutrons would have irradiated the TS, changing some of the nitrogen nuclei to different isotopes. In particular, it would have caused nitrogen atoms to be transformed into  $^{14}\text{C}$  and so the results of the radiocarbon dating of the TS performed in 1988 would have to be corrected to allow for the corresponding systematic effect hypothesized in that paper.

**Keywords:** Turin Shroud, bloodstains, nitrogen, isotopes,  $^{14}\text{C}$ , 1988-radiocarbon dating

### 1. INTRODUCTION

In 1988, the Turin Shroud (TS) was radiocarbon-dated to 1260–1390 A.D. [1]. A piece of linen (officially 7 cm long and 1 cm wide) was cut from the Relic and given to Oxford, Zurich and Tucson (Arizona) laboratories, each of which independently measured the  $^{14}\text{C}/^{12}\text{C}$  isotopic ratio to assign a date to the samples.

The Authors of Ref. [1] declared that “*These results therefore provide conclusive evidence that the linen of the Shroud of Turin is mediaeval.*” but this “*conclusive evidence*” has since been questioned by many researchers, who identified both procedural and statistical problems [2-5] with this test.

The Turin Shroud [6-13] is a handmade 3:1 twill linen cloth, 4.4 m long and 1.1 m wide, on which the front and back images of a human body are permanently and mysteriously imprinted [14, 15]. According to the Catholic Christian tradition, the TS is the burial cloth in which the body of Jesus Christ was wrapped before being placed in a tomb in Palestine about 2000 years ago.

There are some indications [11] that the TS was in Palestine in the first century A.D., and then taken to Edessa (present-day Sanliurfa in Turkey). Several features found on the TS face accurately coincide with those found on depictions of Christ on Byzantine coins starting from the VII century A.D., providing evidence that the TS was seen during the Byzantine empire [11]. After disappearing during the Sack of Constantinople in 1204, the “Shroud of Christ” then reappeared in Europe in 1353 in Lirey, France. In 1532, it was damaged in a fire at Chambéry in France. In 1578 it was taken to Turin where it has remained until now, apart from some short periods of time when it was hidden during wartime.

Numerous bloodstains [16-19] scattered throughout the double body image of the TS show the tortures suffered by the depicted Man [20, 21]: signs of flagellation, crowning with thorns, nail driving in the limbs and a post-mortem wound in correspondence with the side.

The TS contains a particularly unusual double human image which still cannot be adequately explained due to its unique combination of features and characteristics [11, 14] which have so far proved to be impossible to reproduce. Nevertheless, many hypotheses have been formulated [22-27] which propose how this image may have been formed. According to the Author and other experts who have studied the TS, the most plausible explanation is that it was produced by a burst of energy of unknown origin (also of electric type [22]) which emanated from the corpse and reacted with the linen of the TS. The irregular distribution of radiation along the surface of the TS would have produced both the body image and an isotopic alteration of the atoms in the fabric which varied along its surface.

It is obvious that dead bodies do not, typically, produce such a burst of energy capable of creating a body image like that which is seen on the TS and it is for this reason that R.E.M. Hedges [28] wrote: “*If a super natural explanation is to be proposed, it seems pointless to make any scientific measurement on the shroud at all.*” The author however disagrees with Hedges’ statement because even though science is limited and unable to explain everything that can be observed and measured on the TS, we must not limit the application of science only to those things which are known in the natural world. On the contrary, science, remaining strictly within its experimental environment, can help us to deepen our understanding of what is still not completely clear to us today, while providing us with new hypotheses and interpretations of what we touch with our hands.

Although this hypothesis is as yet incomplete and needs further development in order to explain all the characteristics detected on the TS, it can at least partially explain the debated radiocarbon result of 1988. According to T.J. Phillips [29] “*If the shroud of Turin is in fact the burial cloth of Christ, ... then according to the Bible it was present at ... the resurrection of a dead body. .... the body [wrapped in the TS] ... may also have radiated neutrons, which would have irradiated the shroud and changed some of the nuclei to different isotopes.*” In particular he suggested that “*... some  $^{14}\text{C}$  could have been generated from  $^{13}\text{C}$ .*” R.E.M. Hedges [22] also

proposed a second hypothesis: the “*neutron capture by nitrogen in the cloth*” of  $^{14}\text{C}$  atoms which behave “*in the same way as the original  $^{14}\text{C}$ .*”

Without a clear understanding of all the environmental conditions in which the Relic was conserved over the centuries (especially throughout the first centuries and during the hypothesized burst of energy of unknown origin), the radiocarbon dating method cannot be rigorously applied. For example, the phenomenon which created the image may also have altered the percentage of carbon isotopes in the TS, thus producing the non-negligible systematic effect detected by Ref. [2]. R.E.M. Hedges [30] confirms that this textile sample “... *had had an unknown but potentially contaminating history.*”

It is widely accepted among both those who perform radiocarbon dating tests, and those professionals who use radiocarbon dating tests, that it is necessary to recognize all the various environmental conditions to which the sample under analysis was exposed to, along with their possible effects, in order to be confident that a detected  $^{14}\text{C}/^{12}\text{C}$  isotopic ratio can furnish a reliable age of the sample in question.

This paper builds upon the hypothesis, first proposed by T.J. Phillips [29], that neutron radiation possibly irradiated the TS and caused certain isotopic changes. By also taking into consideration the recently discovered anomaly detected in the TS blood, which shows an unexpected absence of nitrogen, it provides a new, additional insight into the result of the 1988 radiocarbon dating of the TS.

## 2. QUANTITIES AND REACTIONS INVOLVING $^{14}\text{C}$

Before outlining the possible effects on the TS of both a hypothesized neutron radiation and the findings presented in Section 3 below, it may be helpful to first review some scientific basis of radiocarbon dating, including the reactions involving  $^{14}\text{C}$  and its quantity present in living organisms.

### 2. 1. Quantity of $^{14}\text{C}$

A living organism such as a flax plant contains an almost constant ratio of carbon isotopes, but once it has died, the unstable radioactive  $^{14}\text{C}$  gradually decomposes to produce nitrogen, while the amount of the two stable carbon isotopes ( $^{12}\text{C}$  and  $^{13}\text{C}$ ) remains the same.

The quantities shown below are those found in living plants or animals and the difference between these values and those found in organic material from organisms that died centuries ago can be used to evaluate its age.

- $^{12}\text{C}$  is the most abundant carbon isotope, which accounts for almost all the carbon contained in a living organism; it is 98.89%. To get an idea of the quantities treated closest to our experience, we refer to a mass of 120 kg of carbon from a living being; then we have 118.7 kg of  $^{12}\text{C}$ .
- $^{13}\text{C}$  isotope accounts for 1.11% of the carbon present in a living organism. 120 kg of pure carbon contains 1.332 kg of  $^{13}\text{C}$  isotope.
- $^{14}\text{C}$  isotope accounts for just  $1.25 \times 10^{-10}$  % of the carbon present in a living organism. 120 kg of pure carbon contains  $1.5 \times 10^{-10}$  kg or better 0.15 micrograms of  $^{14}\text{C}$  isotope, (see Table 1).

It is therefore evident that a very small variation in the amount of  $^{14}\text{C}$  isotope (one  $^{14}\text{C}$  atom for every 791 billion  $^{12}\text{C}$  atoms) present in the sample under test is sufficient to produce a noticeable variation in the presumed age of the sample.

**Table 1.** Abundance of carbon isotopes in nature.

	$^{12}\text{C}$	$^{13}\text{C}$	$^{14}\text{C}$
<b>Percentage</b>	98.89 %	1.11 %	$1.25 \times 10^{-10}$ %
<b>Mass of carbon isotopes in 120 kg of carbon</b>	118.7 kg	1.332 kg	0.15 $\mu\text{g}$

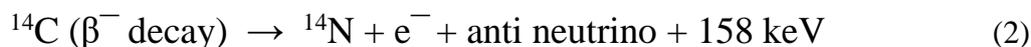
## 2. 2. Production of $^{14}\text{C}$ from N

The production of  $^{14}\text{C}$  occurs continually in nature in the upper layers of the troposphere and in the stratosphere. High energy cosmic rays, consisting of protons, heavier nuclei, or gamma rays interact with nuclei in the atmosphere, and produce high-energy (thermal) neutrons and secondary components. These high-energy (thermal) neutrons collide with the nitrogen atoms present in the atmosphere to produce  $^{14}\text{C}$  atoms. The reaction can be synthetically written as  $^{14}\text{N}(n,p)^{14}\text{C}$  indicating that after an impact with a neutron  $n$ , nitrogen  $^{14}\text{N}$  transforms into  $^{14}\text{C}$  and in the process releases a proton  $p$ . This reaction can be more explicitly expressed as:



## 2. 3. Radioactive decay of $^{14}\text{C}$

The radioactive  $^{14}\text{C}$  produced through the process defined in Eq. 1 is unstable and transforms into  $^{14}\text{N}$  with a half-life of 5730 years according to the formula  $^{14}\text{C}(\beta^-)^{14}\text{N}$ , where carbon  $^{14}\text{C}$  transforms into  $^{14}\text{N}$  nitrogen, producing a  $\beta^-$  decay (consisting of an energetic conversion of a neutron into a proton plus an electron, an electron antineutrino and the production of an energy of 158 keV), or more explicitly, as:



## 2. 4. $^{14}\text{C}$ production from $^{13}\text{C}$

According to the hypothesis of T.S. Phillips [29], “... some  $^{14}\text{C}$  could have been generated from  $^{13}\text{C}$ . If we assume that the shroud is 1950 years old and that the neutrons were emitted thermally, then an integrated flux of  $2 \times 10^6$  neutrons  $\text{cm}^{-2}$  would have converted enough  $^{13}\text{C}$  to  $^{14}\text{C}$  to give an apparent carbon-dated age of 670 years” [670 years correspond to 1280 A.D. (=1950-670) where 1950 is the conventional age defined as a reference in radiocarbon dating; all the  $^{14}\text{C}$  measurements date back from the year 1950]. The corresponding equation is  $^{13}\text{C}(d,p)^{14}\text{C}$  indicating that after impact with deuterium atoms  $d$  ( $^2\text{H}$ ),  $^{13}\text{C}$  transforms into  $^{14}\text{C}$  producing a proton  $p$ , or, more explicitly, as:



### 2. 5. $^{14}\text{C}$ additional production from $^{14}\text{N}$

In addition to the production of  $^{14}\text{C}$  from  $^{13}\text{C}$  of Eq. 3 as hypothesized by T.S. Phillips, the same neutron radiation could transform nitrogen atoms  $^{14}\text{N}$  contained in the linen sheet into  $^{14}\text{C}$  according to Eq. 1.

In 1989, R.E.M. Hedges [28], wrote that: “*N content in linen is 1,000 p.p.m., for which a thermal neutron flux of  $2 \times 10^{13} \text{ cm}^{-2}$  would be appropriate*” to obtain a  $^{14}\text{C}$  enrichment in the TS flax sufficient to produce a shift of 1280 years in a radiocarbon dating.

A specific study of A. Lind et al. (Proc. Int. Workshop, Acheiropoietos Images, ENEA, 2010) was carried out to measure the enrichment of  $^{14}\text{C}$  in a raw linen fabric exposed to the following conditions.

- 1. Neutron radiation of  $1.04 \times 10^{14} \text{ cm}^{-2}$ .
- 2. External environment: air or carbon dioxide.
- 3. Subsequent heating at 175 °C for 75 minutes.

The unbleached modern linen sheet used for the test was washed in a mild detergent and rinsed in distilled water before using. The areal density was  $25 \text{ mg/cm}^2$  (that of the TS is  $22 \text{ mg/cm}^2$ ) and the carbon weight fraction was 43 %.

It was concluded that “*Neutron irradiation of flax linen increases the radiocarbon content by two distinct modes. The first mode is by nuclear reactions with nitrogen indigenous to the flax. ... this radiocarbon was not removed by high temperatures or by chemical cleaning treatments used in 1988 test. ... The second mode of generating radiocarbon is by nuclear reactions with the nitrogen of the air ... [but] it is not permanently bound to the linen ...*”

The calculations of A. Lind et al. agree with experimental tests, showing that the neutron flux used for the tests shifts the age of the linen sample by about 1300 years, consistent with the 1988 radiocarbon result. The main results are reported in Table 2 which shows the nitrogen content measured in the linen samples tested by A. Lind et al.

**Table 2.** Nitrogen content in linen samples tested by A. Lind et al.

Reference sample (3 subsamples)	Neutron radiated Sample 3 (17 subsamples)	Neutron radiated Sample 5 (29 subsamples)
720 ±32 ppm	614 ±50 ppm	566 ±62 ppm

It is evident that it is not easy to clearly determine the reduction of nitrogen content in raw linen for the following reasons, especially if, as in the case of TS, irradiated samples cannot be directly compared with non-irradiated samples.

-1. The amount of nitrogen in linen varies from fabric to fabric according to the processing conditions. Variations of the order of 20-30% are possible.

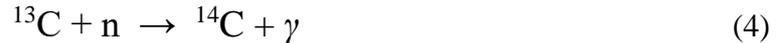
-2. The relatively small amount of nitrogen in flax makes accurate measurements not easy and unreliable.

-3. Following Points 1 and 2, the nitrogen reduction in linen, due to neutron irradiation of the order of  $10^{14}$  particles per square centimeters, is not easy to detect because it can be masked by side effects, including background noise.

Due to these problems, a different approach will be followed in Section 3.

## 2. 6. Other $^{14}\text{C}$ productions

The processes described in Eqs. 1 and 3 of Sections 2.2 and 2.4 are not the only ways of producing  $^{14}\text{C}$ , although these are the most common and abundant.  $^{14}\text{C}$  can also be produced in the atmosphere by other neutron reactions, such as  $^{13}\text{C}(n,\gamma)^{14}\text{C}$  and  $^{17}\text{O}(n,\alpha)^{14}\text{C}$  where  $\gamma$  refers to gamma rays and  $\alpha$  refers to alpha rays. These reactions are more explicitly expressed as:



Therefore, in addition to the  $^{14}\text{C}$  production process outlined in Section 2.2,  $^{14}\text{C}$  is continuously being formed in the upper atmosphere by the interaction of cosmic rays with atmospheric nitrogen, carbon and oxygen as described by Eqs. 1, 3, 4 and 5.

## 2. 7. $^{13}\text{C}$ and N to $^{14}\text{C}$ transformations

The amount of  $^{13}\text{C}$  and  $^{12}\text{C}$  in a sample does not change over time since they are both stable isotopes, unlike radioactive  $^{14}\text{C}$  which gradually decays. A simplified form of the equation used for the  $^{14}\text{C}$  dating is as follows:

$$n = n_0 e^{k(T/5730)} \quad (6)$$

where  $n$  is the number of  $^{14}\text{C}$  atoms remaining in the sample,  $n_0$  is the number of  $^{14}\text{C}$  atoms originally present in the sample when the living being which produced it was still alive,  $k = \ln(1/2) = -0.69315$  and  $T$  is the age of the sample in years.

From Eq. (6), we have as follows:

- At the death of the living being under test  $T = 0$  and so  $n/n_0 = 1$ .
- After  $T = 5,730$  years (half-life)  $n/n_0 = 0.5$ .
- After  $T = 11,460$  years (two half-lives)  $n/n_0 = 0.25$ .
- After  $T = 2000$  (birth of Christ) years  $n/n_0 = 0.7851$ .
- After  $T = 625$  (mean radiocarbon age of the TS = 1950-1325 years)  $n/n_0 = 0.9272$ .

Therefore the measured number of  $^{14}\text{C}$  atoms found on the 1988 TS samples was 0.9272 times the quantity contained in a recent (of 1950 AD, as defined above) linen sheet whereas, if the TS was about 2000 years old, that value would have been 0.7851, instead of 0.9272.

According to the hypotheses described by Eqs. 1 and 3, regarding the production of new  $^{14}\text{C}$  from N and  $^{13}\text{C}$ , if the TS is about 2000 years old instead of 625 years old as supposed by Ref.[1], but still contains 0.9272 times the quantity of  $^{14}\text{C}$  atoms expected in a medieval linen sample, there must have been a  $^{14}\text{C}$  atom enrichment of 0.1421 ( $=0.9272-0.7851$ ).

Therefore, to get an idea of the quantities involved in reference to the TS, according to Table 1, of each of the supposed 118.7 kg of  $^{12}\text{C}$  atoms of carbon,  $0.021 \mu\text{g}$  ( $=0.15 \mu\text{g} \times 0.1421$ ) of  $^{14}\text{C}$  should have transformed from N and  $^{13}\text{C}$ , a so minimal quantity that various environmental factors could have produced.

## 2. 8. $\delta^{13}\text{C}$ - stable isotopes ratios

$\delta^{13}\text{C}$  is measurement of the ratio of stable isotopes  $^{13}\text{C} / ^{12}\text{C}$ , reported in parts per thousand. It is widely used in archaeology for the characterization of the sample under analysis and it is defined as:

$$\delta^{13}\text{C} \text{ ‰} = (\text{R}_{\text{sample}} / \text{R}_{\text{standard}} - 1) \times 1000 \quad ; \quad \text{R} = ^{13}\text{C} / ^{12}\text{C} \quad (7)$$

where the standard is an established reference material generally typical of the calcium carbonate of marine deposition (PeeDee Belemnite, PDB).

While inorganic samples have a null  $\delta^{13}\text{C}$ ,  $\text{C}_4$  plants (plant species of warm climates but with reduced water availability, such as corn, sorghum and sugar cane) have a  $\delta^{13}\text{C}$  in the range of  $-16\text{‰}$  to  $-10\text{‰}$ , and  $\text{C}_3$  plants (plants having their habitat in temperate climates) have a  $\delta^{13}\text{C}$  in the range of  $-33\text{‰}$  to  $-24\text{‰}$ ; flax typically has values of  $\delta^{13}\text{C} = -25\text{‰}$ .

During the 1988 radiocarbon dating of the TS [1] Arizona, Zurich and Oxford laboratories determined the values of  $\delta^{13}\text{C}$  to be  $-25.0\text{‰}$ ,  $-25.1\text{‰}$ ,  $-27.0\text{‰}$  respectively. The discrepancy in the Oxford result, which showed a  $^{13}\text{C}$  quantity below the normal value expected, indicates a possible transformation of some  $^{13}\text{C}$  atoms into  $^{14}\text{C}$  following the process described by Eq. 3 of Section 2.4.

## 3. QUALITATIVE EVALUATION OF NITROGEN CONCENTRATION

It would be interesting to test the hypothesis of an uneven enrichment of  $^{14}\text{C}$  isotopes in the TS as described in Section 1, but there are significant challenges in doing so, mainly due to the scarcity of material previously taken from the TS that could be used for such tests. In fact, the only materials available for research are a very small number of flax fibers, microscopic fragments of blood and other particles embedded in adhesive tapes that have been taken by authorized researchers in the past century.

Consequently, all types of destructive or highly invasive tests normally employed in the course of similar research have to be excluded at present and traditional tests that require quantities of material greater than that contained in micrometric particles cannot be considered.

In order to confirm the hypothesis of the effect of neutron radiation on the TS, we can first refer to the reaction described by Eq.1 which describes one of the possible methods hypothesized for the production of  $^{14}\text{C}$  outlined in Section 2. In fact, it is relatively simple to verify

if the quantity of nitrogen present in a TS sample is normal or not. In particular, if Eq. 1 acted on the flax of the TS, we should expect the quantity of nitrogen contained in the flax to be reduced below normal values.

In this study, only an analysis of the type “is there or not” is of interest; in the event that these preliminary results show encouraging data, it will then perhaps be possible to proceed quantitatively using other methods.

Among the possible tests, this paper qualitatively considers the elemental analysis performed by means of Energy Dispersive X-Ray Fluorescence Analysis (XRF-EDS), also called Energy-dispersive X-Ray spectroscopy (EDX) because it is not destructive. The analysis was carried out with Environmental Scanning Electron Microscope instrumentation (ESEM), FEI mod. Quanta 200, in order to achieve information concerning the morphology and the elemental composition of the particles. With this technique, in the low vacuum mode, it is possible to observe the samples as they are, without any surface preparation or manipulation. The ESEM is coupled to an XRF-EDS spectrometer (EDAX, Mod. Element), to obtain an elemental analysis. The spectra acquired in XRF show the peaks of all elements involved, thus allowing a semi-quantitative determination of the sample composition.

### **3. 1. XRF-EDX Spectra of linen fibers**

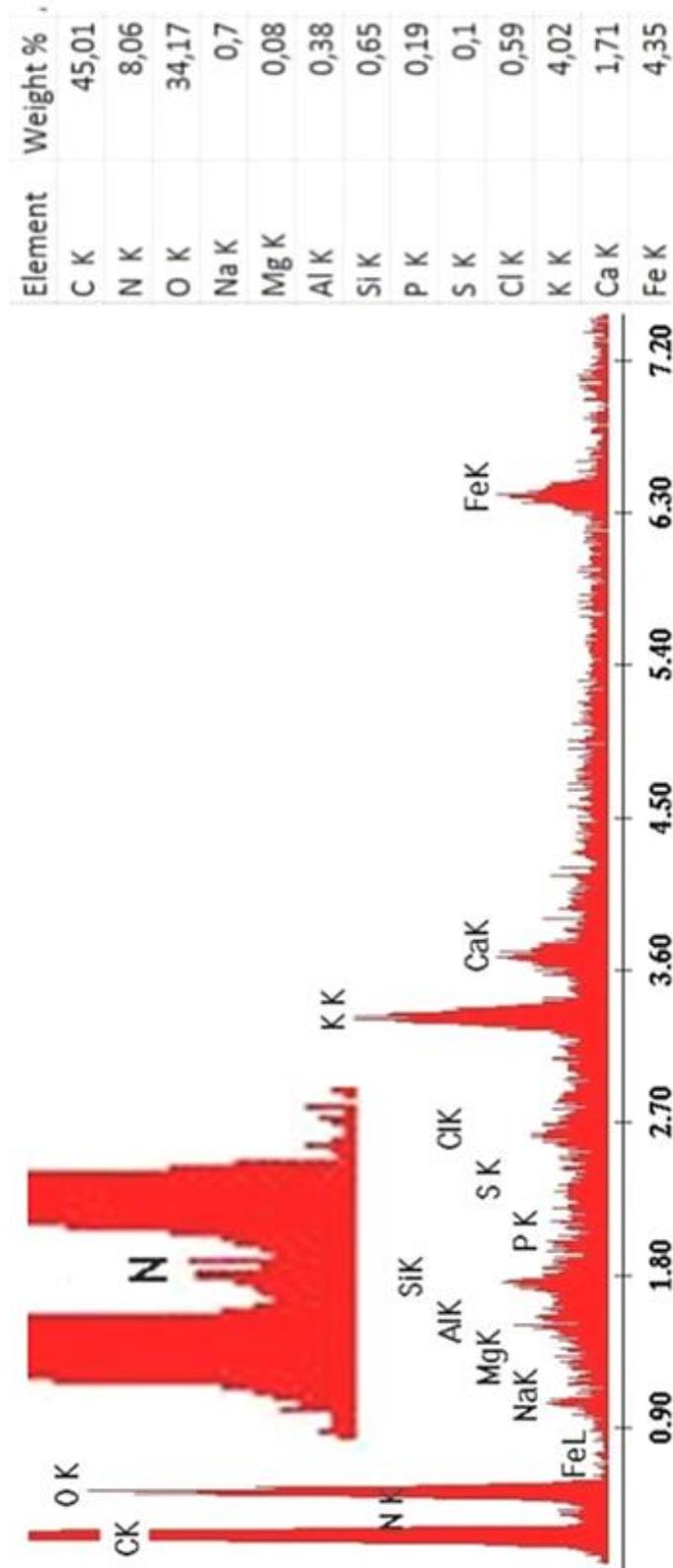
This analysis started from the assumption that if neutron radiation occurred then according to Eq. 1, the nitrogen peak should be reduced in amplitude. Some previously tested TS fibers show small peaks corresponding to the nitrogen *N* atoms, see for example Fig. 1. The relatively low nitrogen content is visible despite the background noise produced by this kind of instrument (it was measured at  $720 \pm 32$  ppm, see Table 2, in a recent linen fabric).

In contrast, the spectra obtained from modern linen fabrics hardly show the peak corresponding to nitrogen due to its amplitude being so low that it is almost masked by instrument background noise, or it is not even detectable at all, as is shown in the example in Fig. 2.

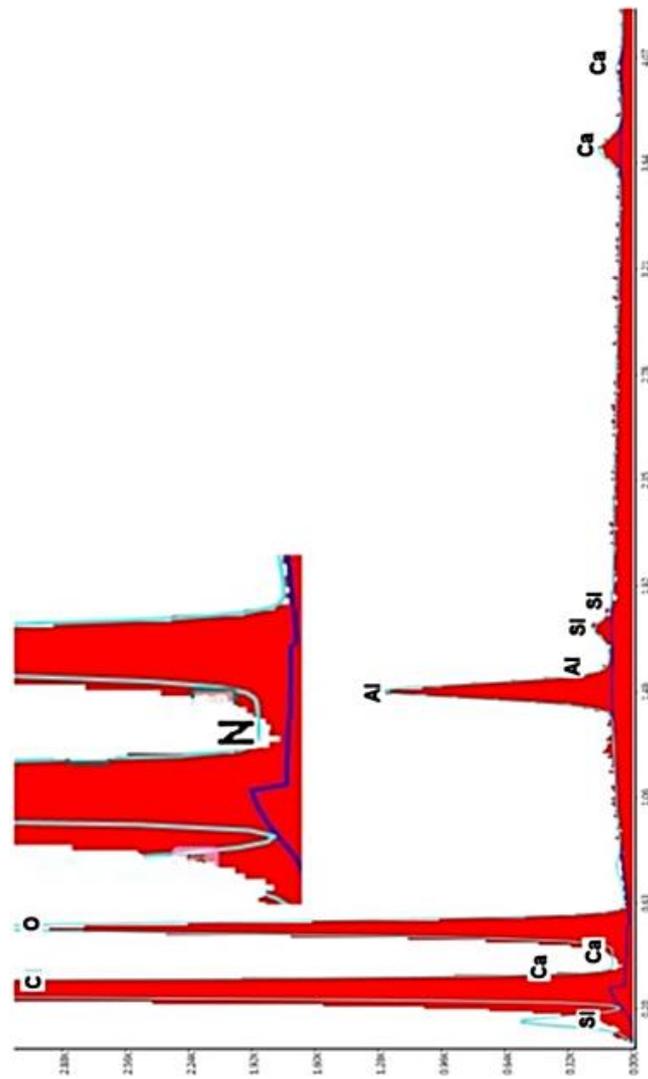
More in-depth studies of the spectra of the fibers coming from TS have shown that they are often encrusted with organic (containing nitrogen) and inorganic material (for example calcium carbonate). As such, the peak corresponding to nitrogen shown in Fig. 1 is probably not from the fiber under examination but instead must be due to external contamination.

It appears from this analysis that ESEM coupled with XRF-EDX type instruments, similar to the one used, do not have sufficient resolution to show a possible variation of the nitrogen content in linen fibers due to hypothetical environmental effects. Other instruments such as the CHNS elemental analyzer have not been taken into consideration because they require the combustion of the sample and are therefore destructive.

However, this analysis performed on linen fibers does have some value because the spectra of these fibers confirms that the quantities of nitrogen are too small to be visible above the background noise. In the following section, therefore, when blood crusts adhering to linen fibers are analyzed, we will know that any nitrogen present in the spectrum cannot be from the underlying fiber.



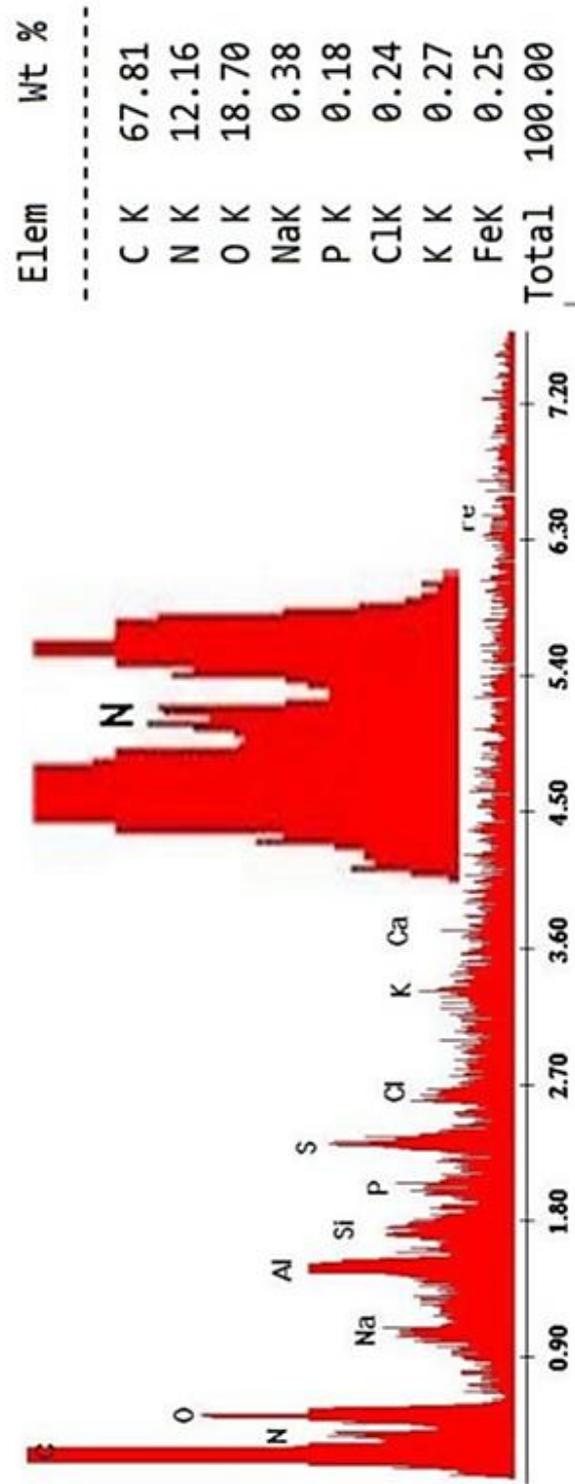
**Figure 1.** Nitrogen N content in a TS linen sample taken from dusts vacuumed by G. Riggi di Numana in 1978 (filter “h”). The peak of nitrogen is just above the noise.



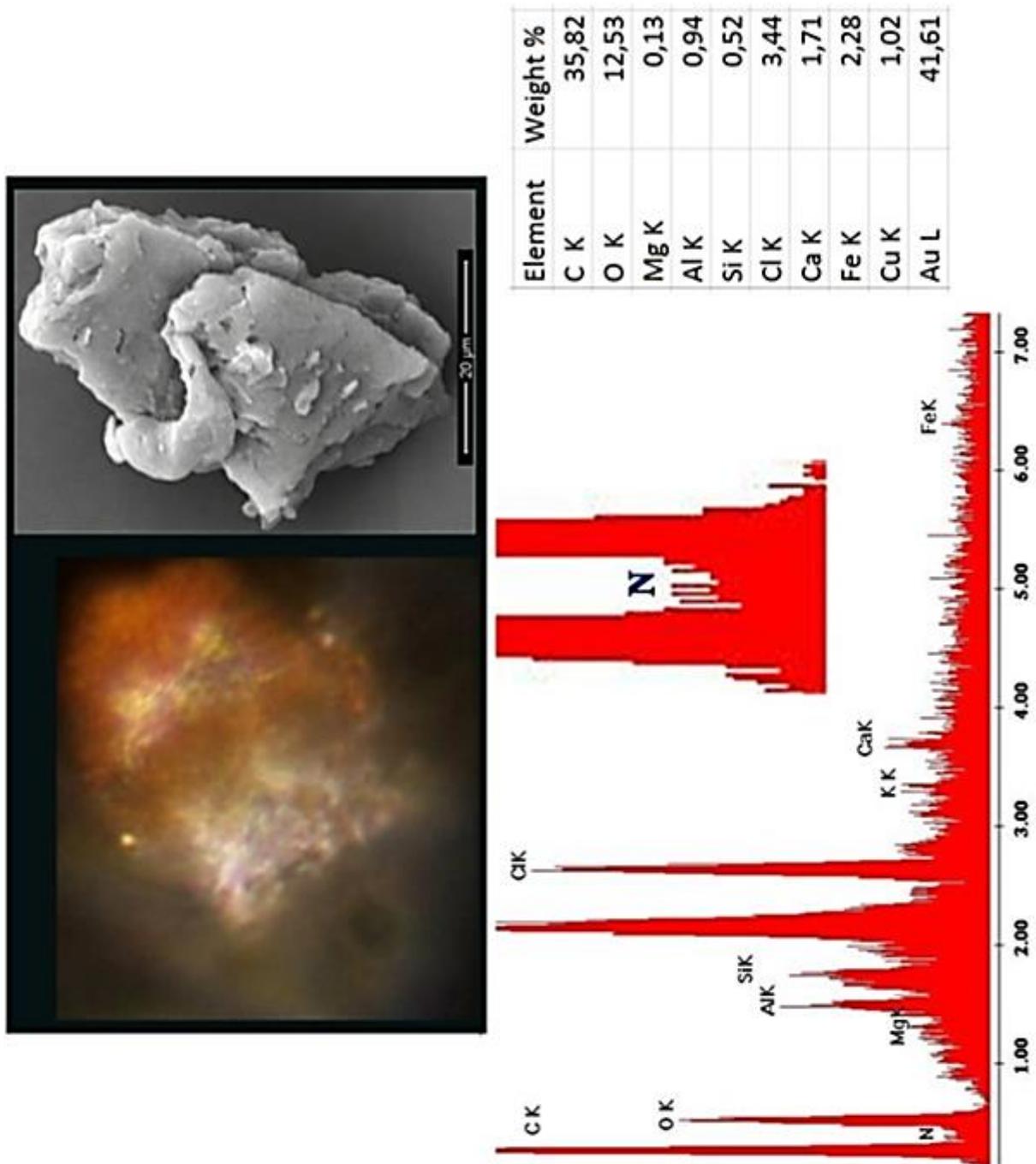
Element	Weight %
C K	62,6
O K	33,74
Al K	2,93
Si K	0,17
Ca K	0,56

**Figure 2.** Nitrogen N content in a modern linen sample. The peak of nitrogen is absent; the aluminum Al peak is due to the support.

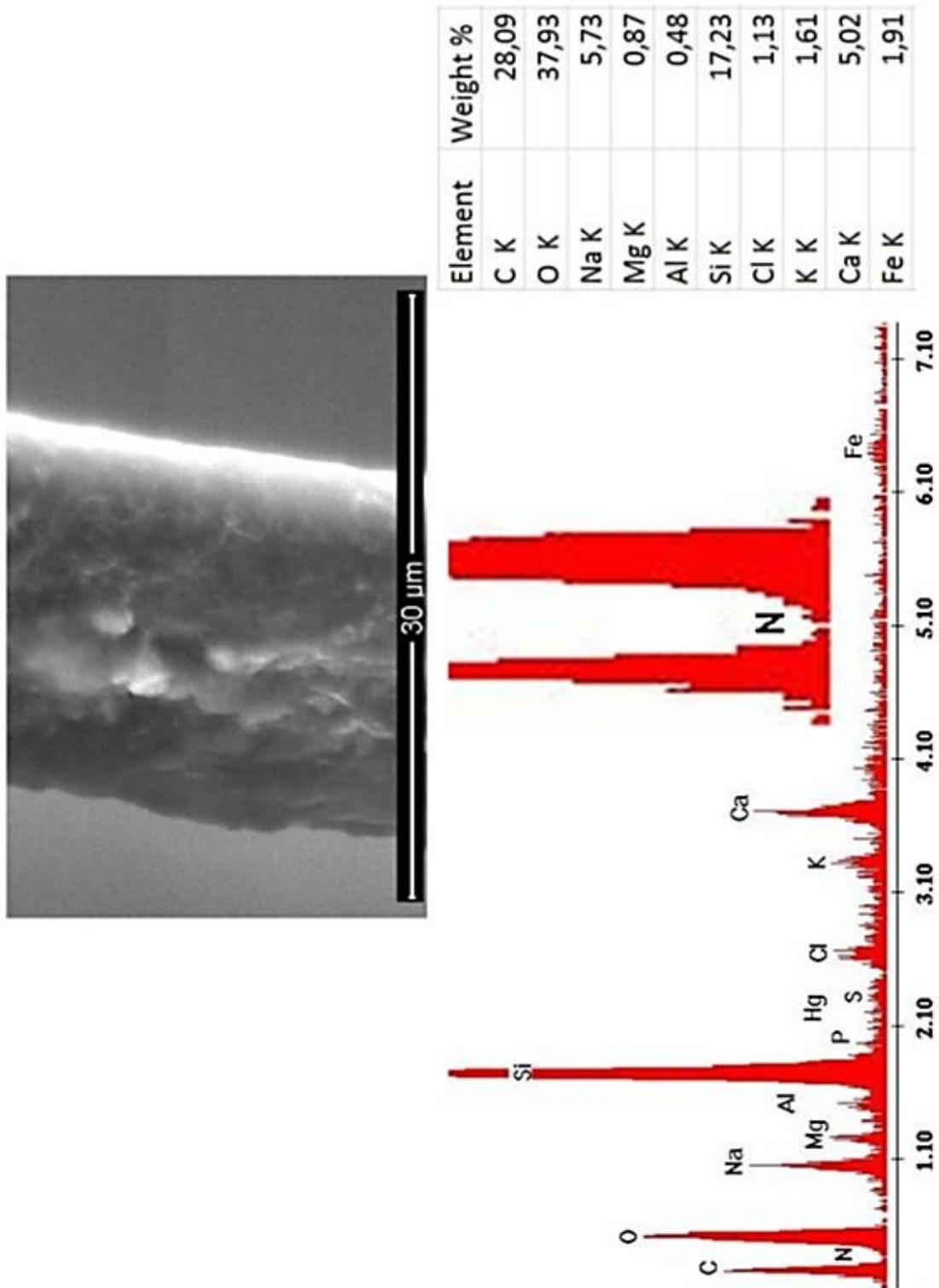
3. 2. XRF-EDX Spectra of blood



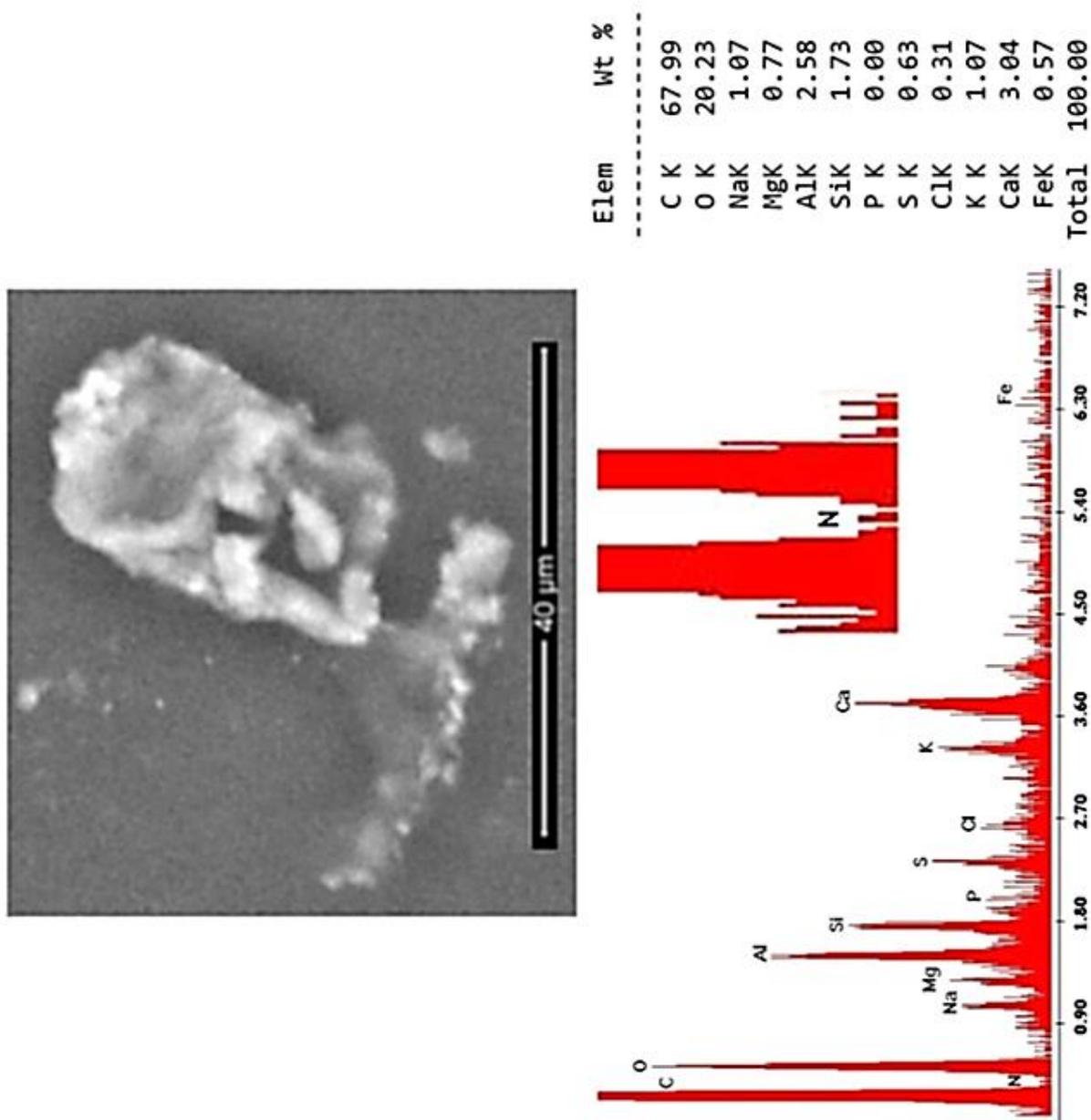
**Figure 3.** Nitrogen N content in a common blood sample. The peak of nitrogen is evident; the aluminum Al peak is due to the support.



**Figure 4.** On the top, blood crust of about 15 micrometers coming from dusts vacuumed by G. Riggi di Numana in 1978 from the face area, seen through an optical microscope on the left and through an ESEM on the right. The possible nitrogen N peak is masked by the noise. The aluminum Al peak is due to the support.



**Figure 5.** On the top, TS bloody fiber (1HB from STERA Inc. taken during 1978-STuRP campaign) of about 20 micrometers seen through an ESEM. Nitrogen N peak is absent here. The silicon Si peak is due to the glass support.



**Figure 6.** On the top, TS bloody fiber (3EF from STERA Inc. taken during 1978-STuRP campaign) of about 20 micrometers seen through an ESEM. Nitrogen N peak is absent here. The aluminum Al peak is due to the support.

An analysis of the TS blood spectra obtained using the instrumentation used in Section 3.1 evidences a possible depletion in its nitrogen level. Blood contains non-negligible quantities of nitrogen; the azotemia alone (amount of total non-protein nitrogen present in the blood) varies from 150 to 500 mg/l or 0.14‰ – 0.47‰ in weight (the weight density of blood is 1.06 g/cm<sup>3</sup>) but most of the nitrogen is contained in blood proteins.

As an example, Fig. 3 shows a typical XRF-EDX spectrum of common human blood where the nitrogen peak is clearly visible, corresponding to 12% in weight, thus confirming that this element can easily be detected in human blood.

On the other hand, it is interesting to note an anomaly found in the spectra relating to the blood crusts coming from the TS.

Figs. 4-6 show three TS blood crusts taken from:

-Fig. 4, dusts vacuumed by G. Riggi di Numana in 1978 from the face area;

-Fig. 5, bloody fiber removed using an adhesive tape [1HB from Shroud of Turin Education and Research Association, Inc. (STERA, Inc.)] placed in correspondence with the blood of the feet of the dorsal body image during 1978-StuRP (Shroud of Turin Research Project) campaign;

-Fig. 6, crust of blood taken using an adhesive tape (3EF from STERA Inc.) placed in correspondence with the blood of the left wrist of the frontal body image during 1978-STuRP campaign.

Unlike normal human blood spectra, these spectra show the absence of nitrogen (or at least the nitrogen level is so low that it is masked by background noise). This anomaly in the blood removed from the TS, which gives no indication of nitrogen in the blood spectrum, is not easy to explain as there is no obvious chemical or biological reason why the nitrogen content of blood proteins should have reduced so drastically over time. An explanation for this anomaly could instead be provided by Eq. 1 of Section 2.2.

#### **4. CONCLUDING REMARKS**

The hypothesis stated in this paper presents an explanation for a blood anomaly coming from TS. Unlike common human blood which contains nitrogen (weight percentages of the order of 10%), the level of nitrogen in TS blood is lower than the background noise of the instrument (approximately 1%).

It is not easy to find an explanation for this result. However, if we refer to the hypothesis formulated by T.J. Phillips [29] who first assumed the effect of neutron radiation upon the TS and its bloodstains which have undergone extensive analysis, it is possible to qualitatively understand what may have altered the result as outlined above.

The hypothesis of T.J. Phillips is that neutrons would have irradiated the TS, and in doing so, changing some of the  $^{13}\text{C}$  nuclei to different isotopes. In particular, according to Eq. 3, if the  $^{13}\text{C}$  nuclei had been transformed into  $^{14}\text{C}$ , the results of the radiocarbon dating of the TS performed in 1988 would have to be corrected for the corresponding systematic effect hypothesized here. A more influent hypothesis is that of R.E.M. Hedges, which is based upon a reaction involving the production of  $^{14}\text{C}$  from nitrogen atoms according to Eq. 1. This would also result in new  $^{14}\text{C}$  atoms being produced in the TS linen.

According to Teruaki Enoto et al. [31], to the two known natural productions of carbon isotopes on Earth (primordial  $^{13}\text{C}$  originating from stellar nucleosynthesis, and  $^{14}\text{C}$  produced by atmospheric interactions with cosmic rays), we must add the production of carbon isotopes produced by lightning and storm clouds which are natural particle accelerators.

These phenomena in accordance with Eq. 1, produce  $^{14}\text{C}$  atoms from nitrogen atoms. Consequently, this evidence makes easier to think that the explosion of energy hypothesized by

some scholars for the formation of the body image of TS also contributed to varying the isotopic percentage of carbon contained in the linen of the Relic.

This paper has developed a first possible qualitative verification of the hypotheses formulated by T.J. Phillips [29], R.E.M. Hedges [28] and Teruaki Enoto et al. [31] and this will obviously have to be confirmed by parallel analyses such as measuring the weight percentage of nitrogen in TS samples and comparing them with reference samples.

The analysis began with a measurement of the nitrogen content in linen fibers, but the instrument noise prevented the detection of any possible nitrogen variation. The blood coming from the TS instead showed a significant anomaly with a depletion in the nitrogen content to levels below the background noise level.

This result is therefore clearly in favor of the hypothesis of burst of energy that, while produced the double body image of the TS, it also altered the isotopic percentage of carbon atoms of the linen in the Relic, but it requires additional confirmation.

Various avenues of verification are possible because if the hypothesis of the transformation of nitrogen into  $^{14}\text{C}$  is correct, it is likely that the same hypothetical radiation has also affected other elements present in the blood and in the flax such as sodium Na and chlorine Cl, which may also show changes to their isotopic percentages from the neutron radiation.

At present, it also seems unnecessary to proceed further with some quantitative analysis because it must be remembered that the nitrogen reduction was found only in the blood. It will be necessary to show a corresponding nitrogen reduction in the TS flax fibers before to confirm additional doubts [2-5] to the results of the radiocarbon dating of 1988 [1].

At this point, however, should there be any future radiocarbon dating of the TS, it is strongly recommended that prior to the test, some fibers should be taken from the TS and analyzed to determine if their nitrogen content is within normal limits or if, as suggested by this study, their nitrogen content is reduced. If the hypothetical percentage of nitrogen transformed into  $^{14}\text{C}$  is eventually verified and quantified, then it will be possible to predict the systematic effect of this isotopic transformation on the result of any future new radiocarbon dating of TS.

#### **Acknowledgements**

Many thanks to Barrie Schwartz president of Shroud of Turin Education and Research Association, Inc. (STERA, Inc.), for having kindly lent the author the 1HB and 3EF sticky tapes and for having allowed the publication of the data relating to them; warm thanks to Michael Kowalski of Shroud-Science Group for the advices and the corrections concerning the English language he made in this paper; thanks to Teddi Pappas of Shroud-Science Group too for her useful advices; lastly the author thanks the Holy Spirit who inspired the paper.

#### **References**

- [1] Damon P.E., Donahue D.J., Gore B.H., Hatheway A.L., Jull A.J.T., Linick T.W., Sercel P.J., Toolin L.J., Bronk C.R., Hall E.T., Hedges R.E.M., Housley R., Law I.A., Perry C., Bonani G., Trumbore S., Wölfli W., Ambers J.C., Bowman S.G.E., Leese M.N., Tite M.S., “Radiocarbon dating of the Shroud of Turin”. *Nature*, Vol. 337 (1989) 611-615
- [2] Riani, M., Atkinson, A.C., Fanti, G. *et al.* Regression analysis with partially labelled regressors: carbon dating of the Shroud of Turin. *Stat Comput* 23, 551–561 (2013)

- [3] R. N. Rogers. Studies on the Radiocarbon Sample from the Shroud of Turin. *Thermochimica Acta* 425 (2005): 189–194
- [4] Thomas McAvoy, On Radiocarbon Dating of the Shroud of Turin. *Int. J. of Archaeology*, 9:2 (2021) 34-44
- [5] Schwalbe L., B. Walsh, On Cleaning Methods and the Raw Radiocarbon Data from the Shroud of Turin. *Int. J. of Archaeology*, 9:1 (2021) 10-16
- [6] Jumper E.J., Adler A.D., Jackson J.P., Pellicori S.F., Heller J.H., Druzik J.R., A comprehensive examination of the various stains and images on the Shroud of Turin, *Archaeological Chemistry III, ACS Advances in Chemistry* 205, 22 (1984) 447-476
- [7] Schwalbe L.A., R.N. Rogers, Physics and chemistry of the Shroud of Turin, a summary of the 1978 investigation. *Analytical Chemical Acta*, 135 (1982) 3-49
- [8] Heller John H., Alan D. Adler, Peter M. Rinaldi and William Meacham, On the Turin Shroud. *Current Anthropology*, 24: 4 (1983)
- [9] Kearse Kelly P. Icons, Science, and Faith: Comparative Examination of the Shroud of Turin and the Sudarium of Oviedo. *Theology and Science*, 11:1 (2013) 52-61
- [10] Casabianca Tristan, The Shroud of Turin: A Historiographical Approach. *The Heythrop Journal* 54:3 (2013) 414-23
- [11] Fanti Giulio, Open issues regarding the Turin Shroud. *Scientific Research and Essays* 7:29 (2012), p. 2507.
- [12] Ball, P. Shrouded in mystery, *Nature Mater* 7, (2008) 349.
- [13] Fanti Giulio, Claudio Furlan, Do gold particles from the Turin Shroud indicate its presence in the Middle East during the Byzantine Empire?, *J. of Cultural Heritage*, 42 (2020) 36-44.
- [14] Fanti G. Hypotheses regarding the formation of the body image on the Turin Shroud. A critical compendium. *J. of Imaging Sci. Technol.* 55:6 (2011) 060507.
- [15] Fanti G., Can Corona Discharge explain the body image formation of the Turin Shroud? *J. of Imaging Science and Technology*, 54:2 (2010) 020508-1/10.
- [16] Adler Alan, Blood on the Shroud of Turin, *Applied Optics*, 19:16 (1980) 2742-2744.
- [17] Heller J.H., A.D. Adler, A Chemical Investigation of the Shroud of Turin, *Canadian Society of Forensic Science J.*, 14:3, (1981) 81-103
- [18] Bevilacqua Matteo et al., ‘Do we really need new medical information about the Turin Shroud?’, *Injury* 45:2 (2014) 464.
- [19] Fanti Giulio, Giuseppe Zagotto, Blood reinforced by pigments in the reddish stains of the Turin Shroud, *J. of Cultural Heritage* 25 (2017)113-120.
- [20] Bevilacqua M, Fanti G, D’Arienzo M (2017) New Light on the Sufferings and the Burial of the Turin Shroud Man. *Open J Trauma* 1(2): 047-053. DOI: 10.17352/ojt.000010

- [21] Svensson Niels, Thibault Heimburger, Forensic aspects and blood chemistry of the Turin Shroud Man. *AJ Scientific Research and Essays*, 7:29 (2012) 2513-2525, 080A92329177
- [22] Fanti G. and R. Maggiolo. The Double Superficiality of the Frontal Image of the Turin Shroud. *J. of Optics A: Pure and Applied Optics* 6 (2004) 491-503
- [23] Fazio Giovanni, A Stochastic Process to Explain the Turin Shroud Body Image Formation. *J. of Modern Mathematics Frontier*, 2, (2021) 99-102
- [24] Fanti Giulio, Comments on a stochastic hypothesis about the body image formation of Turin Shroud, *The Journal of The Textile Institute*, 106:8 (2015) 900-903.
- [25] Jumper Eric J. and Robert W. Mottern, Scientific investigation of the Shroud of Turin. *Applied Optics* 19:12 (1980) 1909-1912
- [26] Fanti G., Basso R., Bianchini G., Turin Shroud: Compatibility between a Digitized Body Image and a Computerized Anthropomorphous Manikin. *J of Imaging Sci Technol* 54 (2010) 50503-1/8
- [27] Fanti, G., Moroni, M., Comparison of Luminance between Face of Turin Shroud Man and Experimental Results. *J. of Imaging Science and Technology*, 46:2 (2002)142-154
- [28] Hedges R.E.M, Reply to Shroud irradiated with neutrons? *Nature* Vol. 33716 (1989).
- [29] Phillips T.J., 1989, Shroud irradiated with neutrons? *Nature* Vol. 33716 (1989).
- [30] Hedges R.E.M, Sample Handling in Radiocarbon Dating by Accelerator with Special Reference to the Turin Shroud, *Analytical Proceedings*, 27 (1990) 45.
- [31] Teruaki Enoto, Yuuki Wada, Yoshihiro Furuta, Kazuhiro Nakazawa, Takayuki Yuasa, Kazufumi Okuda, Kazuo Makishima, Mitsuteru Sato, Yousuke Sato, Toshio Nakano, Daigo Umemoto & Harufumi Tsuchiya, Photonuclear reactions triggered by lightning discharge. *Nature Letter*, 483 (2017), 24630