East African Journal of Health and Science
eajhs.eanso.org
Volume 7 Issue 1, 2024
Print ISSN: 2707-3912 | Online ISSN: 2707-3920
Title DOI: https://doi.org/10.37284/2707-3920

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Comparative Analysis of Particulate Content in Cigarette Smoke: Implications for Respiratory Health of Active and Passive Smokers

Umar Mawegye[1], Peter Olusakin Oladoye[2] & Ivan Oyege[1,2]*

[1] Busitema University, P. O. Box, 236, Tororo, Uganda.
[2] Florida International University, Miami, FL, USA.
*Author ORCID ID: https://orcid.org/0000-0003-4410-5640; Email: ioyeg002@fiu.edu

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

Date Published:

04 June 2024

Keywords:

Health Issues, Cancer, Chemical, Cigarette, Composition.

ABSTRACT

Cigarette smoke is a heterogeneous mixture of gases, uncondensed vapours and liquid particulate matter with millions of particles per cubic centimetre. Cigarette smoking can negatively impact the health of smokers and non-smokers. As such, there is a need to constantly assess the quantity of toxic substances emanating from smoking cigarettes. This study investigated the total amount of particulates to which smokers and non-smokers are exposed and identified the chemical compositions of total particulates in cigarette smoke from some selected cigarette brands obtained from Nagongera town council shops in Uganda. To achieve this, we made use of an apparatus that mimics the smoking process of a human being and a passive smoker by connecting this set to another set-up containing a cigarette to be burnt. Qualitative tests for chemical composition were conducted using conventional tests for organic functional groups. It was found that Sportsman and locally cured tobacco had the highest total particulate content (116 mg and 73 mg) while Supermatch and Safari had the lowest total amount of particulates 45.5 mg and 40.3 mg, respectively. The investigated cigarettes were found to be composed of the following functional groups: aromatics, phenolics, nitrosamines and alkaloids. However, aldehyde and ketonic groups were not identified. The cigarette composition results in cigarette smoke composition either in the mainstream or the side stream causing disease to a respiratory system like lung cancer, emphysema and cancers in the mouth cavity and oesophagus. This study confirmed that the brand of cigarette smoked could determine the quantity of particulate smokers and non-smokers of cigarettes might be exposed to and that functionalities and/or chemical compositions vary amongst Ugandan cigarette brands.

APA CITATION

Mawegye, U., Oladoye, P. O. & Oyege, I. (2024). Comparative Analysis of Particulate Content in Cigarette Smoke: Implications for Respiratory Health of Active and Passive Smokers Review *East African Journal of Health and Science*, *7*(1), 268-275. https://doi.org/10.37284/eajhs.7.1.1969.

CHICAGO CITATION

Mawegye, Umar, Peter Olusakin Oladoye and Ivan Oyege. 2024. “Comparative Analysis of Particulate Content in Cigarette Smoke: Implications for Respiratory Health of Active and Passive Smokers”. *East African Journal of Health and Science* 7 (1), 268-275. https://doi.org/10.37284/eajhs.7.1.1969.

HARVARD CITATION

Mawegye, U., Oladoye, P. O. & Oyege, I. (2024) “Comparative Analysis of Particulate Content in Cigarette Smoke: Implications for Respiratory Health of Active and Passive Smokers”, *East African Journal of Health and Science*, 7(1), pp. 268-275. doi: 10.37284/eajhs.7.1.1969.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

IEEE CITATION

U., Mawegye, P. O., Oladoye & I., Oyege, "Comparative Analysis of Particulate Content in Cigarette Smoke: Implications for Respiratory Health of Active and Passive Smokers", *EAJHS*, vol. 7, no. 1, pp. 268-275, Jun. 2024.

MLA CITATION

Mawegye, Umar, Peter Olusakin Oladoye & Ivan Oyege. "Comparative Analysis of Particulate Content in Cigarette Smoke: Implications for Respiratory Health of Active and Passive Smokers". *East African Journal of Health and Science*, Vol. 7, no. 1, Jun. 2024, pp. 268-275, doi:10.37284/eajhs.7.1.1969.

INTRODUCTION

Cigarette smoking is a widespread habit in our society (Ussher et al., 2014) and the social, political, aesthetic and medical issues resulting from cigarette smoking have affected smokers and non-smokers in the same way (Gowing et al., 2015). According to the American Lung Association, cigarette smoking is the primary cause of lung cancer (Addolorato et al., 2016) and emphysema (Jou et al., 2019) which occurs when alveoli walls begin to break down. Also, tobacco smoke has been documented to cause numerous diseases such as asthma, bronchitis, heart diseases, high blood pressure, stroke, stomach ulcers and, many cancers such as cancer of the lungs, throat and mouth (Lei et al., 2023). Tobacco smoking can also increase complications of tuberculosis (TB), diabetes and HIV/AIDS (Mrigpuri et al., 2021).

In Uganda, 26% of deaths are due to cancers of the respiratory system and 14.0% of deaths due to other respiratory diseases were attributable to tobacco smoking (World Health Organization, 2011). Statistical data provided by WHO indicated that 17.2%, 2.6% and 9.9% of males, females and both sexes, respectively, in Uganda are currently smoking tobacco, respectively (World Health Organization, 2011). Further, it is important to highlight that many organic and inorganic chemicals in the aerosol (volatile, and particulate phases) of cigarette and tobacco smoke appear to contribute to the toxicity of the smoke to the respiratory system. Examples are hydrocarbons, aldehydes, ketones, organic acids, phenols, cyanides, acrolein, and nitrogen oxides (Hashizume et al., 2023). Some components contribute to the development of chronic mucus hypersecretion in the central airways, whereas others play a greater role in the production of small airway abnormalities and emphysematous injury to the peripheral air sacs. Oxidizing agents in smoke inhibit the enzymes that defend against the destruction of lung elastin (Hong et al., 2022).

In view of the prevalence of cigarette smoking in Uganda, there is a great need to provide information about aerosols in smoke by ascertaining the particulate content smokers and non-smokers are exposed to. Therefore, this study is targeted at determining the particulate content in cigarette smoke from selected cigarette brands common on the market in Uganda. Specifically, the study aimed to determine the particulate content in cigarette smoke and to test for the chemical composition of cigarette smoke particulates with carcinogenic effects.

MATERIALS AND METHODS

Experimental Setup

The experimental setup consisted of a Humboldt vacuum aspirator, Welch vacuum pressure pump, Pyrex Buchner flasks, rubber tubing, glass funnel, glass tubing, filter papers, retort stand, and an analytical balance (Ohaus Pioneer). The diagram of the setup is shown in *Figure 1*.

Chemicals and Cigarettes

Reagent grade chemicals used in the study; Ammonia solution, chloroform, Mayer's reagent, Iron (III) chloride, sodium nitrite, 2,4-dinitrophenylhydrazine, Fehling's solution (A+B), hydrochloric acid, nitric acid, and sulfuric acid. Additionally, four (4) commercially available cigarette brands on the Uganda market Safari, Sportsman, Super Match, Rex, and locally cured tobacco (hereafter called local), were used for the study, as shown in *Figure 2*. The locally cured tobacco was made by rolling 3 g of tobacco on a piece of paper.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

Figure 1: Set-up used for the smoking apparatus

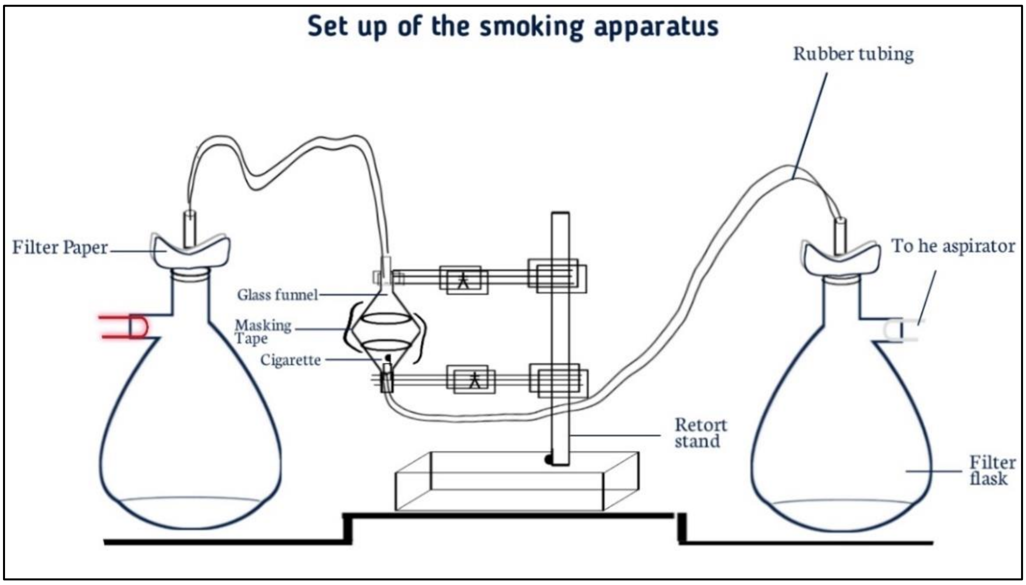

Figure 2: Ugandan cigarette brands considered: (A) Super Match; (B) Sportsman; (C) Rex and (D) Locally cured tobacco.

Determination of Particulate Content in Cigarette Smoke

Two filter papers (Whatman no. 1) were carefully labelled as "1" for mainstream smoke and "2" for second-hand smoke. Each filter paper was weighed using an analytical balance (Ohaus Pioneer), with masses recorded. Filter paper 1 was attached to the Buchner flask connected to the smoker, while filter paper 2 was attached to the Buchner flask connected to the non-smoker. The flasks were sealed with rubber stoppers and connected to vacuum pumps (Welch vacuum pressure pump) via rubber tubing. Each cigarette brand was individually weighed, and a mark was made at 5 cm from the burning end using a pencil. The burning end of the cigarette was inserted into the funnel attached to the smoker's flask, which was connected to the vacuum aspirator. The cigarettes were lit and allowed to burn until reaching the marked point. During the burning process, the vacuum pump was alternated on for 10 seconds and off for 5 seconds. After the cigarettes burned up to the mark, the vacuum pump was disconnected, and the aspirator

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

(Humboldt vacuum aspirator) was left on for 2 minutes to collect all the second-hand smoke before disconnecting the vacuum pump. The two filter papers were gently removed from the flasks, and their weights were measured. The remaining unconsumed portion of the cigarette was also weighed, and all relevant data were recorded. Proper disposal measures were taken for the filter papers and cigarette remnants, ensuring complete extinguishing of the cigarettes. The funnels were cleaned using tissue paper to remove any solid residue from the burned cigarettes. This process was repeated for each cigarette brand in the study. The percentage particulate content per cigarette brand, TPM in mg/g of tobacco or cigarette, percentage TPM in mg/ g of cigarette and total TPM in mg/g of cigarette are calculated using equations (1), (2), (3) and (4), respectively.

The percentage particulate content per cigarette brand = $\frac{Mass\ of\ particulate}{mass\ of\ cigarette\ brunt} X\ 100$ (1)

TPM in mg/g of tobacco or cigarette = $\frac{\text{mass of TPM in mg}}{\text{mass of burnt cigarette in g}}$ (2)

Percentage TPM in mg/ g of cigarette = $\frac{\text{mass of TPM in mg}}{\text{mass of cigarette burnt in mg}} X\ 100$ (3)

Total TPM in mg/g of cigarette = $\text{mass of TPM for active smoker in mg/g} + \text{mass of TPM for passive in mg/g}$ (4)

Analysis of Particulates in Cigarette Smoke

To analyse the particulates, present in the cigarette smoke, the following tests were conducted using previously described qualitative test protocols (Schmid et al., 1986; Sutoyo et al., 2021; TV & Table, 1921).

Test for Polycyclic Aromatic Hydrocarbons

A chloroform-aluminium test was performed by heating 0.2 g of $AlCl_3$ in a boiling test tube until it sublimed and adhered to the tube's walls. Then, 2 mL of the sample in $CHCl_3$ was carefully introduced along the sides of the test tube, and the resulting colour upon contact with $AlCl_3$ was observed. The presence of red, orange, blue, or green colours indicated the presence of aromatic hydrocarbons.

Test for Alkaloids

Mayer's reagent was prepared by dissolving 0.136 g of mercuric chloride in 10 mL of distilled water (solvent A). Separately, 0.5 g of potassium iodide was dissolved in 1 mL of distilled water (solvent B). Solvent A and solvent B were mixed and allowed to stand.

For the alkaloid test, the test solution in a test tube was treated with ammonia solution and left to stand for a few minutes. Then, chloroform was added, and the mixture was shaken, filtered, and treated with Mayer's reagent. The formation of a cream-coloured precipitate indicated the presence of alkaloids.

2.4.3 Test for phenol

Drops of alcoholic iron (III) chloride solution were added to the test solution in a test tube. A small amount of the sample was added to a minute crystal of $NaNO_2$ in a dry test tube and gently heated for a minute. After cooling, a few drops of concentrated H_2SO_4 were added from the sides.

Test for Carbonyl Compounds

Drops of 2,4-dinitrophenylhydrazine solution (in excess) were added to the test solution. The appearance of a red/orange precipitate indicated the presence of aldehydes or ketones. Additionally, drops of Fehling's solution (A+B) were added to the test solution and warmed in a water bath. The formation of a red precipitate indicated the presence of aldehydes, while the absence of a precipitate indicated the presence of ketones.

Test for Nitro Compounds

The test solution was dissolved in dilute hydrochloric acid in a test tube and added to a solution of $NaNO_2$. The mixture was then boiled to remove nitrogen and allowed to cool. The formation of a white precipitate indicated the presence of aromatic amines.

Statistical Analysis

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

Statistical analysis was conducted using MiniTab version 21 statistical software where One way ANOVA was conducted followed by post hoc analysis using Tukey at a 95% confidence level.

RESULTS

The particulate matter content in various cigarette brands was analysed for both smokers and passive smokers. *Table 1* presents the average mass of particulates, total mass of particulates, and percentage particulate content for each cigarette brand. On the other hand, *Table 2* shows the particulate chemical composition of cigarette smokers and non-smokers.

Our results demonstrated that all the cigarette brands examined contained aromatic compounds, alkaloids, phenols, and nitro compounds in their particulate content. Notably, carbonyl compounds were not detected in any of the brands, suggesting a unique chemical profile in the studied cigarettes. Regarding TPM levels, significant variations were observed among active smokers, ranging from 65.91 mg/g of cigarette (Safari) to 110.2 mg/g of cigarette (Sportsman). For passive smokers, the TPM content ranged from 7.15 mg/g of cigarette (local brand) to 25.66 mg/g of cigarette (Supermatch). However, statistical analysis revealed no significant differences in particulate content or the percentage of TPM across the different cigarette brands for both active and passive smokers. Moreover, the total particulate content (combining active and passive smoking) did not significantly differ among the brands. Nonetheless, active smokers exhibited significantly higher TPM levels compared to passive smokers, suggesting reduced exposure for the latter group.

DISCUSSION

The findings of this study shed light on the chemical composition (Table 2) and total particulate matter (TPM) levels in various cigarette brands, as well as the comparison between active and passive smokers. The presence of aromatic compounds, alkaloids, phenols, and nitro compounds in the particulate content of all examined cigarette brands aligns with previous research, confirming their consistent presence in tobacco smoke (Braun et al., 2019; Wen et al., 2022). An intriguing result of this study was the absence of carbonyl compounds in all the studied cigarette brands. Carbonyl compounds, known for their harmful effects, are commonly found in cigarette smoke (Díez-Izquierdo et al., 2018; Marcilla et al., 2022). The unique chemical profile lacking carbonyl compounds suggests that the studied cigarettes may differ from others in terms of their potential health risks.

Significant variations in TPM levels were observed among active smokers across different cigarette brands, indicating differences in the concentration of solid and liquid particles emitted during smoking. These variations can be attributed to several factors, including the composition of tobacco, the manufacturing process, and the design of the cigarettes themselves (Dai et al., 2022). Different brands may employ varying levels of additives, filters, and paper materials, which can influence the amount of particulate matter produced during combustion. Sportsman exhibited the highest TPM levels (110.2 mg/g of cigarette), while Safari had the lowest (65.91 mg/g of cigarette). These disparities highlight the importance of considering brand-specific characteristics when assessing the exposure of active smokers to particulate matter (Braun et al., 2019). Passive smokers, exposed to second-hand smoke, also displayed varying TPM content depending on the brand being smoked by active smokers nearby. The range of TPM levels for passive smokers was from 7.15 mg/g of cigarette (local brand) to 25.66 mg/g of cigarette (Supermatch). These findings emphasize the influence of the brand being smoked on the particulate matter exposure experienced by passive smokers.

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

Table 1: Particulate matter content in the cigarette brands for smokers and passive smokers

Cigarette brand	Average TPM per gram of tobacco (mg/g)		Total TPM per gram of tobacco (mg/g)	Percentage TPM in mg per g of cigarette	
	Active Smoker	Passive Smoker		Active smoker	Passive smoker
Supermatch	81.5± 25.6[a]	25.66 ± 13.31[b]	107.1 ± 22.5[c]	11.72 ± 4.06[d]	3.66 ± 1.86[e]
Rex	83.86 ± 1.03[a]	12.17 ± 0.832[b]	96.03 ± 1.62[c]	12.81 ± 0.65[d]	1.86 ± 0.03[e]
Sportsman	110.2 ± 37.4[a]	11.13 ± 6.73[b]	121.3 ± 39.4[c]	19.23 ± 8.23[d]	1.87 ± 1.13[e]
Safari	65.91 ± 8.91[a]	22.67 ± 10.97[b]	88.58 ± 10.11[c]	10.84 ± 2.07[d]	3.79 ± 2.11[e]
Local	105.21 ± 28.3[a]	7.15 ± 1.21[b]	112.4 ± 28.2[c]	9.58 ± 2.84[d]	0.64 ± 0.06[e]

Statistical significance: a, b, c, d, e, f, g. All values are given as averages

Table 2: Particulate chemical composition of cigarette smokers and non-smokers

	Smoker					Nonsmoker				
Chemical composition	Cigarette smoke brands					Cigarette smoke brands				
	Sportsman	Supermatch	Rex	Safari	Local	Sportsman	Supermatch	Rex	Safari	Local
Aromatic compounds	+	+	+	+	+	+	+	+	+	+
Alkaloids	+	+	+	+	+	+	+	+	+	+
Phenols	+	+	+	+	+	+	+	+	+	+
Carbonyl compounds	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitro compounds	+	+	+	+	+	+	+	+	+	+

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

Interestingly, statistical analysis revealed no significant differences in particulate content or the percentage of TPM across the different cigarette brands for both active and passive smokers. This suggests that, despite variations in TPM levels, the overall composition of particulate matter in the smoke was relatively similar among the studied brands. It implies that the types of particles emitted, and the overall percentage of particulate matter were comparable across brands, although the absolute amounts of TPM differed. Similar findings were reported by (Cao et al., 2015). Furthermore, the total particulate content, combining both active and passive smoking, did not significantly differ among the cigarette brands. This indicates that when considering the overall amount of particulate matter generated by smoking, regardless of whether it was inhaled directly by active smokers or experienced by passive smokers, there were no significant variations among the brands examined (Schulz et al., 2016).

CONCLUSIONS

Comparing active and passive smokers, the study demonstrated that active smokers exhibited significantly higher TPM levels compared to passive smokers. This discrepancy in TPM levels suggests that active smokers are exposed to a greater amount of particulate matter, attributable to the direct inhalation of smoke from their own cigarettes. In contrast, passive smokers are exposed to smoke that has undergone partial dilution and filtration by the surrounding air before reaching them, resulting in lower TPM levels. The reduced exposure of passive smokers reflects a potentially lower health risk compared to active smokers. These research findings provide valuable insights into the chemical composition and TPM levels of different cigarette brands, as well as the disparities in exposure between active and passive smokers. The absence of carbonyl compounds in the studied brands and the significant differences in TPM levels underscore the importance of considering brand-specific characteristics and smoking behaviours when evaluating the potential health risks associated with cigarette smoking.

ACKNOWLEDGEMENT

The authors are grateful for the help received from technicians and members of the Department of Chemistry, Busitema University during the conduct of this study.

Funding

There was no funding for this study.

REFERENCES

Addolorato, G., Bataller, R., Burra, P., DiMartini, A., Graziadei, I., Lucey, M. R., Mathurin, P., O'Grady, J., Pageaux, G., & Berenguer, M. (2016). Liver Transplantation for Alcoholic Liver Disease. *Transplantation*, *100*(5), 981–987. https://doi.org/10.1097/TP.0000000000001156

Braun, M., Koger, F., Klingelhöfer, D., Müller, R., & Groneberg, D. (2019). Particulate Matter Emissions of Four Different Cigarette Types of One Popular Brand: Influence of Tobacco Strength and Additives. *International Journal of Environmental Research and Public Health*, *16*(2), 263. https://doi.org/10.3390/ijerph16020263

Cao, S., Yang, C., Gan, Y., & Lu, Z. (2015). The Health Effects of Passive Smoking: An Overview of Systematic Reviews Based on Observational Epidemiological Evidence. *PLOS ONE*, *10*(10), e0139907. https://doi.org/10.1371/journal.pone.0139907

Dai, X., Gakidou, E., & Lopez, A. D. (2022). Evolution of the global smoking epidemic over the past half century: strengthening the evidence base for policy action. *Tobacco Control*, *31*(2), 129– 137. https://doi.org/10.1136/tobaccocontrol-2021-056535

Díez-Izquierdo, A., Cassanello-Peñarroya, P., Lidón-Moyano, C., Matilla-Santander, N., Balaguer, A., & Martínez-Sánchez, J. M. (2018). Update on thirdhand smoke: A comprehensive systematic review. *Environmental Research*, *167*, 341–371. https://doi.org/10.1016/j.envres.2018.07.020

Article DOI: https://doi.org/10.37284/eajhs.7.1.1969

Gowing, L. R., Ali, R. L., Allsop, S., Marsden, J., Turf, E. E., West, R., & Witton, J. (2015). Global statistics on addictive behaviours: 2014 status report. *Addiction, 110*(6), 904–919. https://doi.org/10.1111/add.12899

Hashizume, T., Ishikawa, S., Matsumura, K., Ito, S., & Fukushima, T. (2023). Chemical and in vitro toxicological comparison of emissions from a heated tobacco product and the 1R6F reference cigarette. *Toxicology Reports*, *10*, 281– 292. https://doi.org/10.1016/j.toxrep.2023.02.005

Hong, S. W., Teesdale-Spittle, P., Page, R., & Truman, P. (2022). A review of monoamine oxidase (MAO) inhibitors in tobacco or tobacco smoke. *NeuroToxicology*, *93*, 163–172. https://doi.org/10.1016/j.neuro.2022.09.008

Jou, S. S., Yagihashi, K., Zach, J. A., Lynch, D., & Suh, Y. J. (2019). Relationship between current smoking, visual CT findings and emphysema index in cigarette smokers. *Clinical Imaging, 53*, 195– 199. https://doi.org/10.1016/j.clinimag.2018.10.024

Lei, T., Li, M., Zhu, Z., Yang, J., Hu, Y., & Hua, L. (2023). Comprehensive evaluation of serum cotinine on human health: Novel evidence for the systemic toxicity of tobacco smoke in the US general population. *Science of The Total Environment*, *892*, 164443. https://doi.org/10.1016/j.scitotenv.2023.164443

Marcilla, A., Berenguer, D., & Martinez, I. (2022). Effect of the addition of zeolites and silicate compounds on the composition of the smoke generated in the decomposition of Heet tobacco under inert and oxidative atmospheres. *Journal of Analytical and Applied Pyrolysis*, *164*, 105532. https://doi.org/10.1016/j.jaap.2022.105532

Mrigpuri, P., Gupta, A., Jha, R., Singla, P., & Singla, R. (2021). Tobacco use, tuberculosis and Covid-19: A lethal triad. *Indian Journal of Tuberculosis*, *68*, S86–S88. https://doi.org/10.1016/j.ijtb.2021.08.010

Schmid, R., Trease, G. E., & Evans, W. C. (1986). Pharmacognosy. *Taxon*, *35*(1), 209. https://doi.org/10.2307/1221084

Schulz, M., Gerber, A., & Groneberg, D. (2016). Are Filter-Tipped Cigarettes Still Less Harmful than Non-Filter Cigarettes?—A Laser Spectrometric Particulate Matter Analysis from the Non-Smokers Point of View. *International Journal of Environmental Research and Public Health*, *13*(4), 429. https://doi.org/10.3390/ijerph13040429

Sutoyo, S., Amaria, Sanjaya, I. G. M., Hidayah, R., Sari, D. P., & Fadzlillah, N. A. (2021). Phytochemical Screening, Total Flavonoid Content, and Total Phenolic Content of Ethanol Extract of the Indonesian Fern Selaginella Plana. *Advance in Engineering Research*, *209*(Ijcse), 357–362. https://www.atlantis- press.com/proceedings/ijcse-21/125966487

Tv, W., & Table, F. (1921). With Tv/enty-seven Plates (162 Photomicrographs) and a Folding Table of Reactions.

Ussher, M., Brown, J., Rajamanoharan, A., & West, R. (2014). How Do Prompts for Attempts to Quit Smoking Relate to Method of Quitting and Quit Success? *Annals of Behavioral Medicine*, *47*(3), 358–368. https://doi.org/10.1007/s12160-013-9545-z

Wen, Z., Li, X., Gu, X., Zhang, W., Pang, Y., Jiang, X., Hou, H., Hu, Q., Wang, J., Zhang, L., Liu, Y., & Tang, X. (2022). Online analysis of chemical composition and size distribution of fresh cigarette smoke emitted from a heated tobacco product. *MethodsX*, *9*, 101912. https://doi.org/10.1016/j.mex.2022.101912

World Health Organization. (2011). GLOBAL STATUS REPORT on non-communicable diseases 2014.