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Research Article

Assessment of Nicotine Degradation in Cigarette Smoke under Different Storage Conditions (Light and Duration)

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Nicotine, the primary component of cigarette smoke, is not only addictive but also indirectly contributes to lung diseases by increasing heart rate and blood pressure upon inhalation. Therefore, managing nicotine content in cigarette smoke necessitates accurate quantitative analysis. Nicotine from cigarette smoke is collected using a Cambridge filter, subjected to solvent extraction, and analyzed using instrumental techniques. However, since nicotine is susceptible to light-induced oxidation, losses may occur during pretreatment, reducing result reliability. This study assesses nicotine loss under various lighting conditions and storage durations. Nicotine collected in Cambridge filters is exposed to dark, visible radiation, and UV radiation (254 nm) for different time intervals (0–48 h), and the nicotine content is analyzed and compared. In dark conditions, a 1.6% decline in nicotine concentration occurs after 48 h. With visible radiation, a 9% reduction is observed, while under UV exposure, the concentration decreases by 16.9%. The UV radiation-associated decrease in nicotine concentration is $-0.335\%\ h^{-1}$, exhibiting strong linearity ($R^2 = 0.9465$). Consequently, significant nicotine loss in Cambridge filter-collected samples is influenced by storage duration and lighting conditions. This study's findings can enhance the accuracy of nicotine quantification in cigarette smoke, thereby improving the understanding of nicotine's harmful effects in cigarette smoke.

1. Introduction

Cigarette smoke contains more than 5000 chemicals, including dozens of harmful substances that can adversely affect human health [1, 2]. The World Health Organization estimates that more than 100,000 people die annually from cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer due to smoking [3]. To minimize the damage caused by smoking, cigarette sales must be highly regulated and managed; this requires data on the chemicals in cigarette smoke and their toxicity.

Nicotine, the major component of cigarette smoke, is toxic and addictive; hence, it is used as an indicator for the harmfulness of cigarette smoke. When the human body is exposed to nicotine, it excites or paralyzes the central and peripheral nervous systems. In addition, nicotine constricts intestinal blood vessels, thus leading to an increase in blood pressure [4–6]. Nicotine, which is important for evaluating the toxicity of cigarette smoke, can be easily oxidized when exposed to light or air [7–12]. Typically, nicotine photolysis yields a variety of compounds such as alkaloids, ketones, acetic acid, nicotinic acid, and cotinine, primarily through carbon-to-carbon bond cleavage. In addition, the extent of photodegradation and the type and concentration of byproducts generated can vary with the degree of oxygen exposure and radiation dosage [7–12]. Therefore, in the pretreatment

procedures for the quantitative analysis of nicotine in cigarette smoke (i.e., smoke collection, smoke storage, etc.), loss of nicotine occurs, and consequently, the nicotine concentration may be underestimated.

Cigarette smoke is collected and analyzed by dividing it into particulate and gaseous phases. The particle phase is collected using a Cambridge filter and then subjected to solvent extraction and quantified through an analytical instrument [13–15]. The Cambridge filter, primarily used for capturing particulate matter in cigarette smoke, is a specialized collection medium typically composed of glass fibers [16, 17]. It "traps" particulates as smoke is drawn through it. Its use is a standardized practice in the cigarette industry and scientific research for procuring particulate samples from cigarette smoke [17]. The gaseous phase of the cigarette smoke is quantified by instrumental analysis after sampling with a solvent and pretreatment procedures suitable for the characteristics of the analyte [18–20]. The nicotine collected on the Cambridge filter is physically adsorbed and can be lost rapidly upon exposure to light and air [7–12].

Accurate quantification of nicotine in cigarette smoke is crucial for assessing toxicity and addiction potential. Standard methods for nicotine quantification do not account for potential light-induced oxidation during smoke collection and pretreatment, leading to nicotine loss. Consequently, to achieve precise evaluations, the degree of nicotine loss from light exposure should be considered in the quantification process. In this study, as part of obtaining accurate quantitative data on nicotine in cigarette smoke, the nicotine loss was assessed under different light conditions. After collecting nicotine standard samples or cigarette smoke on the Cambridge filters, the nicotine loss was evaluated by exposure to dark, visible radiation, and ultraviolet (UV) radiation conditions for a certain period of time. Sunlight comprises UV, visible, and infrared radiations. This study focused on UV radiation, which has a strong energy that can influence nicotine loss, and visible radiation, known for its material absorption and reflection characteristics, as light exposure conditions. Infrared radiation, which affects molecular motion and vibration in gases and is related to thermal energy, was excluded. In indoor spaces where cigarette smoke is collected and analyzed, sunlight's impact is expected to be less than outdoors, resulting in minimal UV exposure. Nonetheless, UV radiation was included as an exposure condition, considering the small amount of UV emitted by indoor lighting [21–23]. Conventional fluorescent lamps, at a distance of 1.5 m, emit UV-A and UV-C at 0.3 and 0.05 $W\,m^{-2}$, respectively [24]. This emission is approximately 2 to 10 times lower than the UV-A level of outdoor sunlight measured between 11 : 00 and 15 : 00, though it remains a nonnegligible amount (UV-A exposure in sunlight ranges from 0.724 to 7.147 $W\,m^{-2}$) [25]. Moreover, due to nicotine's sensitivity to light-induced oxidation in cigarette smoke, even slight exposure to UV radiation could result in nicotine loss. The experiment investigating nicotine loss was thus performed under dark, visible radiation, and UV radiation conditions.

2. Experimental

2.1. Experiment Schemes. In this study, nicotine samples were collected using a 44 mm Cambridge filter (GE Healthcare, Buckinghamshire, UK), and the extent of nicotine loss under varying light conditions and exposure times was evaluated (Table 1). Nicotine samples were prepared using nicotine solution and cigarette smoke samples and were exposed to dark and visible radiation (Bioultra6, Telstar Technologies, Spain) and UV radiation (TN-4LC, Korea Ace Scientific, Republic of Korea) conditions (all ambient light was screened out). The nicotine samples were exposed to each light condition for 0, 6, 12, 24, and 48 h. The nicotine collected on the filter was extracted in methanol and subsequently analyzed by gas chromatography (GC; GC-2010, Shimadzu, Japan)-mass spectrometry (MS; GCMS-QP2010 ultra, Shimadzu, Japan).

The duration required for cigarette smoke generation and collection typically ranges from 10 min to 1 h, depending on the type of cigarette, and is based on 30 cigarettes. The desiccation process for the moisture-laden Cambridge filter postcollection spans approximately 6-24 h [26, 27]. Furthermore, preliminary treatment of the nicotine sample (i.e., solvent extraction, solvent removal, concentration, etc.) demands at least an additional 3 h [17]. Thus, the established light exposure times for nicotine were determined in consideration of the cumulative time required for smoke generation, collection, and sample preparation. Further details regarding the experimental procedure for each type of nicotine sample are provided in Table 1, Table S1, and Figure 1. The chromatograms of the nicotine solution and cigarette smoke samples analyzed are shown in Figure 2.

2.1.1. Nicotine Standard (Experimental Stage 1). Reagent-grade nicotine (20 μL) was injected into the Cambridge filter and then placed in a sealed 50 mL transparent polypropylene conical tube (BD Falcon^{TM}, USA). The conical tube had a negligible effect on both visible and UV radiation, attenuating less than ±0.12% of the irradiance. Thirty-nine samples were prepared following the aforementioned procedure. Each of the 12 samples was exposed to dark, visible radiation, and UV radiation for 6, 12, 24, and 48 h. The remaining three samples served as blank samples for calculating a reference concentration. The reference concentration was used to assess nicotine recovery based on the light exposure conditions. After light exposure, the nicotine in the filter was extracted with 10 mL methanol and analyzed using the GC-MS system.

2.1.2. Cigarette Smoke (Experimental Stage 2). 3R4F reference cigarettes were used to produce mainstream cigarette smoke (University of Kentucky, Lexington, KY, USA). The mainstream smoke is the smoke that a smoker inhales directly into their lungs when they puff on a cigarette. The cigarettes were conditioned at 22 ± 1°C and 60 ± 3% relative humidity for a minimum of 48 h, in accordance with ISO 3402 [28]. Subsequently, the cigarettes were smoked on a cigarette smoke generator (SG-300, Sibata, Japan), following the HCI regimen conditions [29]. The puff flow, puff

Table 1: Basic experimental information for this study.

	Experimental stage 1	Experimental stage 2
Sample type	Nicotine solution	3R4F reference cigarette
Sampling condition	Spiking[a]	HCI regimen[b]
Light condition	(1) Dark (2) Visible radiation (i) Lamp: fluorescent lamp (Bioultra6, Telstar Technologies, Spain) (ii) Measuring device: light meter (LX-1108, Lutron Electronic Enterprise Co., Ltd., Taiwan) (iii) Irradiance: 8.12 ± 0.08 W m^2 (about 1028 ± 10.1 Lux) (iv) Distance between light source and sample: 0.25 m (3) UV radiation (254 nm) (i) Lamp: UV lamp (TN-4LC, Korea Ace Sci., Republic of Korea) (ii) Measuring device: UVC light meter (UVC-254SD, Lutron Electronic Enterprise Co., Ltd., Taiwan) (iii) Irradiance: 0.28 ± 0.01 W m^2 (iv) Distance between light source and sample: 0.25 m	
Container temperature (°C)	25 ± 1	
Nicotine concentration (ng μL^{-1})	40.4[c]	80.4[c]
Sampler	44 mm Cambridge filter	
Exposure time (h)	0, 6, 12, 24, and 48	(1) Dark and visible: 48 (2) UV: 0, 6, 12, 24, and 48
Sample pretreatment	Methanol extraction (10 mL)	

[a]20 μL reagent-grade nicotine (purity, ≥99%) was spiked on the Cambridge filter. [b]Puff volume: 55 mL; puff interval: 30 s; puff duration: 2 s. [c]Experimental stage 1: theoretical concentration; experimental stage 2: mean analytical concentration.

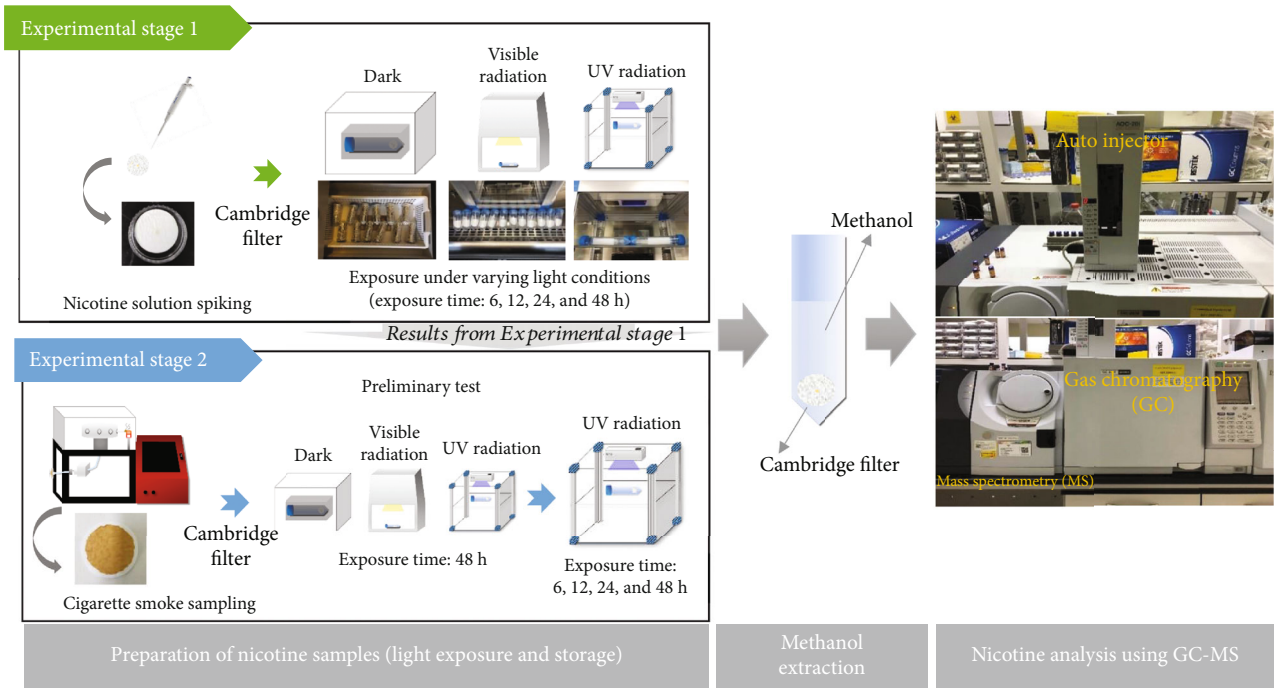

Figure 1: Experimental design for assessing nicotine degradation under different storage conditions (type and duration of light exposure).

duration, puff volume, filter vent blocking, and interpuff period were set to 1.65 L·min^{-1}, 2 s, 55 mL, 100%, and 30 s, respectively. The Cambridge filter was weighed pre- and postcigarette smoke collection to determine the total particulate matter (TPM) concentration (mg·cig^{-1}) in the smoke. Twenty-one samples of Cambridge filters collecting mainstream cigarette smoke were prepared and sealed in 50 mL conical tubes. These samples were exposed to dark ($n = 3$), visible radiation ($n = 3$), and UV ($n = 12$) conditions, with the remaining three samples used as blank samples for

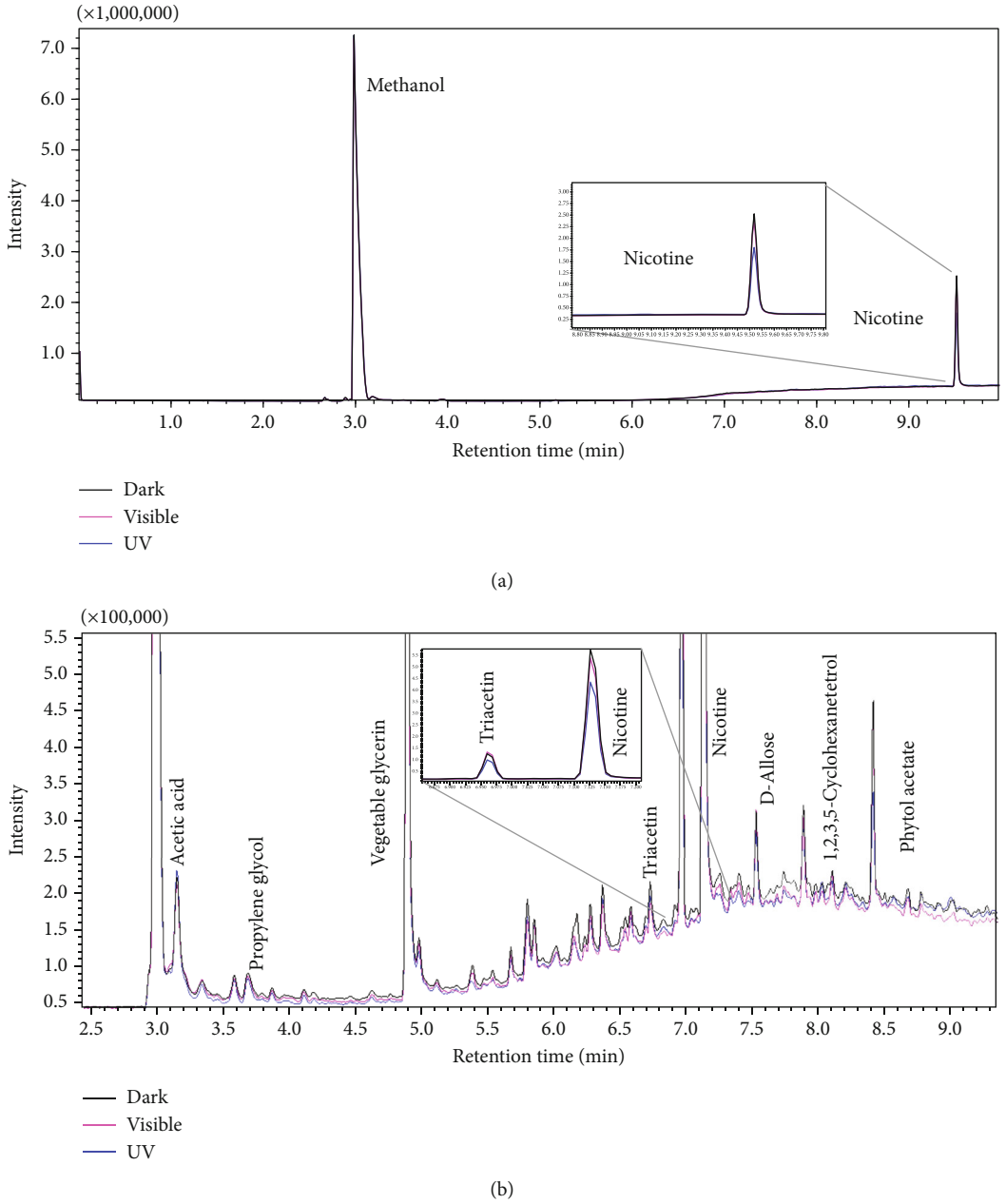

Figure 2: Chromatograms of nicotine samples exposed to various light conditions for 48 h using (a) nicotine solution and (b) cigarette smoke.

calculating the reference concentration. Exposure times of 48 h were used for Cambridge filter samples exposed to dark and visible radiation, whereas exposure times of 6, 12, 24, and 48 h were used for samples exposed to UV radiation. The nicotine in the light-exposed filter was extracted using 10 mL methanol and analyzed with the GC-MS system.

2.2. Preparation of Liquid Nicotine Standards. The reagent-grade nicotine (purity, 99%) was purchased from Sigma-Aldrich (USA). In addition, the high-pressure liquid chromatography- (HPLC-) grade methanol for dilution of the reagent-grade chemical (RGC) was purchased from Honeywell International, Inc. (USA). The liquid standards were prepared by a two-step gravimetric dilution of RGC using the methanol. The primary standard (PS) was prepared by mixing the RGC with methanol on nicotine concentrations of 9,999 ng·μL^{-1}. The first liquid-working standard (1st L-WS) was then made by mixing PS (40 μL) with methanol (1,960 μL) in a 2 mL vial, thus resulting in a concentration of 200 ng·μL^{-1}. The final liquid-working standards (final L-WS) for the calibrations were prepared by diluting the 1st L-WS with methanol to yield six concentrations of nicotine: 1, 5, 10, 20, 50, and 100 ng·μL^{-1}. Calibration curves were obtained in experimental stages 1 and 2 using different concentrations of the final L-WS. Detailed information on the preparation of the liquid-working standards is presented in Table S2.

2.3. Instrumental System. All nicotine-containing samples, including the nicotine solution and cigarette smoke, were analyzed using a GC-MS system, with different instrument

conditions used for each sample type. The liquid standards were analyzed in the same manner as each sample. In the analysis, nicotine samples were injected into the GC injector using the autosampler (AOC-5000, Shimadzu, Japan). Subsequently, the target analyte was transferred to the capillary column (Agilent, USA) for separation using a carrier gas (He, >99.999%). The analyte was analyzed by adjusting the oven temperature under ramping conditions to separate it; the separated analyte was subsequently detected by the MS system. The target analyte was quantified in total ion chromatogram mode in a mass range of 35–600 m/z. In the case of the cigarette smoke samples, extracted ion chromatogram mode was applied to the minimized interfaces using significant ions identified from the spectrum of nicotine (Table S1). Detailed setting information of the instrument conditions is presented in Table S3.

2.4. Calibration Analysis of the Nicotine Standards. The nicotine collected on the Cambridge filter was quantified using calibration curves derived from the final L-WS for experimental stages 1 and 2. The calibration data comprises the slope (ng^{-1}), intercept, coefficient of determination (R^2), limit of detection (LOD, pg), and actual detection limit (ADL, ng) [17].

The calibration curve slope and intercept for experimental stage 1, which involved quantitative analysis of the nicotine solution, were 116,364 ng^{-1} and −87,739, respectively. In addition, the calibration curve exhibited good linearity ($R^2 = 0.9999$) and had a very low LOD value of 13.7 pg. However, the ADL value, considering the negative intercept of the nicotine calibration curve, was 0.75 ng, which is higher than that of the LOD. Nevertheless, quantifying the analytical mass of nicotine in the nicotine solution sample above the ADL level presented no issues. The nicotine calibration curve for experimental stage 2, which quantified cigarette smoke, had a slope of 50,627 ng^{-1} and intercept of −268,039. The calibration curve exhibited excellent linearity ($R^2 = 0.9982$), and its LOD and ADL values were 3.64 pg and 5.29 ng, respectively. The analytical mass of nicotine in the cigarette smoke sample was all analyzed at a higher concentration level than the second point of the calibration curve, and the ADL value is the analytical mass level of the first point of the calibration curve. Table S4 provides detailed results of the two calibration experiments for experimental stages 1 and 2.

3. Results and Discussion

3.1. Assessment of Nicotine Recovery under Light Exposure Conditions Using Nicotine Solutions (Experimental Stage 1). Experimental stage 1 evaluated the relative recovery of nicotine lost under different light conditions and exposure times using nicotine solution (Figure 3). The relative recovery of nicotine was calculated based on the nicotine mass of the blank sample analyzed immediately after injecting the reagent-grade nicotine into the Cambridge filter.

$$\text{Relative recovery (\%)} = \frac{\text{nicotine mass (ng) of nicotine solution sample exposed to lights}}{\text{nicotine mass (ng) of nicotine solution blank sample}} \times 100 \quad (1)$$

In the dark samples, the relative recovery of nicotine decreased at a rate of −0.378% h^{-1} as the storage time increased, and the linearity was excellent ($R^2 = 0.9689$). Until 6 h after storage, almost no loss of nicotine occurred in the dark sample (relative recovery = 101 ± 1.26%); however, the relative recovery decreased significantly to 83.4 ± 4.72% at 48 h. This suggests that nicotine collected on the Cambridge filter was lost in proportion to the storage time, regardless of light exposure. The nicotine loss in the visible radiation sample was similar to that in the dark sample. The relative recovery reduction rate of the visible radiation sample according to the exposure time was −0.3334% h^{-1}, and the R^2 value was good (0.9351). The relative recovery value of the visible radiation sample was 100 ± 1.51% after 6 h under visible radiation exposure, and it decreased to 84.3 ± 3.44% after 48 h, which is similar to that of the dark sample. Thus, no significant loss of nicotine due to visible radiation exposure was observed. The relative recovery of nicotine in the UV radiation sample differed from that in the dark and visible radiation samples. After exposure to UV radiation for 6 h, the relative recovery value of nicotine was 90.5 ± 4.98%, thus indicating an additional loss of approximately 10% compared with the dark sample. After 48 h of UV exposure, the relative recovery decreased to 70.5 ± 11.7%, and the relative recovery reduction rate was −0.5255% h^{-1}. The reduction rate of the relative recovery value of the UV radiation sample was 39.0% and 57.6% smaller than that of the dark and visible radiation samples, respectively. The intercept value of the nicotine reduction rate was 94.5%, thus indicating that nicotine loss occurs even with short exposure times of less than 6 h.

Nicotine is susceptible to oxidative losses caused by light and air [7–12]. In experimental stage 1, nicotine loss by light exposure was significant only in the UV radiation samples, and the loss occurred within a relatively short period (within 6 h). Additionally, even when the Cambridge filter, from which nicotine was collected, was sealed and stored, a certain level of nicotine loss occurred with increasing storage time, regardless of light exposure. This may be attributed to nicotine interaction with the Cambridge filter in the nicotine solution and volatilization into the headspace of the sealed container [30, 31].

3.2. Nicotine Recovery Assessment in Cigarette Smoke under UV Radiation Exposure Conditions (Experimental Stage 2). During experimental stage 2, the relative loss of nicotine under UV light exposure conditions was examined using

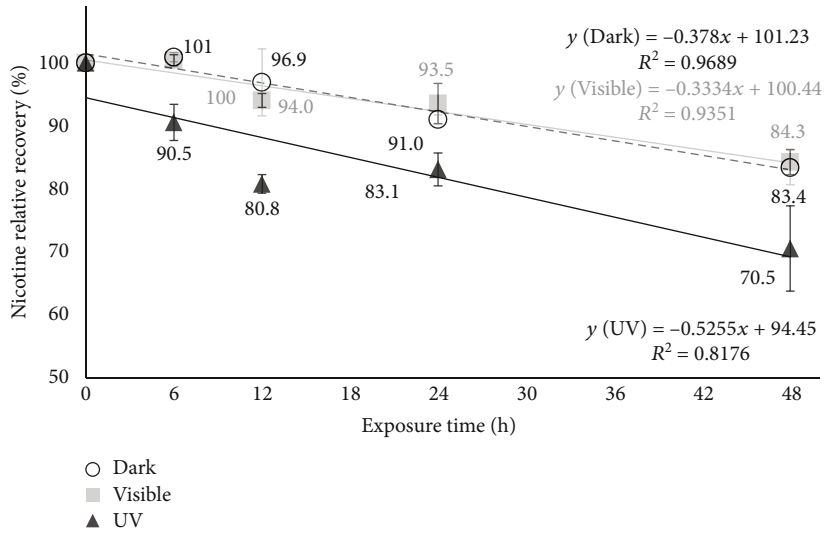

Figure 3: Variation in nicotine recovery on Cambridge filter impacted by light type and exposure time (using nicotine solution).

cigarette smoke samples (Figure 4). Based on the results from the experimental stage 1, the largest nicotine loss was observed under UV radiation exposure. Therefore, in the experimental stage 2, the loss of nicotine in cigarette smoke was evaluated specifically under UV radiation conditions. The relative recovery of nicotine was determined based on the concentration of the blank sample of nicotine in cigarette smoke collected with a Cambridge filter and analyzed immediately prior to UV radiation exposure.

$$\text{Relative recovery (\%)} = \frac{\text{nicotine fraction (\%) of cigarette smoke sample exposed to UV radiation}}{\text{nicotine fraction (\%) of cigarette smoke blank sample}} \times 100$$
$$\text{Nicotine fraction (\%)} = \frac{\text{nicotine concentration } \left(\text{mg} \cdot \text{cig}^{-1}\right)}{\text{total particulate matter concentration } \left(\text{TPM, mg} \cdot \text{cig}^{-1}\right)} \times 100 \quad (2)$$

To reduce the error in evaluating nicotine loss caused by variation in the mass concentration of cigarette smoke collected by the Cambridge filter, the relative recovery of nicotine was defined as the fraction of nicotine concentration in the TPM concentration of cigarette smoke. The average TPM concentration of the blank sample was 17.7 ± 0.81 mg·cig^{-1}, and the nicotine fraction among the TPM concentration was $9.55 \pm 0.51\%$.

The relative recovery of nicotine in cigarette smoke collected on the Cambridge filter decreased with increasing UV radiation exposure time. The reduction rate of relative recovery was -0.3347% h^{-1}, and the reduction line exhibited good linearity ($R^2 = 0.9465$). Nicotine loss was 4.22% after 6 h of UV radiation exposure and increased to 11.4% after 24 h. After exposure for 48 h, the relative recovery was $83.1 \pm 0.17\%$. These results confirm that nicotine loss increased as the exposure time to UV radiation increased. The concentration of TPM in cigarette smoke samples ranged from 16.5 to 17.9 mg·cig^{-1}, with a nicotine fraction of 7.93–9.55%.

Furthermore, the relative recoveries of additional components present in the cigarette smoke samples, such as propylene glycol, vegetable glycerin, and triacetin, were evaluated depending on UV radiation exposure time, using peak area. Propylene glycol and vegetable glycerin did not exhibit any significant change in relative recovery after 48 h of UV radiation exposure. However, triacetin exhibited a steady decrease in relative recovery as the exposure time of UV radiation increased (relative recovery reduction rate = -0.3552% h^{-1}, $R^2 = 0.9025$). Despite this, the relative recovery value of triacetin in cigarette smoke exhibited a high deviation in the UV radiation exposure experiment, averaging at 8.64%. Thus, this study confirmed that UV radiation exposure and, particularly, elapsed time of exposure caused the loss of nicotine in cigarette smoke.

3.3. Comparison of Nicotine Recovery in Nicotine Solution and Cigarette Smoke under Different Light Conditions. Nicotine loss due to UV radiation exposure was confirmed in both experimental stages 1 and 2 (Figure 5). However, the degree of nicotine loss varied depending on the type of nicotine sample (nicotine solution vs. cigarette smoke). The relative recovery reduction rate of nicotine by UV radiation

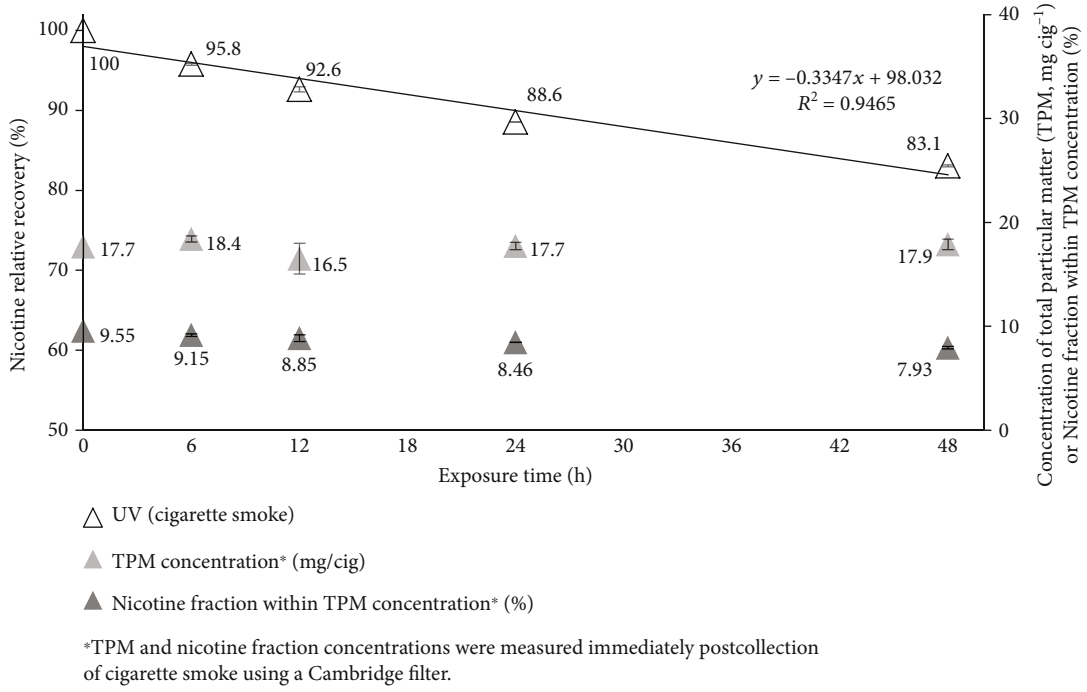

Figure 4: Variations in nicotine recovery with varying UV radiation exposure durations, TPM concentrations of cigarette smoke, and nicotine fraction within TPM concentrations.

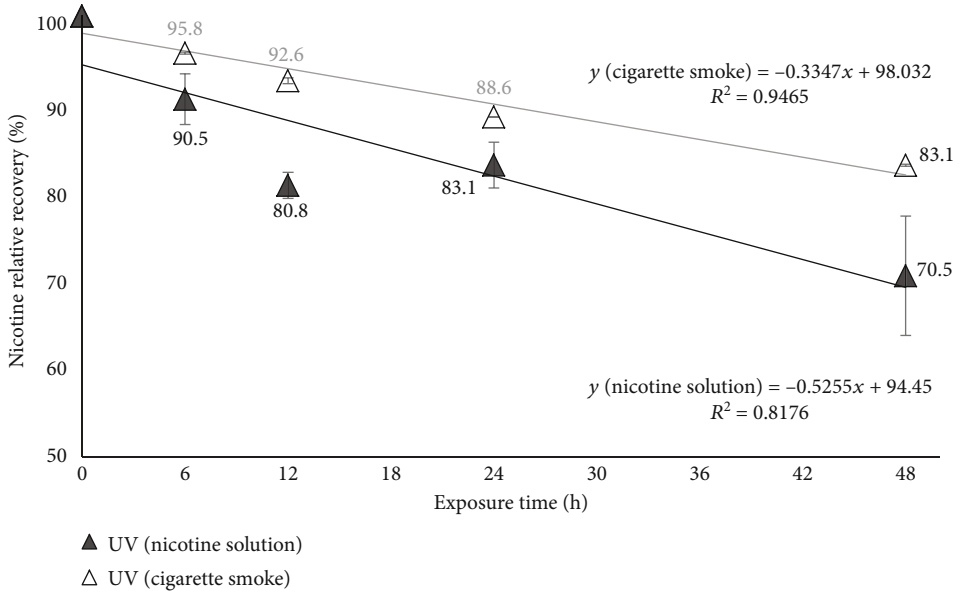

Figure 5: Comparison of the relative recovery of nicotine between nicotine solution and cigarette smoke under UV radiation exposure.

was higher for the nicotine solution (−0.5255% h^{-1}) than that for cigarette smoke (−0.3347% h^{-1}). Nicotine relative recovery after 48 h of UV radiation exposure was lower for the nicotine solution (70.5 ± 11.7%) than for cigarette smoke (83.4 ± 0.17%). Although interactions, such as nicotine and physical adsorption reactions, could reduce the loss of various organic compounds in the Cambridge filter collected from cigarette smoke, significant nicotine loss was still observed with increased UV radiation exposure and sample storage time. This highlights the need for rapid sample pretreatment for accurate quantitative evaluation of nicotine in cigarette smoke.

The relative recovery of nicotine in nicotine solution and cigarette smoke samples exposed to light for 48 h was compared (Figure 6). Cigarette smoke recorded lower relative nicotine recovery under dark, visible radiation, and UV radiation exposure conditions compared with the nicotine solution. The dark and visible radiation conditions exhibited a 7–15% higher relative recovery value in the cigarette smoke sample than the nicotine solution sample. Nicotine loss

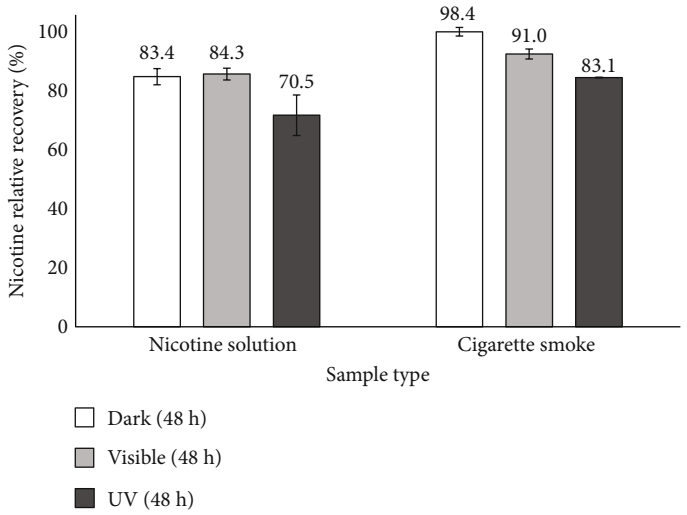

Figure 6: Comparison of the relative recovery of nicotine between nicotine solution and cigarette smoke under different light exposures after 48 h.

due to light exposure and elapsed storage time was small in the cigarette smoke sample (relative recovery under dark conditions was 98.4 ± 2.48% for cigarette smoke and 83.4% for nicotine solution). The nicotine relative recovery between the dark and visible samples in cigarette smoke presented a difference of approximately 7%. Thus, in contrast to the nicotine solution, nicotine loss due to visible radiation also occurs in the cigarette smoke sample. In summary, the extent of nicotine loss in nicotine solution and cigarette smoke samples varies depending on storage duration and light exposure type.

3.4. Study Significance, Limitations, and Further Research Requirements. This study assessed nicotine loss under various light exposures, as a step towards accurate quantification of nicotine concentrations in cigarette smoke. By comparing nicotine standards with cigarette smoke, we confirmed the specific impact of environmental sample components on nicotine degradation. However, this work is limited by its inability to characterize nicotine loss in relation to the precise light irradiation levels. The irradiation exposure of samples in an indoor lab environment, where cigarette smoke is generated and pretreated, may vary. As a consequence, subsequent research should assess nicotine degradation based on a range of irradiation doses. Additionally, future studies should consider establishing a framework for evaluating the light-induced degradation of other major chemical substances apart from nicotine.

4. Conclusions

This study is aimed at assessing nicotine loss under various light conditions and exposure durations. Nicotine samples, prepared using nicotine solution and cigarette smoke, were exposed to dark, visible, and UV radiation conditions for up to 48 h. Nicotine loss was evaluated by quantifying the nicotine collected on the Cambridge filter using GC-MS. Evidently, nicotine loss due to light exposure was significant only in the UV radiation samples, and the loss occurred within a relatively short time (within 6 h). Even when the Cambridge filter, from which nicotine was collected, was sealed and stored, a certain level of nicotine loss was observed with increasing storage time, regardless of the light exposure. Both nicotine solution and cigarette smoke samples experienced UV-induced loss, though the extent varied between sample types. Cigarette smoke samples showed less nicotine loss due to light exposure and storage time, likely because of adsorption reactions with various organic compounds in the smoke. Nonetheless, prompt pretreatment is essential for accurate nicotine quantification, as substantial nicotine loss occurs during storage of cigarette smoke samples. If the pretreatment time surpasses 6 h, the nicotine concentration should be adjusted to account for nicotine loss, as per this study's findings. Moreover, when storing cigarette smoke samples for extended periods, it is advised to seal the samples and keep them in a dark room without exposure to light, not exceeding 48 h.

This study proposes that by controlling light exposure during cigarette smoke sample collection, nicotine quantification can be improved. Incorporating our findings into standardized methods could enhance nicotine evaluation accuracy. Consequently, by accurately quantifying nicotine, a crucial factor in cigarette product management, our study may facilitate the development of guidelines for safer cigarette usage.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Young-Ji An did the formal analysis, methodology, investigation, data curation, and writing of the original draft. Yong-Hyun Kim did the conceptualization; investigation; writing, which includes review and editing; and supervision.

Acknowledgments

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Supplementary Materials

Table S1: basic information of nicotine and methanol (solvent). Table S2: preparation of the nicotine-working standards. Table S3: operational conditions for the nicotine analysis. Table S4: calibration results for the GC-MS system using final L-WS. *(Supplementary Materials)*

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