DOI: 10.2507/36th.daaam.proceedings.xxx

USING LUMINESCENCE SPECTROSCOPY TO MONITOR THE AGING OF LATENT FINGERPRINTS

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This Publication has to be referred as: Indra M[ichal]; Mikuličová M[ichaela] & Křesálek V[ojtěch] (2025). Using Luminescence Spectroscopy to Monitor the Aging of Latent Fingerprints, Proceedings of the 36th DAAAM International Symposium, pp.xxxx-xxxx, B. Katalinic (Ed.), Published by DAAAM International, ISBN 978-3-902734-xx-x, ISSN 1726-9679, Vienna, Austria
DOI: 10.2507/36th.daaam.proceedings.xxx

Abstract

The article deals with the estimation of the age of latent fingerprints using luminescence spectroscopy. For the purpose of measurement, 7 samples were analyzed (5 from men, 2 from women; age 24-37 years). Subsequently, the samples were measured for a period of twelve weeks using luminescence spectroscopy. Characteristic trends were selected from the measured values of luminescence intensity and emission spectra, with the help of which the luminescence behavior of latent fingerprints can be described over time. Two significant peaks were found in the regions of approximately 360 nm and 480 nm of the emission spectrum.

Keywords: Luminescence, Spectroscopy, Dactyloscopy, Latent Fingerprint, Fingerprint Aging

1. Introduction

Forensic dactyloscopy is one of the oldest and most important criminalistic disciplines. It examines the papillary lines found on the palms, soles and joints of the fingers. Thanks to three important properties, which are uniqueness, immutability and relative irremovability of papillary lines, they can be used for individual identification of a person. When examining and analyzing fingerprints, one usually works only with certain characteristic parts or patterns in which the papillary lines have specific shapes [1], [2].

According to the method of creation, dactyloscopic traces are divided into three-dimensional and planar. Three-dimensional traces are formed when pressure is applied to a soft material (e.g. wax), i.e. the print is pressed into the material. On solid materials, these are planar traces, which are of two types. Layered traces, which are composed of substances adhered to the skin (e.g. blood, sebum, dust particles, etc.), and delaminated traces, when, on the contrary, contact with an object causes part of the impurities from the object to adhere to the skin (e.g. a layer of dust, paint, varnish, etc.) [1], [3]. Dactyloscopic traces are also divided according to visibility, namely into visible traces, which can be clearly seen even by the human eye and are formed, for example, by blood or paint, and invisible or latent traces, which are the most common and are formed mainly by sweat and sebum [4], [5].

Latent fingerprints must be made visible before being photographed, secured (e.g. on fingerprint film) and subsequently examined. Various methods are used for this, the choice of which depends on the properties of the particular fingerprint. Physical methods use the adhesion or stickiness of a fingerprint powder (e.g. argentorate) applied with a brush

to the fingerprint, to which it adheres. Chemical methods use the reaction of chemical agents (e.g. silver nitrate) with various substances in the fingerprint. Physico-chemical methods include, for example, the application of cyanoacrylate vapors. The latter methods are special methods, working mainly with laser devices [4], [5], [6] It is not always possible to use a latent fingerprint for classical identification. The fingerprint is not suitable in situations where it is damaged or blurred in some way, and the papillary line cannot be distinguished accurately. Nevertheless, several pieces of information about the originator (e.g. gender, use of medications or drugs, age, etc.) can be determined from the fingerprint by analyzing its chemical composition. The imprint contains various substances found in human sweat (secreted by eccrine sweat glands) and sebum (secreted by sebaceous glands, which are not found on the palms or soles, but during normal activities when a person touches, for example, hair or face, the hands are also contaminated with sebum), such as fatty acids, amino acids or sugars. External contaminants (e.g. residues of food, cosmetics, inks, medications, etc.) may also be present in the fingerprint. The chemical composition of the imprint changes over time due to external conditions (e.g. temperature and humidity), which, among other things, cause the oxidation or evaporation of some substances [4], [7].

Currently, methods are being developed that can roughly estimate the age of latent fingerprints. In forensic investigations, this could be helpful, for example, in cases where it is necessary to determine whether a fingerprint found was created before a crime was committed. One option is to use dactyloscopic powders, which monitor their changing adhesion or the degree of visibility of the papillary terrain over time, as described, for example, in a study [8], where latent fingerprints were monitored over time when exposed to various conditions (e.g. light, humidity, etc.) and made visible using titanium dioxide-based powder. However, no specific conclusions were drawn. In [9], the prints were monitored for 90 days and after a certain period of time after the powder was applied, changes in color saturation were monitored. A more significant decrease in saturation occurred between days 3 and 7. The saturation did not change much over the last 30 days.

Another option is electrical methods that use the change in the electrical charge of the fingerprint over time. The study [10] dealt with contact electrification, where the electrical potential of the latent fingerprint was scanned by a scanning device with a contactless probe. A decreasing areal density of the electrical charge was recorded over time, while in very old fingerprints the charge was not detected at all.

For the analysis of the chemical composition of fingerprints, it is good to use destructive, but very accurate gas chromatography-mass spectrometry (GC-MS). This method was also used to determine the age of latent fingerprints in [11], [12]. In [11], 8 samples from different individuals were monitored for 28 days. The conclusions point to a faster decrease in some compounds over time (mainly squalene) in samples stored in the light. There was also an increase in some fatty acids over time.

Other methods that can be used to roughly estimate the age of latent fingerprints include Raman spectroscopy, which was used, for example, in [13]. Among other things, it was found that the Raman bands of squalene degrade much faster in light, where they cease to be detectable after approximately 140 hours. If the samples were stored in the dark, the bands were still present in the spectrum after 700 hours. The FT-IR (Fourier Transform Infrared Spectroscopy) method was used, for example, in a study [14], which focused on fingerprints of children (2 to 11 years). The analysis showed that acid salts are suitable for studying children's fingerprints due to their stability. Some methods, in turn, deal with the physical degradation of the papillary terrain of the fingerprint over time (addressed, for example, in [15]), but the problem in this case is that it depends very much on the original quality of the fingerprint.

Luminescence spectroscopy has a wide range of applications in many areas, including forensic analysis, for example, in detecting counterfeit banknotes [16]. It can potentially be used to estimate the age of latent fingerprints. Since this method only works with the chemical composition, it is not necessary to address the original quality of the print, i.e. even a blurred or partial print can be analyzed. The method is based on the different luminescent properties of organic and inorganic substances found in the print. In [17], the change in luminescence intensity over time was monitored for compounds formed by the oxidation of unsaturated lipids. In the first three weeks, it was possible to estimate the age of the prints for approximately half of the male samples. In the study [18], two main peaks were found in the emission spectrum, approximately in the regions of 340 nm and 440 nm. In [19], faster degradation of latent prints in light or at higher air humidity was observed. It was also found that the intensity of the first peak at 340 nm decreases with time, and therefore it is more appropriate to focus on the region around 440 nm, in which the luminescence intensity increases with time. Luminescence spectroscopy is used to monitor the aging of latent fingerprints in this article as well. Due to the many advantages and simplicity of this method, it could potentially be used in forensic practice.

Seven fingerprints were measured over a twelve-week period using luminescence spectroscopy. Two significant peaks were found in the regions of approximately 360 nm and 480 nm of the emission spectrum. A tendency for the luminescence intensity to increase was observed for male samples, while for female samples the opposite was observed and the intensity decreased. The amount of material examined does not affect the measurement, but significant changes are caused by contamination of the samples, for example with cosmetics.

2. Instrumentation, Sample Preparation and Measurement

The emission spectra of latent fingerprints were measured with a Shimadzu RF-6000 spectrofluorimeter with a 150W high-pressure xenon lamp as the excitation source and a Hamamatsu R928 photomultiplier as the detector. LabSolutions

RF software was used for setup and control. The most suitable excitation wavelength was experimentally determined to be λex = 280 nm. The emission spectra were measured in the range of 300–540 nm.

7 samples from 5 men and 2 women aged 24–37 years were analyzed. Sample collection and preparation took place in several steps. First, the individual washed his hands with soap and then dried them thoroughly. The individual ran a dry, arbitrarily selected finger over his face and forehead and made an impression on a clean glass slide. In order to maintain the same conditions, all samples were stored in the dark at room temperature. Fingerprint measurements were taken once a week for 12 weeks, with the first measurement taken immediately after sample collection.

3. Results and Discussion

For reasons of accuracy, all measured values are always reported after subtracting the luminescence intensity of the slide used as the base material. The emission spectra of the male sample M–1, which were measured over a period of 12 weeks, are shown in Fig. 1.

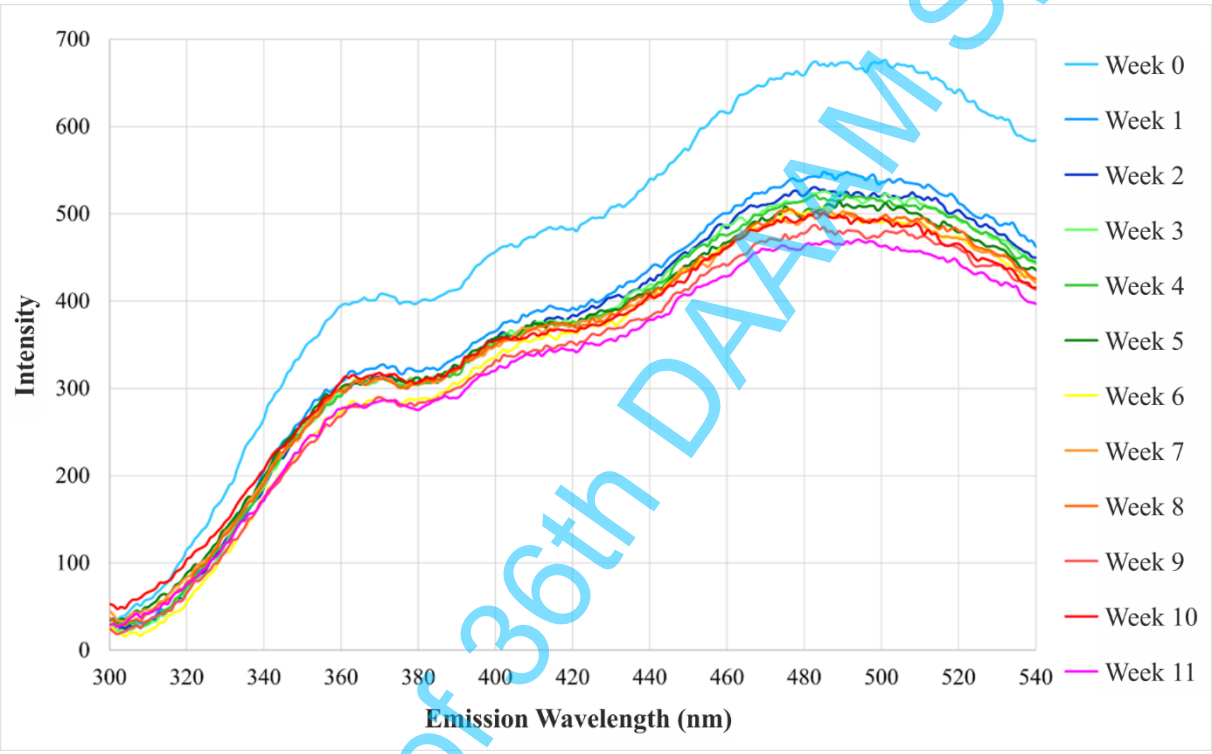

Fig. 1. Emission spectra of male sample M–1 over time.

Two main peaks can be observed in the emission spectrum. The first peak is located around 360 nm and is shown in more detail in Fig. 2a. The second peak is located around 480 nm and is shown in more detail in Fig. 2b. One smaller peak is also around 400 nm. The intensity values vary from sample to sample, but the location of the peaks and the shape of the spectrum are almost unchanged.

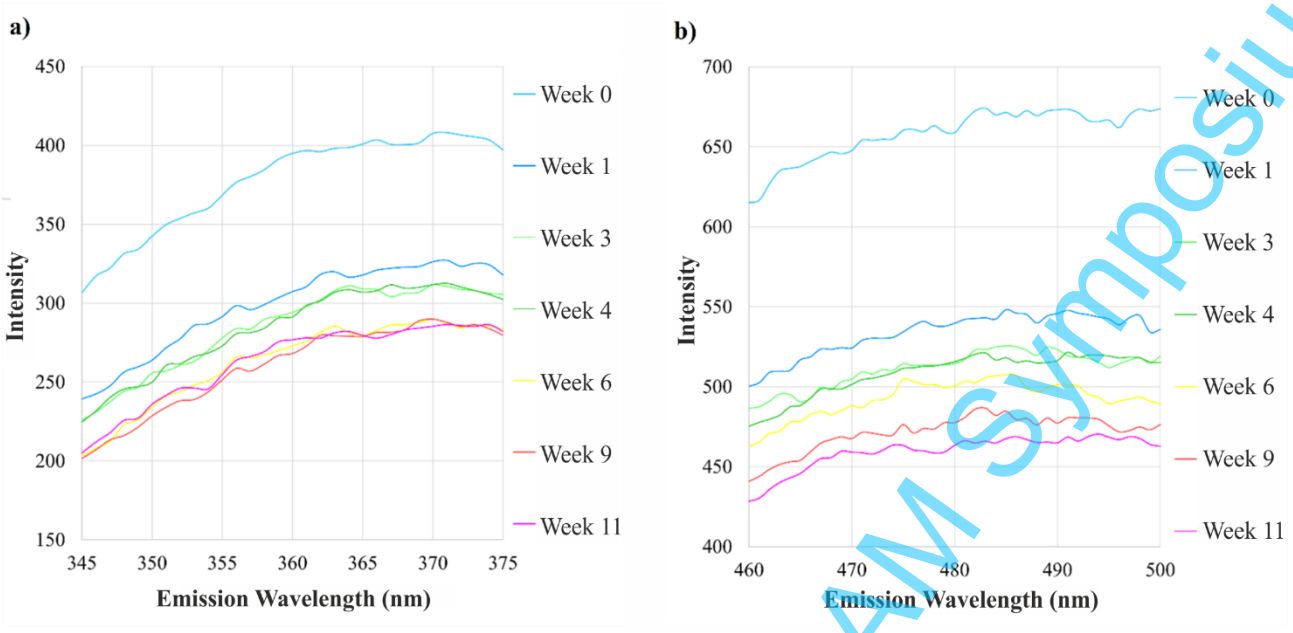

Fig. 2. Selected emission spectra of male sample M–1. a) region 345 nm to 375 nm, b) region 460 nm to 500 nm.

In 4 out of 5 male samples, the luminescence intensity decreased over time (most significantly during the first 2 weeks). In the following weeks, the intensity continued to decrease, but to a lesser extent and mainly at longer wavelengths (especially in the region around 480 nm of the emission wavelength). Fig. 3 shows the dependences of selected wavelengths of the emission spectrum of the male sample M–2 on time. The measurement uncertainty was determined by repeated measurements to be 3% and is shown by error bars. The graph shows that at 480 nm the greatest decrease in intensity occurs during the first week. In the following weeks, the intensity also decreases, but to a lesser extent. At wavelengths of 400 nm and 360 nm, the intensity also decreases during the first weeks, but the luminescence intensity did not change much in the remaining weeks.

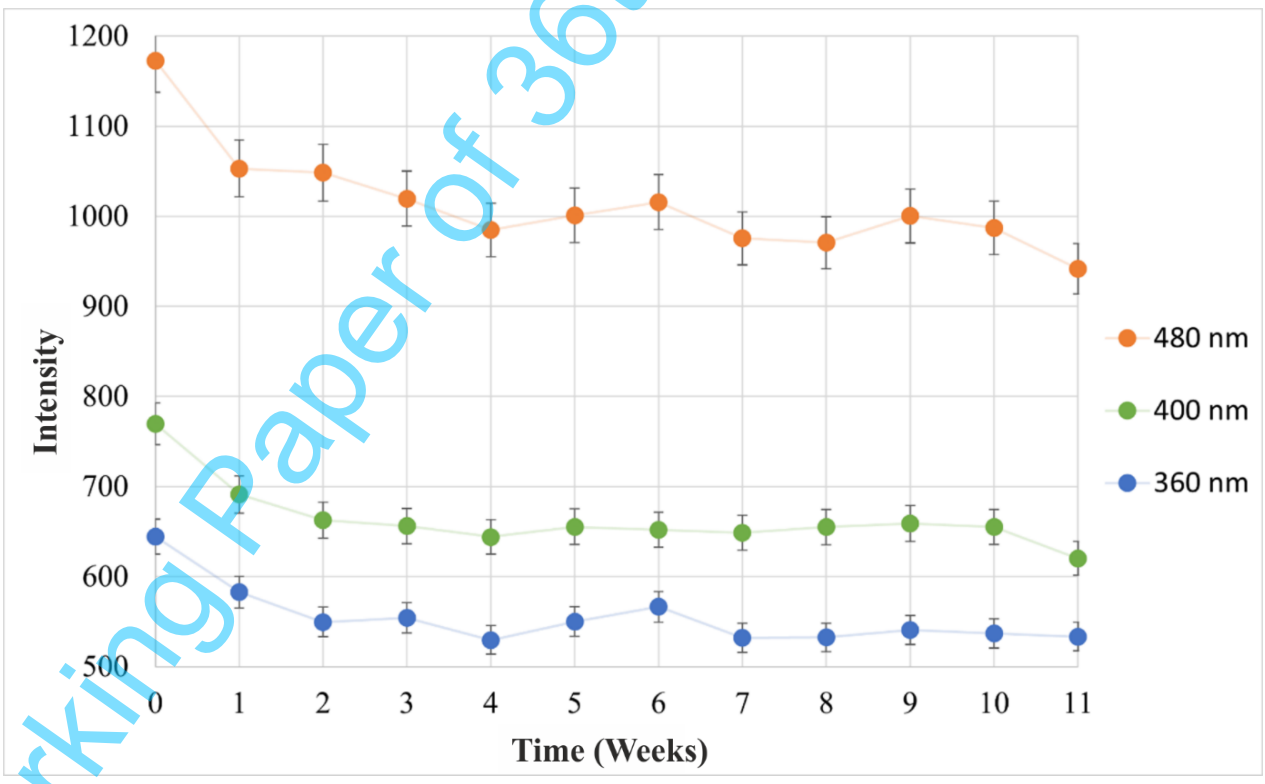

Fig. 3. Dependence of selected wavelengths of the emission spectrum of the male sample M–2 on time (12 weeks).

Unlike the male samples, the luminescence intensity of both female samples increased over time. The increase in intensity lasted for the first 9 weeks, with the most pronounced during the first 3 weeks. A decrease in intensity was recorded during the final 3 weeks. Figure 4 shows selected wavelengths of the emission spectrum for the female sample F–1. It is also possible to notice relatively high values of the luminescence intensity, which is caused by two identical and mutually overlapping prints on the glass slide. In practice, this situation occurs when, for example, a perpetrator leaves multiple prints on a specific object while manipulating it, which subsequently overlap. This overlap can significantly complicate classical dactyloscopic identification, but it is evident from the measurements that, apart from the higher luminescence intensity, the overlapping prints do not affect the shape of the spectrum.

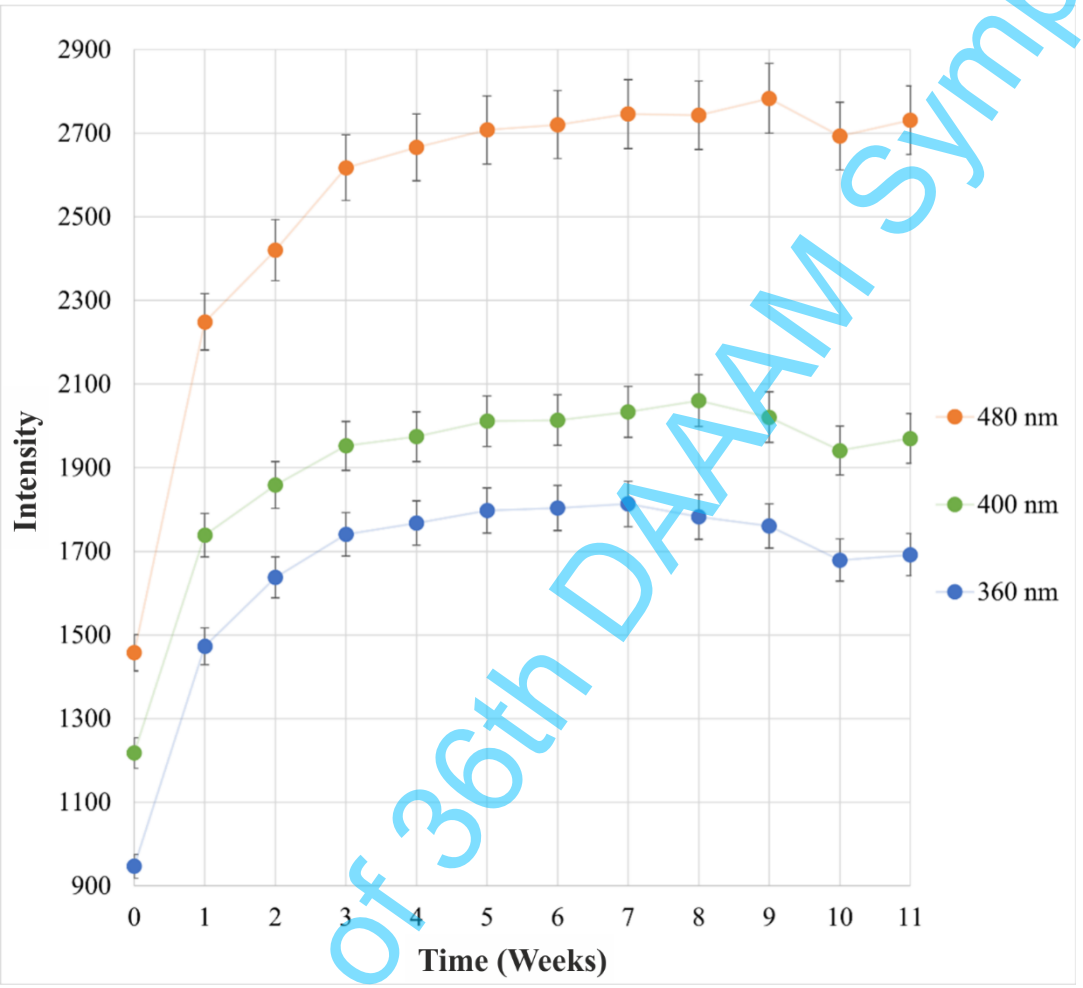

Fig. 4. Dependence of selected wavelengths of the emission spectrum of the female sample F–1 (two overlapping prints) on time.

Selected emission spectra of the female sample F–2 are shown in Fig. 5a. In the range from 350 nm to 430 nm (i.e. approximately in the region of the first peak), a significant change in the luminescence intensity is evident compared to other graphs, specifically its significant decrease. The first peak has practically disappeared and in the range between 380 nm and 410 nm, the emission spectra of all weeks almost overlap. However, the increasing tendency of the luminescence intensity remains, similarly to that of the female sample F–1. The attenuation of the intensity of this sample is caused by the admixture of external contaminants. The print contains trace amounts of cosmetics that got into it when the finger came into contact with the face during the sample collection phase. This is a simulation of a real situation that is relatively common in practice. A latent print is almost never composed only of human sweat and sebum. It also contains various external contaminants, such as the aforementioned cosmetics, varnishes, inks, food residues or gunpowder.
The second peak in the region around 480 nm remains almost unchanged (see Fig. 5b), only the emission spectrum of week 0 is probably slightly affected by contaminants, when a steeper decrease in luminescence intensity is visible in the region from 475 nm to 500 nm. The remaining emission spectra do not contain any more visible changes. Similarly to the sample F–1, the luminescence intensity increases over time.

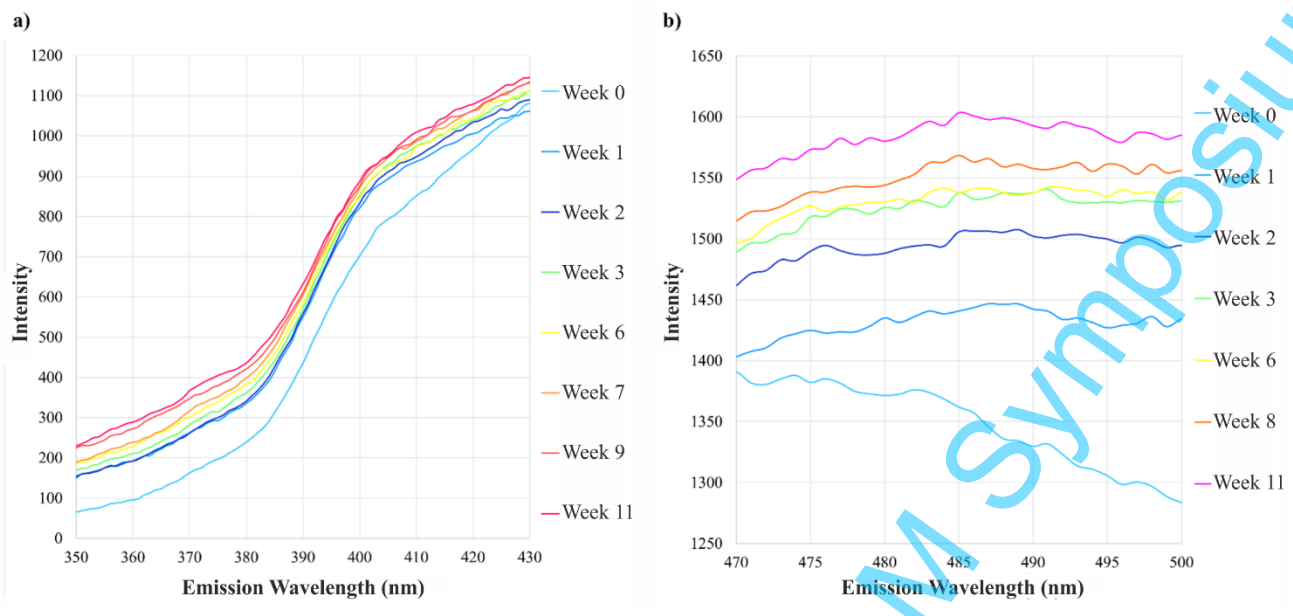

Fig. 5. a) Selected emission spectra of female sample F–2 (containing external contaminants – cosmetics) over time, b) selected emission spectra of female sample F–2 (containing external contaminants – cosmetics) over time (detail of the second peak in the region around 480 nm).

4. Conclusion

In this article, 7 latent fingerprint samples (5 from men, 2 from women) were analyzed for 12 weeks using luminescence spectroscopy to describe the luminescence behavior of the fingerprint over time. Two significant peaks were found in the emission spectrum (in the regions of approximately 360 nm and 480 nm), with the luminescence intensity mainly decreasing over time in male samples and increasing in female samples. It was also found that the amount of material in the fingerprint does not affect the shape of the spectrum itself, but only the value of the luminescence intensity. On the contrary, external contaminants (specifically cosmetics) significantly affect the shape of the spectrum, since absorption occurs at shorter wavelengths. According to the analyzed measurement results, luminescence spectroscopy could potentially be used to estimate the age of latent fingerprints, but the results need to be verified in further studies on a much larger set of samples.

5. Acknowledgments

This work was supported by the Internal Grant Agency of Tomas Bata University under the project No. IGA/CebiaTech/2024/003.

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