Recovering the missing aura — a study on the feasibility of rebinding and the paper strength of fire-damaged books

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In June 2019, a series of manuscripts written by a Taiwanese indigenous writer, Sakini Ahronglong, was delivered to the National Museum of Taiwan Literature (NMTL). Sakini is a significant indigenous writer in Taiwan; her works not only won influential literary awards in Taiwan, but were also translated and published in English and Japanese. Through these manuscripts spanning decades, one can observe Sakini's wisdom and the beautiful moments in life. Moreover, it could be seen as an important part of her literary creations. The expected donation of manuscripts included some diaries, essays, notes, sketches, etc. but instead of intact items, only those salvaged from the fire could be seen.

In order to properly plan the conservation procedures for the manuscripts salvaged from ashes, especially with conditions such as burned edges, water stains and mold, this investigation discussed the need of follow-up treatments by observing and analyzing the current condition of the manuscript papers. The preliminary examinations were also designed to verify the feasibility of future treatment strategies. (Fig.1, Fig.2)

Documentation
Classification of Manuscripts:
According to the condition of the fire-damaged paper, it is roughly divided into four types:
- **Category 1**: piles of paper left in large quantities; with front and back covers; can clearly distinguish individual volumes.
- **Category 2**: piles of paper left in large quantities; no front or back cover; unable to clearly distinguish individual volumes.
- **Category 3**: piles of paper left in small quantities; no front and back cover; can not be precisely judged as a book.
- **Category 4**: Incomplete loose pages.

The degree of the remaining paper
Focusing on the category 1 and 2 of fire-damaged paper which are relatively complete, it shows that the remaining areas are approximately 75–83% of the originals. (Fig. 3, Fig. 4)

Paper fiber identification and pH value measurement
The paper fibers observed are composed of mainly pure cotton, (Fig. 5) and their FTR spectra also have similar peaks (Fig. 6). In addition, the pH of paper now is about 5-6.

Mold growth
After salvaging it from water following the fire damage, mold and mildews are found almost everywhere on the inner pages. The mycelium growth is deeply embedded in the paper fibers, (Fig. 7, Fig. 8)

Discussion
- **The category 1 & 2**, which have a comparatively complete appearance and content, are evaluated as of value to be collected by the museum. The category 3 & 4 are incomplete manuscripts expected to be used for future pre-treatment tests.
- After the paper was damaged by fire, the absorption cotton fibers of pH 5-6 will be more sensitive to hydrolysis and acidification.
- While the surface mold can be cleaned by the vacuum, the mold deeply embedded in the paper fibers will be difficult to remove, and may easily recur in the future.
- After the fire damage, the paper fibers in the A, B, and C areas can still be seen with no embrittlement phenomenon when touched. In contrast, area D is without a stable fiber structure and has been completely carbonized. Therefore, future conservation will be focused on the three areas ABC as much as possible.
- The blending media of ballpoint pens and signature pens make the result unsuitable for using polar solvents (such as alcohol) on them when doing treatment to inhibit mold.
- Washing is deemed required in order to resolve the above issues, which is not only used to remove harmful residual substances, but also to mask paper distortion. Therefore, the problem of eliminating mildew in paper will be considered first before wet treatment.

Experiments & Results
This study adopted a two-stage experiment process. The first stage was to evaluate the effect of radiation on mold removal. The second stage was to evaluate the effect of mold removal with the determined radiation dose and wash them. The results evaluated the change and recovery of paper strength.

Mold removal test using Gamma-radiation
Gamma radiation is a kind of electromagnetic energy that can penetrate the irradiated object with no residual radiation and remove fungus and pests by destroying their DNA. In this study, the paper was irradiated with low-dose radiation of 0.5, 1, 3, 5, 7, and 10 kGy, and then the sterilization effect evaluated. (Fig. 10 – Fig. 12)

The results showed that using 3 kGy was a safe and effective dose to remove mold for these manuscripts. In each experiment, paper sample was tested by TFR, and there was no noticeable chemical bond change in the fiber spectrum irradiated with all test doses (Fig. 13).

Changes in chemical and physical properties
According to the FTR spectrum, the chemical bonds of the paper remained unchanged after being burned and irrigated, but the physical properties have a downward trend (Table 1). It could be believed that the radicals of the cellulose macromolecules were just destroyed and reduced, but did not disappear, resulting in a decrease in the degree of polymerization.

Effects of burning and radiation
From Table 1, the sediment and irradiated paper has almost no change in the folding endurance for machine direction (MD), in contrast, it decreased significantly after burning and irradiation (compare T-A & T-B with T-G & T-H groups). It indicates that fibers’ resistance to radiation was much lower after high temperature. The water molecule structure in the fiber was destroyed. However, it is interesting that the burnt paper has increased folding endurance than the unburnt paper in cross-direction (CD) generally. Because the composition of commercial paper contains not just fibers but also additives and sizing, these added macromolecules may cause cross-linking reactions due to high temperature and irradiation, which indirectly enhanced the strength of burnt paper.

Effects of aging
The folding endurance of the aged irradiated paper significantly deteriorated, the pH dropping from 5 to 4. That might be due to the decrease of hydrogen bonds, and or the generation of free radicals (such as hydroxyl) radicals in the irradiated paper as a result of accelerated oxidation and acidification.

The benefits of washing
Radiation and fire affected the hydrogen bonds in the paper fibers. Fortunately, both the paper strength in MD and CD of the unaged paper group were all recovered to their original state by washing, improving even the aged paper.

Credibility of experiment
Comparing the burnt sample paper and the manuscript paper, their folding endurance change ratios in MD after irradiation were similar. The burnt sample paper decreased by 28%, while the manuscript had a decrease of 16%.

Conclusion & Future works
Taiwan is located in a subtropical climate with high temperature and humidity. To avoid mold growth on manuscripts is a Herculean task. Luckily, through the irradiative experiment, mold can be eliminated completely and contribute to the possibility to further wet conservation.

In the washing experiments, the paper strength could be restored to the original after irradiation. This result contributes to the basis for subsequent bookrebinding, especially for treating the first and second categories of manuscripts in the future.

irradiation might decompose the large molecules of cellulose in cotton fiber into small ones. When the irradiated paper was aged by heat, the folding endurance performed even more unsatisfactorily. It will be recommended that the paper after irradiation should be stored in an environment with a stable relative humidity and avoid an overly dry condition.

References