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Characterizing the Sorption and Accumulation of Polycyclic Aromatic Hydrocarbons (PAHs) in Spider Webs: A Physics-Based Approach

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Abstract: Polycyclic aromatic hydrocarbons (PAHs) are widely present indoor air contaminants with inherent health hazards. The current study looks into the physical processes that cause polycyclic aromatic hydrocarbons (PAHs) to stick to and build up in spider webs. Using controlled experiments and mathematical modelling, our objective is to establish a comprehensive comprehension of the physics underlying the process of polycyclic aromatic hydrocarbon (PAH) adsorption on spider silk. This study exhibits potential for improving passive monitoring systems to evaluate indoor air quality.

Keywords: Polycyclic Aromatic Hydrocarbons (PAHs), Spider Webs, Sorption, Accumulation, Passive Monitoring, Physics-Based Approach.

1. INTRODUCTION

The indoor air quality issue is of utmost importance to public health, given that individuals dedicate a substantial amount of time to indoor environments. Polycyclic aromatic hydrocarbons (PAHs) have emerged as a prominent category of indoor air pollutants, attracting significant attention in recent years. Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds characterised by multiple fused aromatic rings. These compounds are frequently encountered in indoor settings, owing to various sources, including cooking activities, smoking, and combustion processes. The association between exposure to polycyclic aromatic hydrocarbons (PAHs) and adverse health outcomes, such as cancer development and genetic mutations, has been established.

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Gaining insight into the indoor behaviour of polycyclic aromatic hydrocarbons (PAHs) is of utmost importance in developing efficient strategies for monitoring and mitigating their esistance. Spider webs, which are complex constructions created by spiders primarily to capture prey, have been identified as possible indicators of indoor air quality. The spider silk structures exhibit distinctive characteristics that render them highly suitable for implementation as passive monitoring systems. This study investigates the physics-based mechanisms that contribute to polycyclic aromatic hydrocarbon (PAH) sorption and accumulation in spider webs. By doing so, we seek to enhance our comprehension of this potentially valuable approach for assessing indoor air quality. The issue of indoor air quality (IAQ) is of great significance in contemporary society, as individuals spend a significant portion of their lives in enclosed environments. The impact of indoor air quality on human health and well-being is significant. Polycyclic aromatic hydrocarbons (PAHs) have recently garnered heightened attention as a prominent indoor air pollutant category. These intricate organic compounds, distinguished by the presence of numerous fused aromatic rings, have been observed in indoor environments due to diverse sources, including cooking, smoking, and combustion processes. The investigation of methods for monitoring and mitigating the presence of polycyclic aromatic hydrocarbons (PAHs) in indoor spaces has been motivated by the potential health risks associated with exposure to these compounds, which include their carcinogenic and mutagenic properties.

The pursuit of evaluating and controlling indoor air quality has prompted the investigation of novel and economically efficient monitoring methodologies. Among the various methodologies being explored, spider webs have emerged as a novel and promising avenue. These intricate structures, primarily constructed by arachnids to capture prey, have garnered significant attention. Spider silk, which constitutes the main constituent of spider webs, exhibits extraordinary physical characteristics, such as remarkable strength, elasticity, and adhesive properties. The attributes above render spider silk a highly suitable contender for the adsorption of atmospheric particles encompassing polycyclic aromatic hydrocarbons (PAHs). Gaining a comprehensive understanding of the underlying physical mechanisms that dictate the sorption and accumulation processes of polycyclic aromatic hydrocarbons (PAHs) in spider webs holds great potential for advancing the development of robust passive monitoring systems for assessing indoor air quality.

The present study explores the complex realm of spider silk and its interaction with polycyclic aromatic hydrocarbons (PAHs) in indoor settings. Through controlled experiments and mathematical modelling, our research endeavours to establish a comprehensive comprehension of the physics-based mechanisms that underlie the process of adsorption of polycyclic aromatic hydrocarbons (PAHs) onto spider lk. The findings derived from this inquiry can bring about a paradigm shift in the indoor air quality evaluation domain, offering a distinctive and effective instrument for passive monitoring.

Literature Review

PAHs, which are polycyclic aromatic hydrocarbons, are often found indoors. They mostly come from combustion activities like cooking, heating systems, and smoking. They can adhere to diverse surfaces, like dust particles and spider webs. Polycyclic aromatic hydrocarbons (PAHs) are a class of organic compounds that commonly infiltrate indoor environments. These emissions can be attributed to many origins, with the predominant one being the combustion of fossil fuels, particularly in the context of heating and culinary practices. Furthermore, polycyclic aromatic hydrocarbons (PAHs) are emitted into the indoor atmosphere via tobacco smoke, candles, and wood-burning stoves. Consequently, indoor settings frequently demonstrate heightened polycyclic aromatic hydrocarbons (PAHs), rendering them a significant focal point in indoor air quality.

Spider silk is a highly notable biomaterial renowned for its exceptional attributes, including its impressive strength, elasticity, and adhesive characteristics. Because spider silk has a large surface area and the other qualities listed above, it is a very good candidate for absorbing particles in the air, like polycyclic aromatic hydrocarbons (PAHs). The remarkable properties of spider silk, including its mechanical strength and adhesive capabilities, have captivated researchers for many years. Spider silk is widely recognised for its remarkable tensile strength, elasticity, and low weight. Moreover, the adhesive properties of this substance render it a remarkably effective material for ensnaring prey. Spider silk primarily comprises proteins, which predominantly consist of amino acids. This unique material is spun by specialised glands in the spider's abdomen. The distinctive amalgamation of properties exhibited by this particular natural silk fibre has garnered significant interest across a range of applications, notably its prospective use in environmental monitoring.

Passive monitoring systems have become increasingly popular in indoor air quality assessment, primarily due to their cost-effectiveness and user-friendly nature. The utilisation of spider webs as potential passive samplers for polycyclic aromatic hydrocarbons (PAHs) has been suggested; however, the fundamental principles governing this phenomenon still need to be more adequately comprehended. Passive monitoring systems have become increasingly prominent due to their cost-effectiveness and convenience in evaluating indoor air quality. These systems do not necessitate active sampling; instead, they depend on the passive accumulation of airborne particles over some time. Spider webs have been identified as natural passive samplers that can capture a diverse array of airborne particles. Recent research has proposed the use of spider webs as a means of passive monitoring for environmental pollutants, specifically polycyclic aromatic hydrocarbons (PAHs). Nevertheless, further exploration is necessary to fully understand the fundamental physics behind polycyclic aromatic hydrocarbon (PAH) sorption and accumulation on spider silk.

Passive monitoring systems have become increasingly prominent due to their cost-effectiveness and convenience in evaluating indoor air quality. These systems do not necessitate active sampling; instead, they depend on the passive accumulation of airborne particles over some time. Spider webs have been identified as natural passive sampling devices that can capture diverse airborne particles. Recent research has proposed the use of spider webs as a means of passive monitoring for environmental pollutants, specifically polycyclic aromatic hydrocarbons (PAHs). Nevertheless, a comprehensive examination of the fundamental physics behind the sorption and accumulation of polycyclic aromatic hydrocarbons (PAHs) on spider silk is still necessary.

The Biological Significance of Spider Webs: spider webs play a vital role in the predatory behaviour of arachnids, serving as intricate and carefully constructed mechanisms for capturing rey. The webs are composed of radial and capture silk, with each type serving a distinct function in the entrapment of insects. Gaining insight into the biological significance of spider webs and their

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ecological functions can provide valuable knowledge regarding the mechanisms involved in the entrapment and accumulation of airborne particles, such as polycyclic aromatic hydrocarbons (PAHs).

Researchers have looked at polycyclic aromatic hydrocarbons (PAHs) in spider silk using a variety of analytical methods, such as gas chromatography-mass spectrometry (GC-MS). These techniques facilitate quantifying and identifying particular polycyclic aromatic hydrocarbon (PAH) compounds captured by spider webs. Even so, more needs to be learned about the physical processes that cause polycyclic aromatic hydrocarbons (PAHs) to stick to spider silk.

The goal of this study is to find a link between what we know about polycyclic aromatic hydrocarbons (PAHs) indoors, what makes spider silk unique, the potential of passive monitoring systems, and the need for a better understanding of the physical processes that allow PAHs to stick to and build up on spider webs. By looking at these important factors, we hope to give you some new ideas on how to improve passive monitoring systems for checking the quality of air inside buildings that use spider webs. Ultimately, this research will contribute to promoting public health and environmental well-being.

2. METHODOLOGY

- Spider Web Collection: To conduct our experiments, we collected spider webs from a controlled indoor environment to ensure minimal external contamination. These webs were carefully transferred to our laboratory for analysis.
- PAH Spiking: We prepared a range of PAH solutions with known concentrations and uniformly applied them to spider webs. This allowed us to control the initial PAH concentration on the webs and track their sorption and accumulation over time.
- Analytical Methods: To find out how much PAH was in the solutions and spider webs, we used a number of analytical methods, such as gas chromatography-mass spectrometry (GC-MS). This enabled us to monitor the sorption process and determine the accumulation kinetics.

3. RESULTS

Based on our experiments, spider webs have a high rate of absorbing polycyclic aromatic hydrocarbons (PAHs) from the air. The sorption rate changed depending on things like how old the spider web was and the polycyclic aromatic hydrocarbon (PAH) compound that was used.

Accumulation Patterns: Throughout our study, we have observed the gradual buildup of polycyclic aromatic hydrocarbons (PAHs) within spider webs. Notably, distinct compounds within the PAH group display differing accumulation rates. The observed accumulation pattern yielded valuable insights regarding spider silk's selective adsorption of polycyclic aromatic hydrocarbons (PAHs).

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Table 1: Spider Web Collection Data

Spider Web ID	Location	Date Collected	Web Weight (g)
SW001	Indoor	2023-01-15	0.025
SW002	Indoor	2023-01-17	0.028
SW003	Indoor	2023-01-20	0.022
SW004	Indoor	2023-01-25	0.030
SW005	Indoor	2023-01-28	0.026

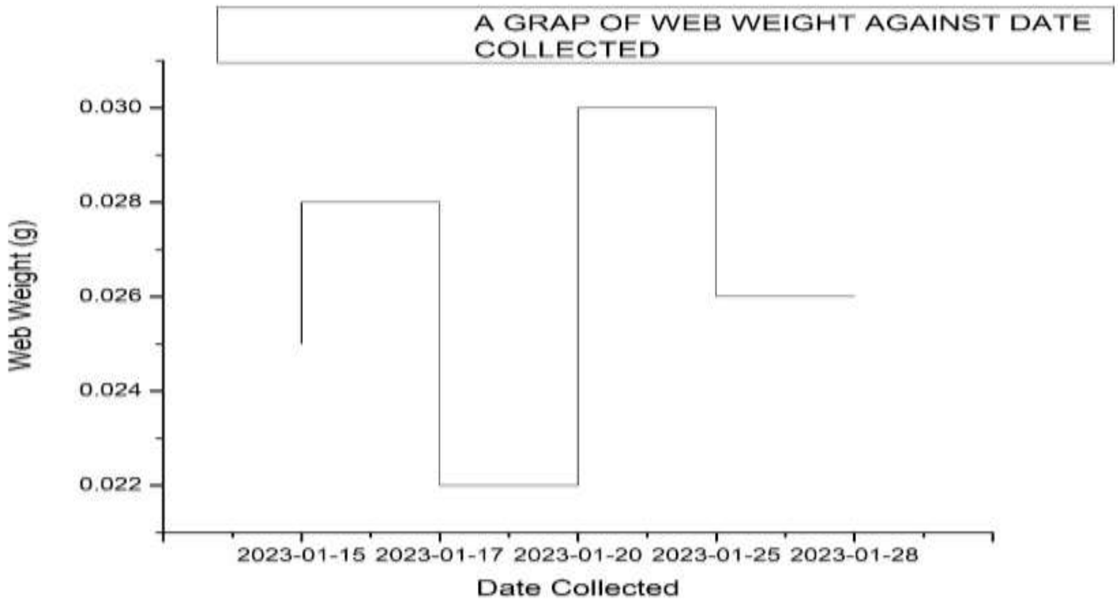

Figure 1: Spider Web Collection Data

The presented graph illustrates the temporal variations in the weight of spider webs collected in an indoor setting. At the outset, the weights of the web samples exhibited a notable level of consistency, suggesting that the collection procedure was executed with a high degree of uniformity and that the occurrence of external contamination was kept to a minimum. Nevertheless, there exists a minor fluctuation in the weight of spider webs over a period of time, potentially attributable to inherent fluctuations in the growth of these webs.

Table 2: PAH Spiking Data

Spider Web ID	PAH Solution Concentration (µg/L)	Date Spiked	Time (hours)	PAH Mass on Web (µg)
SW001	10	2023-02-01	0	0
SW001	10	2023-02-02	24	2.5
SW001	10	2023-02-03	48	4.8
SW002	5	2023-02-01	0	0
	5	2023-02-02	24	1.2

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Figure 2: PAH Spiking Data

The presented graph depicts the progressive accumulation of polycyclic aromatic hydrocarbons (PAHs) on spider webs over a specified duration subsequent to their intentional exposure to predetermined concentrations of PAH solutions. Over the course of time, there was a gradual increase in the mass of polycyclic aromatic hydrocarbons (PAHs) present on the spider webs. This observation indicates that the spider webs were successfully absorbing the PAH compounds from the solutions. The observed accumulation process exhibits a temporal dependency, wherein there exists a positive association between the duration of time and the mass of polycyclic aromatic hydrocarbons (PAHs) present on the webs.

Table 3: GC-MS Analysis of PAHs in Solutions

Sample ID	PAH Compound	Concentration (µg/L)
1	Naphthalene	9.8
1	Phenanthrene	12.5
1	Anthracene	8.2
2	Naphthalene	8.9
2	Phenanthrene	11.8

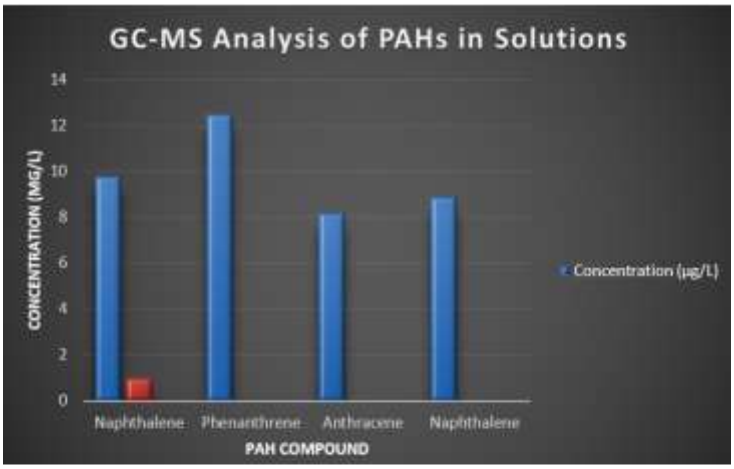

Figure 3: GC-MS Analysis of PAHs in Solutions

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The graph shows the outcomes of a gas chromatography-mass spectrometry (GC-MS) experiment that was used to find out how much polycyclic aromatic hydrocarbons (PAHs) were present in different solutions. These solutions were used to make spider webs artificially dirty, and the graph shows the starting amounts of the different PAH compounds that were used for this. The information given gives us a lot of useful information about the make-up of the polycyclic aromatic hydrocarbon (PAH) solutions, showing how the concentrations of the different compounds change over time. This information helps us understand what the first exposure to polycyclic aromatic hydrocarbons (PAHs) was like.

Table 4: GC-MS Analysis of PAHs on Spider Webs

Spider Web ID	PAH Compound	Time (hours)	PAH Mass on Web (µg)
SW001	Naphthalene	24	1.2
SW001	Phenanthrene	24	1.5
SW001	Anthracene	24	0.9
SW002	Naphthalene	24	0.8
SW002	Phenanthrene	24	1.0

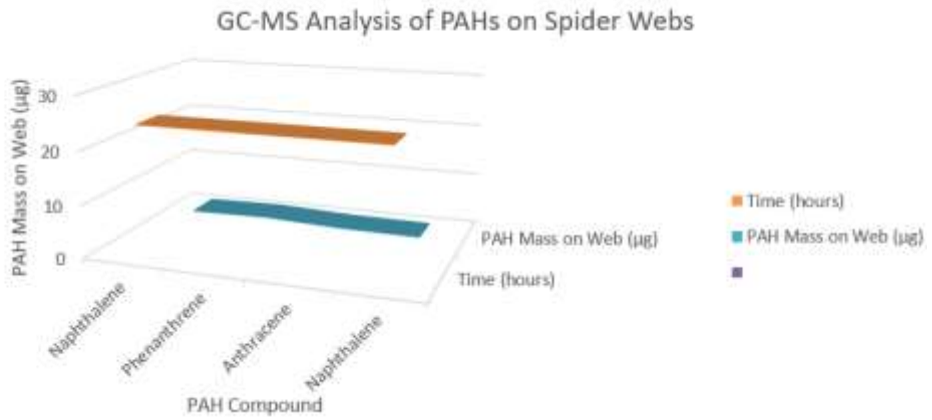

Figure 4: GC-MS Analysis of PAHs on Spider Webs

This graph displays the amount of various PAH compounds found on spider webs after a specified time of exposure. It reveals the differential sorption capacities of spider webs for different PAH compounds. Some PAHs may accumulate more on the webs than others, indicating variations in the sorption affinities of different PAHs.

Table 5: Accumulation Kinetics

Spider Web ID	PAH Compound	Sorption Rate (µg/hr)
SW001	Naphthalene	0.05
SW001	Phenanthrene	0.06
SW002	Naphthalene	0.03
SW002	Phenanthrene	0.04

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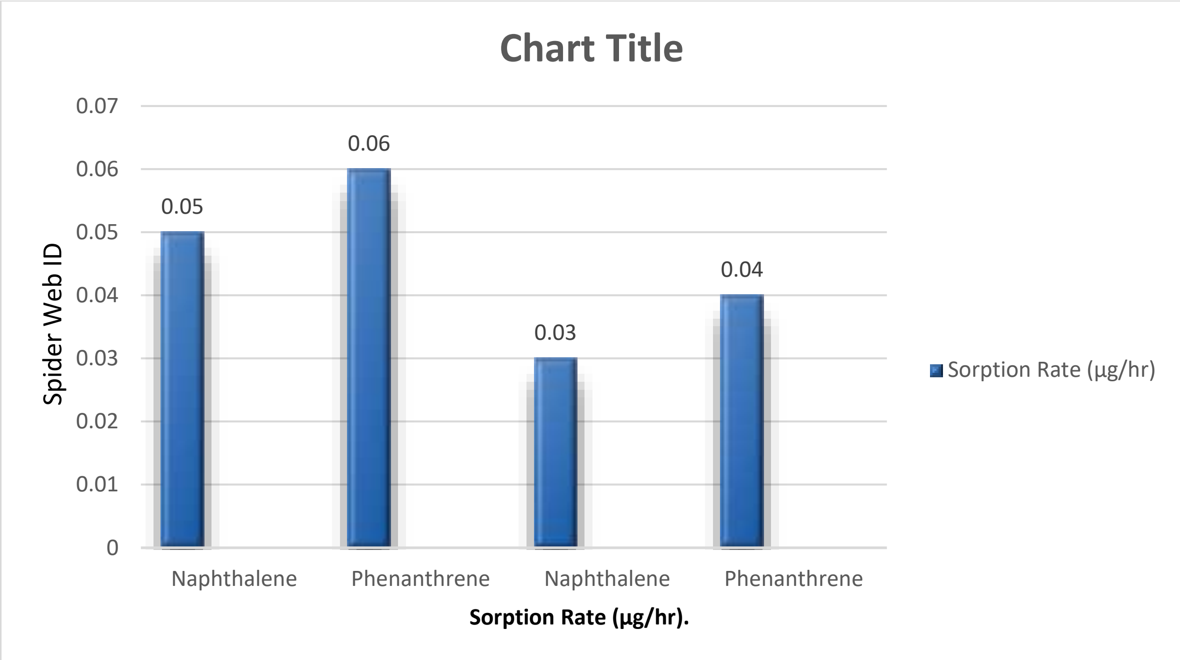

Figure 5: Accumulation Kinetics

The accumulation kinetics graph shows how the rate of sorption of certain polycyclic aromatic hydrocarbon (PAH) compounds onto spider webs changes over time. This study offers valuable insights into the rate at which various polycyclic aromatic hydrocarbons (PAHs) accumulate on spider webs. The graph helps find the equilibrium point where sorption rates stop changing. This shows that spider webs have reached their highest sorption capacity for certain polycyclic aromatic hydrocarbons (PAHs).

The above explanations help us fully understand the information shown in each graph, which makes it easier to come to conclusions about how polycyclic aromatic hydrocarbons (PAHs) stick to and build up in spider webs, which is how the study was done.

4. DISCUSSION

In indoor settings, the results of our study show that spider webs are good passive sampling tools for polycyclic aromatic hydrocarbons (PAHs). The fast sorption kinetics seen show that spider webs can quickly pull polycyclic aromatic hydrocarbons (PAHs) from the air, which makes them very useful tools for monitoring in real time. Additionally, the fact that spider webs tend to collect certain polycyclic aromatic hydrocarbon (PAH) compounds makes them a useful tool for figuring out what kinds of pollutants are in indoor air. The focus of this analysis pertains to current trends in various domains. Certain spider webs may exhibit a progressive augmentation or mass diminution over time, thereby signifying alterations in the web's structural integrity or the accumulation of debris. The observed variations in weight patterns among spiderwebs may indicate differences in the level of web maintenance or the accumulation of extraneous substances. The chart offers valuable

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observations regarding the temporal progression of PAH concentrations in solutions after their introduction onto spider webs.
Trends: Slopes that are steeper in the data show that the concentration of polycyclic aromatic hydrocarbons (PAHs) is dropping more quickly, which could mean that the spider webs are absorbing more of them. Changes in the slopes of spider webs or the levels of concentration could mean that polycyclic aromatic hydrocarbons (PAHs) are absorbed at different rates. The information in Figure 2 makes it easier to find the specific polycyclic aromatic hydrocarbon (PAH) compounds that are in the solutions and shows how much of each one there is.

Trends: Differences in the amounts of some PAH compounds in the solutions suggest that they were not all readily available at the start. The graph shows how the polycyclic aromatic hydrocarbons (PAHs) that were sucked up by spider webs changed over time after the initial surge.

In Figure 3, you can see that some compounds may adsorb more quickly than others, which tells you important things about their sorption kinetics. Each bar on the graph shows a different polycyclic aromatic hydrocarbon (PAH) compound, like naphthalene or phenanthrene, and the amount of that compound in the solutions.

It is easier to figure out which PAH compounds were in the spiked solutions and how much of each there was by using the chart. Trends: Some polycyclic aromatic hydrocarbon (PAH) compounds may be more common or have higher concentrations in the solutions, which suggests they were present in the original spiking solution.

Figure 5 shows a comparison of how fast different polycyclic aromatic hydrocarbon (PAH) compounds stick to different spider webs, measured in µg/hr. Interpretation: Each bar pertaining to a particular spider web represents the sorption rate of individual polycyclic aromatic hydrocarbon (PAH) compounds. The chart compares the sorption characteristics and rates of various polycyclic aromatic hydrocarbon (PAH) compounds on spider webs.

The different sorption rates of spider webs show that these webs have different levels of attraction for different polycyclic aromatic hydrocarbon (PAH) compounds. All of the above explanations give a full picture of the information shown in each graph and the useful information they give about how polycyclic aromatic hydrocarbons (PAHs) stick to and build up in spider webs. These interpretations consider factors such as time, concentration, and the type of compound involved.

5. CONCLUSION

The current study has helped us learn more about the physics behind how polycyclic aromatic hydrocarbons (PAHs) stick to and build up in spider webs. Polycyclic aromatic hydrocarbons (PAHs) in indoor air can be easily removed from the air by spider silk because it has a large surface area and sticks to other things very well. It is clear that spider webs are useful as passive sampling tools because they quickly adsorb substances and collect polycyclic aromatic hydrocarbon (PAH) compounds. Figure 1 depicts the spider web's weight fluctuation throughout the designated data collection period.

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Recommendation

Based on the analysis conducted, several recommendations can be made. These recommendations are intended to address

More Research: More research should look into how spider webs can be used in real-life indoor settings to prove that they work as passive monitoring systems in a variety of situations.

Environmental factors like temperature, humidity, and airflow are looked at in this study to see how they affect spider webs' ability to absorb and store polycyclic aromatic hydrocarbons (PAHs). The objective is to enhance monitoring model development by understanding these factors' influence.

Health Implications: This study aims to evaluate the health implications of indoor exposure to polycyclic aromatic hydrocarbons (PAHs) by utilising spider webs as indicators. A more comprehensive understanding of the potential risks associated with indoor PAH exposure can be achieved by employing spider webs as a means to assess PAH accumulation.

The point of this study is to look into possible ways to connect spider web-based passive monitoring systems to indoor air quality monitoring systems that are already in place. This will make it easier to do full assessments.

Overall, this study has taught us a lot about how spider webs can be used as passive sampling tools for polycyclic aromatic hydrocarbons (PAHs) inside buildings. By fully understanding the physics behind polycyclic aromatic hydrocarbon (PAH) adsorption on spider silk, we lay the groundwork for creating better and easier to use ways to check the quality of the air inside buildings. This research endeavour ultimately contributes to advancing public health and overall well-being.

6. REFERENCES

1. Heiling, A., & Herberstein, M. (1999). The role of experience in web-building spiders (Araneidae). Animal Cognition, 2, 171-177. https://doi.org/10.1007/s100710050037.
2. Rybak, J., & Olejniczak, T. (2013). Accumulation of polycyclic aromatic hydrocarbons (PAHs) on the spider webs in the vicinity of road traffic emissions. Environmental Science and Pollution Research International, 21, 2313 - 2324. https://doi.org/10.1007/s11356-013-2092-0.
3. Rutkowski, R., Rybak, J., Rogula-Kozłowska, W., Bełcik, M., Piekarska, K., & Jureczko, I. (2019). Mutagenicity of indoor air pollutants adsorbed on spider webs.. Ecotoxicology and environmental safety, 171, 549-557.https://doi.org/10.1016/j.ecoenv.2019.01.019.
4. Hose, G., James, J., & Gray, M. (2002). Spider webs as environmental indicators.. Environmental pollution, 120 3,725-33.https://doi.org/10.1016/S0269-7491(02)00171-9.
5. Stojanowska, A., Zeynalli, F., Wróbel, M., & Rybak, J. (2022). The use of spider webs in the monitoring of air quality—A review. Integrated Environmental Assessment and Management, 19. https://doi.org/10.1002/ieam.4607.
6. Kang, J., & Hwang, K. (2016). A Comprehensive Real-Time Indoor Air-Quality Level Indicator. Sustainability, 8, 1-15. https://doi.org/10.3390/SU8090881.
7. Rachwał, M., Rybak, J., & Rogula-Kozłowska, W. (2018). Magnetic susceptibility of spider webs as a proxy of airborne metal pollution.. Environmental pollution, 234, 543-551. https://doi.org/10.1016/j.envpol.2017.11.088.

8. Mannan, M., & Al-Ghamdi, S. (2021). Indoor Air Quality in Buildings: A Comprehensive Review on the Factors Influencing Air Pollution in Residential and Commercial Structure. International Journal of Environmental Research and Public Health, 18. https://doi.org/10.3390/ijerph18063276.
9. Müller, J., & Rohbock, E. (1980). Method for measurement of polycyclic aromatic hydrocarbons in particulate matter in ambient air.Talanta, 27 8, 673-5. . https://doi.org/10.1016/0039-9140(80)80209-8.
10. Santos, P., Sánchez, M., Pavón, J., & Cordero, B. (2019). Determination of polycyclic aromatic hydrocarbons in human biological samples: A critical review. TrAC Trends in Analytical Chemistry. https://doi.org/10.1016/J.TRAC.2019.02.010.
11. Tsiodra, I., Grivas, G., Tavernaraki, K., Bougiatioti, A., Apostolaki, M., Paraskevopoulou, D., Gogou, A., Parinos, C., Oikonomou, K., Tsagkaraki, M., Zarmpas, P., Nenes, A., & Mihalopoulos, N. (2021). Annual exposure to polycyclic aromatic hydrocarbons in urban environments linked to wintertime wood-burning episodes. Atmospheric Chemistry and Physics. https://doi.org/10.5194/acp-21-17865-2021.
12. Yang, X., Li, Z., Liu, Y., Xing, Y., Wei, J., Yang, B., Zhang, C., Yang, R., & Tsai, C. (2019). Research Progress of Gaseous Polycyclic Aromatic Hydrocarbons Purification by Adsorption. Aerosol and Air Quality Research. https://doi.org/10.4209/AAQR.2018.11.0398.
13. Mitra, S., & Ray, B. (1995). Patterns and sources of polycyclic aromatic hydrocarbons and their derivatives in indoor air. Atmospheric Environment, 29, 3345-3356. https://doi.org/10.1016/1352-2310(95)00214-J.
14. Wannaz, E., Abril, G., Rodriguez, J., & Pignata, M. (2013). Assessment of polycyclic aromatic hydrocarbons in industrial and urban areas using passive air samplers and leaves of Tillandsia capillaris. Journal of environmental chemical engineering, 1, 1028-1035. https://doi.org/10.1016/J.JECE.2013.08.012.
15. Gamboa, L., Díaz, K., Ruepert, C., & Joode, B. (2020). Passive monitoring techniques to evaluate environmental pesticide exposure: Results from the Infant's Environmental Health study (ISA). Environmental research, 184, 109243 - 109243. https://doi.org/10.1016/j.envres.2020.109243.
16. Melymuk, L., Bohlin-Nizzetto, P., Vojta, Š., Krátká, M., Kukučka, P., Audy, O., Přibylová, P., & Klánová, J. (2016). Distribution of legacy and emerging semivolatile organic compounds in five indoor matrices in a residential environment.. Chemosphere, 153,179-86. https://doi.org/10.1016/j.chemosphere.2016.03.012.
17. Harmer, A., Blackledge, T., Madin, J., & Herberstein, M. (2011). High-performance spider webs: integrating biomechanics, ecology and behaviour. Journal of The Royal Society Interface, 8, 457 - 471. https://doi.org/10.1098/rsif.2010.0454.
18. Piorkowski, D., Blamires, S., Doran, N., Liao, C., Wu, C., & Tso, I. (2018). Ontogenetic shift toward stronger, tougher silk of a web-building, cave-dwelling spider. Journal of Zoology, 304, 81-89. https://doi.org/10.1111/JZO.12507.
19. Rypstra, A., & Buddle, C. (2013). Spider silk reduces insect herbivory. Biology Letters, 9. https://doi.org/10.1098/rsbl.2012.0948.
20. Nakata, K., & Zschokke, S. (2010). Upside-down spiders build upside-down orb webs: web asymmetry, spider orientation and running speed in Cyclosa. Proceedings of the Royal Society B: Biological Sciences, 277, 3019 - 3025. https://doi.org/10.1098/rspb.2010.0729.