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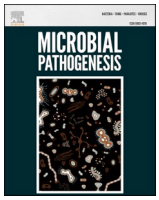

Platinum nanoparticles with photocatalytic binders for swift virus inactivation on textiles and surfaces

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ABSTRACT

Platinum nanoparticles combined with photocatalytic binders enable rapid virus inactivation on diverse surfaces, achieving 99.97 % reduction of Influenza A and 99.9 % of Feline Calicivirus in 15 s. This eco-efficient approach ensures uniform nanoparticle distribution, minimizing waste and offering sustainable antiviral protection for healthcare and other settings, dramatically outperforming existing solutions that require up to 5 min. We tested against Influenza A and Feline Calicivirus, with potential implications for norovirus due to similar viral structures, pending further validation. The binders' role in ensuring uniform nanoparticle distribution represents a breakthrough in sustainable protection technologies, enabling rapid virus inactivation while minimizing material usage across diverse materials including plastics, metals, ceramics, glass, and composites. In healthcare settings such as ICUs, this green technology significantly reduces waste generation and environmental impact while maintaining optimal protection against both current and emerging viral threats.

1. Introduction

Immunology encompasses a wide range of topics, including how the body defends itself against pathogens like viruses and bacteria. Vaccines are a key part of immunology, working by stimulating the immune system to recognize and fight off specific pathogens. Different types of vaccines exist, such as live attenuated vaccines, which utilize a weakened form of the virus that can replicate without causing illness, and inactivated vaccines, which contain viruses that have been killed or inactivated, preventing replication but still triggering an immune response. Inactivating viruses plays an essential role in vaccine development and immunological research. Unfortunately, despite significant progress and ongoing research efforts, a vaccine for norovirus is not yet available. Norovirus, responsible for acute gastroenteritis, poses a considerable public health challenge. Norovirus is a leading cause of acute gastroenteritis worldwide, responsible for approximately 685 million cases each year [1]. This highly contagious virus contributes to an estimated 1.5 million deaths globally annually [1].

This highlights the urgent need for effective prevention strategies, including the development of a norovirus vaccine, to reduce the burden of this disease on public health.

This paper proposes the use of photocatalytic binder materials to instantaneously inactivate a wide range of viruses, thereby eliminating the need for frequent HEPA filter replacements every 33 h in ICUs and hospitals suggested by Obitková et al. [2]. When sprayed onto solid materials, these binder materials can form uniformly distributed platinum nanoparticles that adhere effectively to solid surfaces. This innovative approach not only enhances the efficiency of virus inactivation but also contributes to a more sustainable and cost-effective solution for maintaining clean air and a safe environment in medical settings. The proposed binder materials can be applied to various sanitation areas, including ICUs, hospitals, and other healthcare facilities. The binder ensures uniform distribution of platinum nanoparticles in the liquid agent and promotes their adhesion to treated surfaces.

Platinum (Pt) nanoparticles act as oxidation catalysts [3], facilitating the reaction that transforms Nitric Oxide (NO) and Carbon Monoxide (CO) into Nitrogen Dioxide (NO2) and Carbon Dioxide (CO2). This dual functionality of Pt nanoparticles makes them an invaluable asset in controlling and managing vehicular emissions, thereby contributing significantly to a cleaner and healthier environment.

Platinum nanoparticles, in their singular form, serve as potent oxidation catalysts capable of inactivating a wide array of viruses [4,5]. To boost the performance of these catalysts, this study introduces an innovative approach that involves the integration of a binder or binding agent derived from silica composites. This binding agent serves as a novel photocatalytic material applied to fibers. A comparative analysis was conducted to evaluate the effectiveness of the catalysts both with and without the inclusion of binders. The results, validated through

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official examinations on virus inactivation, provide valuable insights into the role of photocatalytic binders in optimizing the antiviral activity of platinum nanoparticles. This research underscores the potential of platinum nanoparticles as a promising tool in our fight against viral pathogens.

The antiviral activity value is a measure of the effectiveness of a substance in inhibiting the growth or replication of a virus. This value is determined through in vitro testing. The formula of "log (Va)-log (Vc)" can be used as an antiviral activity value when certain conditions are met. Va represents the virus titer in the absence of the antiviral agent, and Vc represents the virus titer in the presence of the antiviral agent. Tests were conducted on platinum nanoparticles for their effectiveness against noroviruses, yielding an antiviral activity value of 0.9^4. These nanoparticles demonstrated the ability to conduct virus inactivation by 87.4 % and repel it. Notably, no binding agent was used in these tests. This reduction percentage aligns with formula $1-10^{-0.9} = 0.874$, confirming the observed results.

In the domain of chemistry, a binder—alternatively known as a binding agent—is either a substance or a photocatalytic material. It serves to preserve a specific distance among individual platinum nanoparticles, thus facilitating their uniform distribution. Moreover, it allows these nanoparticles to permanently attach to the surfaces of solid materials. In the absence of a binder agent, platinum nanoparticles are not uniformly distributed due to the lack of forces. Consequently, numerous holes or areas are devoid of nanoparticles, which can potentially diminish the antiviral effects. However, the proposed binder ensures a uniform distribution of nanoparticles, thereby enhancing their antiviral efficacy. Images of the solid material surfaces adorned with platinum nanoparticles are captured using a nanoscale microscope.

This unification can be achieved through various means such as mechanical force, chemical reactions, adhesion, or cohesion. Binders serve a pivotal role across a wide range of applications. Take textile pigment printing as an example. Binders are employed to secure insoluble pigments, which lack affinity for fibers, onto the fibers themselves. Lifecycle and durability is depending on binders. This paper utilizes binders in the context of textile platinum nanoparticle photocatalytic catalysis to inactivate or neutralize viruses. A binder is essentially a film-forming substance composed of long-chain macromolecules. When it is applied to the textile in conjunction with platinum nanoparticles, it results in the formation of a three-dimensional network. The selection of binders is influenced by the final fastness requirements and the cost-effectiveness of the process. In the field of electrochemistry, binders act as bridges, connecting separate components through chemical or physical interactions. This ensures the mechanical integrity of the electrode without significantly affecting its electronic or ionic conductivity. Therefore, while the specific role of a binder can vary depending on the application, its fundamental function remains the same to draw together or hold other materials. In this application, binders are employed to distribute platinum nanoparticles uniformly across the textile surface.

This paper presents the results of applying photocatalytic binders and platinum nanoparticles to textile surfaces and evaluates their effectiveness in virus inactivation. The antiviral activity tests were conducted using a liquid agent (W-35PGNS), which contains the binders and platinum nanoparticles. Two viruses were tested for antiviral activity: Influenza A virus (H3N2) (A/Hong Kong/8/68; TC adapted ATCC VR-1679) and Feline calicivirus (Strain: F-9 ATCC VR-782). The official tests were conducted and reported by the Japan Textile Products Quality and Technology Center in April 2024. The official certificates, which address the antiviral activity, are attached as supplements. Additionally, the official certificates for fungal disinfection in textiles is also attached as supplements.

2. Methods

Contact time is a critical factor in disinfection testing; shorter durations can significantly reduce the effectiveness of the disinfection process. For our study, we selected a minimum contact time of 15 s, in accordance with the ISO 18184:2019 standard for official testing. This duration was deemed sufficient for evaluating antiviral efficacy while also considering practical application needs.

In this context, it is important to clarify that the primary function of the binder is to uniformly adhere the platinum nanoparticles, as illustrated in Fig. 1 to 3, to the textile surface, ensuring their stability and effectiveness. The platinum nanoparticles themselves are essential for facilitating reactions with oxygen, either by removing or adding oxygen atoms. This interaction is crucial for activating the production of reactive oxygen species (ROS), which can inactivate viruses even in low light conditions. However, it is important to note that the official tests did not assess the effects in complete darkness.

The detailed antiviral tests for Influenza A virus (H3N2) and Feline calicivirus are described as follows.

2.1. Antiviral Test1 against Influenza A virus (H3N2) using liquid agent (W-35PGNS)

2.1.1. Summary of antiviral activity test in suspension

Virus strain: Influenza A virus (H3N2): A/Hong Kong/8/68; TC adapted ATCC VR-1679 Host cell: MDCK cell ATCC CCL-34.

Growth medium: Minimum Essential Medium Eagle; EMEM (SIGMA, Cat#M4655) Fetal Bovine Serum (FBS) (NICHIREl, Cat#l74012).

Negative control: Phosphate buffered saline (PBS) Test sample: Liquid agent (W-35PGNS).

Test condition: 1 part virus + 9 parts of test substance Contact time: 15 s.

Test temperature: 25 °C Neutralizer: SCDLP medium.

Measurement of viral infectivity titer: Plaque assay.

2.1.2. Antiviral activity test

1. Preparation of test virus inoculum
   - 1-1 Drain the growth medium from the flask with the cultured MDCK cells in the monolayer.
   - 1-2 Wash the surface of the cultured cells with EMEM and drain the medium. Repeat the washing procedure 2 times.
   - 1-3 Inoculate the influenza virus suspension prepared to be a concentration of 10^3 to 10^4 PFU/mL on the surface of cell in the flask and spread to the whole surface.
   - 1-4 Put the flask in the CO2 incubator at the temperature of 34 °C and keep it for 1 h to adsorb the virus to the cells.

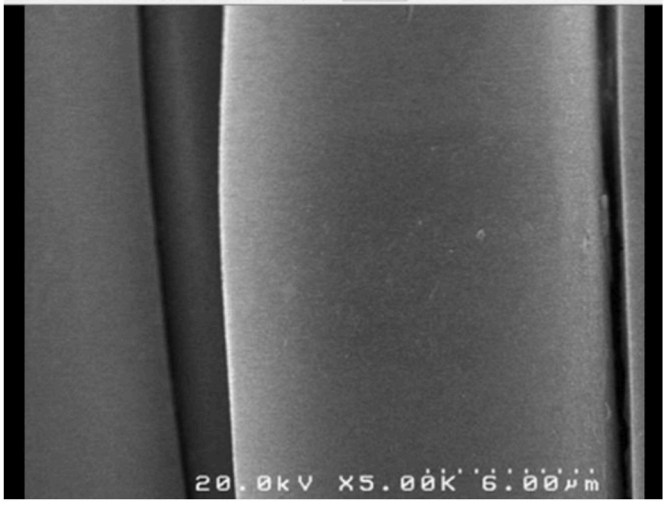

Fig. 1. Polyester Fiber: A 5000 x Close-Up.

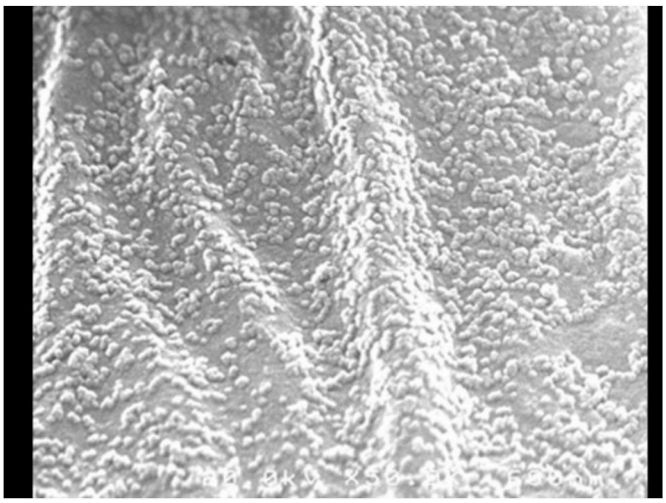

Fig. 2. Polyester Fiber: A 20K x Close-Up.

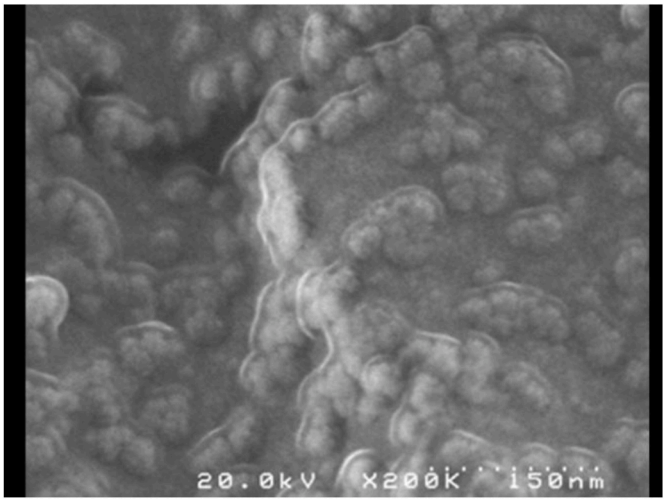

Fig. 3. Polyester Fiber: A 200K x Close-Up.

1-5 Put EMEM containing 1.5 ppm Trypsin derived from beef pancreas in the flask.
1-6 Put the flask in the CO2 incubator at the temperature of 34 °C for 1–2 days to multiply the influenza virus.
1-7 Observe the cytopathic effect under an inverted microscope and judge the multiplication of influenza virus. If the multiplication of influenza virus is confirmed, then, Centrifuge the multiplied virus suspension by using the centrifuge at the temperature of 4 °C and 1000 g for 15 min.
1-8 Take the supernatant suspension from the centrifugal tube after the centrifugation.

This is to be the test influenza virus suspension.

2. Control test
2-1 Verification of cytotoxic effect
I. Take 0.1 mL of EMEM, add it to test tubes containing 0.9 mL of test sample and mix well. This is to be the test mixture.
2. Take 0.1 mL of the test mixture, add it to test tubes containing 0.9 mL of neutralizer and mix well.
3. Prepare a 10-fold serial dilution series with EMEM.
4. Observe if cells damage or not, by plaque assay.

2-2 Verification of cell sensitivity to virus and the inactivation of antiviral activity
I Take 0.1 mL of EMEM, add it to test tubes containing 0.9 mL of test sample and mix well. This is to be the test mixture.
2. Take 0.5 mL of the test mixture, add it to test tubes containing 4.5 mL of neutralizer and mix well.
3 Prepare a 10-fold serial dilution series with EMEM.
4. Take 4.5 mL of the mixtures prepared in 2–2.3. to new tubes.
5. Add 45 μL of virus suspension prepared to be a concentration of 4.0–6.0 $\times$ 10^4 PFU/mL into the tubes.
6. Keep them at 25 °C for 10 min.
7. Determine infective titer by plaque assay.

Verification of "Control test":
Cytotoxic effect: negative Cell sensitivity to virus:
lg(lnfectivity titer (PFU/mL) of negative control)-lg(Infectivity titer (PFU/mL) of test sample) $\leq$ 0.5.

3. Test procedure
1. Add 0.9 mL of test sample into a test tube of suitable capacity for appropriate mixing.
2. Add 0.1 mL of the test virus suspension to the tube and mix well by vortex mixer.
3. Keep at 25 °C for 15 s. This suspension is to be "Test mixture".
4. After contacting, inactivate the test mixture under the condition confirmed to be inactivated in the control test. This suspension is to be "Inactivated mixture".
5. Prepare a series of 10-fold dilutions oflnactivated mixture by using EMEM.

Measure the viral infectivity titer per 0.l mL of inactivated mixture by plaque assay and calculate the viral infectivity titer per 1.0 mL of "Test mixture".
The official certificate is attached in Appendix1.

2.2. Antiviral Test2 against Feline calicivirus using liquid agent (W-35PGNS)

The distinctions between Test1 and Test2 are primarily based on the virus strain, host cell, and growth medium used. The official certificate is attached in Appendix2.

*2.2.1. Virus strain: **Feline** calicivirus; strain: F-9 ATCC VR-782*

Host cell: CRFK cell ATCC CCL-94.
Growth medium: Dulbecco's modified Eagle's medium (high-glucose); DMEM (SIGMA, Cat#D5796) Minimum Essential Medium Eagle; EMEM (SIGMA, Cat#M4655).
While W-35PGNS predominantly consists of water, its complex photocatalytic binder requires several other components—namely, carbon (C), tungsten trioxide (WO3), ammonia (NH3), silicon dioxide (SiO2), tin dioxide (SnO2), molybdenum (Mo), and selenium (Se)—none of which have reported antiviral activity, with the exception of platinum nanoparticles.
Liquid agent (W-35PGNS) is supplied by Japan Nano-Coat in Japan: http://www.japan-nano.co.jp/index.html. W-35PGNS is composed of H2O (95.99 %), SnO2(less than 0.5 %), Pt(less than 0.1 %), SiO2(less than 0.5 %), Mo(less than 0.1 %), Se(less than 0.005 %), C(less than 0.5 %), WO3(less than 0.5 %), NH3(less than 0.1 %), and Basic bismuth nitrate(less than 0.1 %).

3. Results

A liquid agent, designated as W-35PGNS and composed of photo-catalytic binders and platinum nanoparticles, was applied to polyester fibers. Fig. 1 (A 5000 x Close-Up), Fig. 2 (A 20K x Close-Up), and Fig. 3 (A 200K x Close-Up) provide surface views of these polyester fibers,

demonstrating the uniform binding of platinum nanoparticles on their surface. All images were taken by the Yasushi Murakami Laboratory, which is part of the Faculty of Textile Science and Technology at Shinshu University.

Feline Calicivirus serves as an alternative to human norovirus in the absence of the latter [6,7].

The uniform binding of platinum nanoparticles is critical for enhancing the effects of antiviral activity. Table 1 shows the result of antiviral activity value against influenza A virus (H3N2) while Table 2 presents that against Feline calicivirus. In the first test, antiviral activity value against Influenza A virus (H3N2) was 3.6 which indicates the ability to achieve norovirus inactivation by 99.97 % with formula $1-10^{-3.6} = 0.9997$. In the second test, antiviral activity value against Feline calicivirus was 3.0 which indicates the ability to achieve norovirus inactivation by 99.9 % with formula $1-10^{-3.0} = 0.999$.

In the context of the Influenza A virus (H3N2) study, PBS served as the negative control, demonstrating no cytotoxic effects. The average infectivity titer, measured in PFU/mL, was found to be 2.69, indicating a level of cell sensitivity to the virus. Similarly, the liquid agent W-35PGNS also exhibited no cytotoxic effects, with a cell sensitivity represented by an infectivity titer of 2.65. In the assessment of Feline calicivirus, PBS recorded a titer of 2.66, while the liquid agent W-35PGNS yielded a value of 2.64. Both sets of results confirmed that there was no cytotoxic effect observed in the controls.

In both experiments, the photocatalytic binding agent effectively mitigated viral activity using platinum nanoparticles on fibers. This was achieved within a contact time of 15 s, attributed to the uniform distribution of platinum nanoparticles on 2D surfaces of fibers.

Additionally, we conducted tests on the COVID-19 virus, yielding an R-value of 3.2, which represents a remarkable 99.94 % reduction in infectious Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). This demonstrates a significant improvement over previously established methods.

4. Discussion

While the ISO 18184:2019 standard exists for antiviral testing, the current studies primarily demonstrate their methods independently, which highlights a lack of standardization in the field. This lack of uniformity is significant, as it complicates scientific evaluations and makes third-party official tests essential for meaningful comparisons.

Our paper specifically addresses contact time, a critical factor for the effectiveness of antiviral tests. While the ISO 18184:2019 standard does not specify a required contact time, we identified that the minimum contact time for official experimental tests was 15 s. In contrast, previous studies often used a minimum contact time of 5 min.

While the measurement of antiviral activity has been standardized internationally, it appears that many researchers remain unaware of these ISO standards. Specifically, ISO 18184:2019 is an international standard that provides a comprehensive guide to the testing methods used to ascertain the antiviral activity of textile products. This includes a wide range of materials such as woven and knitted fabrics, fibres, yarns, and braids. In a typical ISO 18184:2019 test, the virus is applied to the textile for up to several hours, after which it is recovered and the remaining infectious virus is quantified. However, it's important to understand that the results of one test virus cannot be generalized to other viruses due to the unique sensitivities of each virus. Therefore, the antiviral activity of a textile product may differ based on the specific virus tested.

In our experiments, we took a significant departure from the usual contact time of several minutes or hours. Instead, we opted for a remarkably brief contact time of just 15 s. This method showcased the instantaneous inactivation of viruses when exposed to platinum nanoparticles and binders. Essentially, the duration of contact time emerges as a pivotal element in determining the swift and potent effectiveness of these agents. This underscores the remarkable speed at which these agents can neutralize viruses.

A comprehensive literature review was undertaken, focusing on the methods outlined in ISO 18184:2019 for inactivating viruses. The aim was to potentially compare performance using peer-reviewed publications sourced from the National Library of Medicine, recognized as the world's largest and most trusted database. Zanchettin et al. reviewed and detailed the procedure of ISO 18184:2019 for the processing and performance of fabrics with antipathogenic inorganic agents [8]. Regrettably, they failed to detail the crucial contact time, which serves as an indicator of the immediate effects of the agents against viruses. Qin et al. investigated and detailed the results of catalytic inactivation of influenza virus by iron oxide nanozyme [9]. Unfortunately, they did not utilize the ISO 18184:2019 standard in the absence of official certificates, which could have facilitated a potential performance comparison.

This paper unveils a groundbreaking finding related to binder-focused agents. These agents, characterized by their uniform distribution on the surface, exhibited high performance within a notably short contact time of just 15 s. The uniform distribution of these agents on the surface enables the achievement of high-performance catalytic inactivation. The effectiveness is diminished if the clumps of platinum nanoparticles are biased. However, when the platinum nanoparticles are uniformly dispersed, the effectiveness significantly increases. To substantiate this, an experiment was carried out where the typical contact time with the agent, which usually ranges from 5 min to several hours, was intentionally reduced to 15 s. A comprehensive literature review was undertaken to evaluate the correlation between virus reduction performance and contact time. The findings revealed that the minimum contact time recorded was 5 min.

Borkow and his team were able to achieve a 99 % reduction in viral activity within 2 h of exposure using medical textiles impregnated with cuprous oxide [10]. Similarly, Ma and colleagues reported a significant reduction of 7 log PFU in a virus (specifically, T7 bacteriophages) within

Table 1
Result of antiviral activity test of Influenza A virus (H3N2).

Test sample	Time	Sample	Common logarithm of Infectivity titer (PFU/mL) per 1 mL of test mixture	Common logarithm average	Common logarithm difference between negative control and test sample
PBS (Negative control)	Immediately after contact	n1	7.65	7.69	
		n2	7.70		
		n3	7.71		
	After 15sec.	n1	7.60	7.61	
		n2	7.67		
		n3	7.56		
Liquid agent (W-35PGNS)	After 15sec.	n1	<4.00	<4.00	3.6
		n2	<4.00		
		n3	<4.00		

Virus strain: Influenza A virus (H3N2): A/Hong Kong/8/68; TC adapted ATCC VR-1679.
Viral inoculum suspension: 5.0×10^8 PFU/mL.

Table 2
Result of antiviral activity test of Feline calicivirus.

Test sample	Time	Sample	Common logarithm of Infectivity titer (PFU/mL) per 1 mL of test mixture	Common logarithm average	Common logarithm difference between negative control and test sample
PBS (Negative control)	Immediately after contact	n1	7.28	7.30	
		n2	7.32		
		n3	7.30		
	After 15sec.	n1	7.20	7.27	
		n2	7.30		
		n3	7.29		
Liquid agent (W-35PGNS)	After 15sec.	n1	4.16	4.25	3.0
		n2	4.22		
		n3	4.38		

Virus strain: Feline calicivirus; Strain: F-9 ATCC VR-782.
Test virus suspension: 2.0×10^8 PFU/mL.

just 5 min of contact [11].

Hussain and his team demonstrated the effectiveness of antiviral cotton fabrics enhanced with nano-embossed copper oxide [12]. They reported a significant reduction of 99.99 % in viral activity within a contact time of 2 h [12].

Gonzalez et al. introduced a new method for synthesizing nanocomposites, enabling the growth of zinc oxide nanoparticles within textiles and face mask materials [13]. These nanoparticles, known for their antimicrobial properties, were safely used in various products. The nanocomposite achieved a reduction of over 99.9 % in coronavirus titer within 10 min, effectively disintegrating the viral envelope [13].

Rao et al. presented an efficient antiviral filter, created by combining curcumin with a nanofibrous polytetrafluoroethylene membrane [14]. The filter demonstrated high gas permeance and ultrafine particle rejection rate (>98.79 %). It exhibited a high antibacterial rate against various bacteria (99.84 % for E. coli, 99.02 % for B. subtilis, 93.60 % for A. niger, and 95.23 % for Penicillium). The filter's virucidal efficiency against SARS-CoV-2 reached 99.90 % within 5 min [14].

After a contact time of 2 h, the ultra-thin Ag–Cu film face masks exhibited an average virus titer of 4.91, corresponding to an antiviral activity value of 2.04 ± 0.1412 [15]. Huang et al. provided evidence of the ultra-thin Ag–Cu film face mask's effectiveness in inactivating the influenza A virus H1N1, achieving an impressive antiviral activity rate of up to 99.02 % [15].

Bromberg et al. demonstrated the creation of reusable, polymer-modified, and halogenated textile materials with rapid, durable, and rechargeable antiviral activity [16]. Fabric coupons, modified with PHMB-Br, PVG-Br, and PAH-Br, were sterilized and subjected to a halogenation procedure. The recharged coupons exhibited a >99 % coronavirus inactivation rate. The fabrics, coated with halogenated PHMB, PVG, and PAH, completely inactivated respiratory coronavirus 229E in 0.5-h tests. Their study also highlighted the use of industry-accepted techniques and the maintenance of biocidal properties against various bacteria [16].

Existing studies indicate that the shortest recorded contact time was 5 min. However, this research, which introduces photocatalytic binders infused with platinum nanoparticles as potent antiviral agents, brings new insights to the realms of catalysis and antiviral research. It does so by demonstrating effective virus inactivation within an unprecedentedly brief contact time of just 15 s. In the first test, the antiviral activity against Influenza A virus (H3N2) was 3.6. This suggests a 99.97 % reduction in norovirus inactivation. The second test showed an antiviral activity of 3.0 against Feline calicivirus. This indicates a 99.9 % reduction in norovirus inactivation. Both tests had a contact time of just 15 s.

The two outcomes suggest that the uniform distribution of platinum nanoparticles on 2D surfaces due to silica-based photocatalytic binders significantly contributes to the inactivation of viruses, including the Influenza A virus (H3N2) and Feline calicivirus.

Based on the recent studies [17,18], in catalytic inactivation of viruses, oxygen plays a crucial role. The process involves the formation of reactive oxygen species (ROS), which are highly reactive molecules that can damage biological structures and inactivate viruses. In photocatalytic processes, for instance, light energy is used to excite a catalyst, which then interacts with oxygen to produce ROS. These ROS, including hydroxyl (OH●) and superoxide (O2●−) radicals, can rupture the protective shell of the virus, leading to loss of pathogenicity. Similarly, in photodynamic inactivation, a photosensitizing compound is combined with molecular oxygen and the proper wavelength of illumination to form ROS that damage nearby biological tissues and structures, including viruses. So, in these processes, oxygen is not removed but rather involved in the formation of ROS that inactivate the viruses. Therefore, the presence of oxygen is essential for the catalytic inactivation of viruses. Further research is required to explore the activities of ROS) in future studies.

This study highlights the promising potential of employing sprayed binders as a method to deactivate viruses across a diverse range of surfaces, extending beyond just fibers. The catalytic inactivation of viruses is essential for a wide range of items to prevent the spread of germs and ensure hygiene. This includes medical supplies such as surgical instruments, gloves, and face masks, which are critical for protecting patients and healthcare workers. In the kitchen, items like cutting boards, utensils, and dishes need to be treated to ensure safe food handling. Antibacterial properties are beneficial for maintaining cleanliness in indoor environments, affecting items like carpets, curtains, wallpapers, and flooring. This also extends to toys, personal care items, and sports equipment. Food containers extend the freshness and edible lifespan of fruits and vegetables.

The binder is instrumental in neutralizing viruses, leveraging the effects of silica photocatalysis. Silica-based materials are frequently employed in photocatalysis, attributed to their unique features such as expansive surface area, customizable porosity, and adaptable surface. Here are some recognized silica materials used in photocatalysis:

1. Aminated Silica Colloids (NH2-SiO2 NPs) [19]: These are silica nanoparticles that have been functionalized with amine groups. They have been used in various photocatalytic applications due to their enhanced reactivity.
2. Ag NPs-Decorated Silica (Ag-SiO2 NPs) [20]: This refers to silica nanoparticles that have been decorated with silver nanoparticles. The presence of silver enhances the photocatalytic activity of the silica nanoparticles.
3. Silicon Composites (Si-BC) [21]: This is a silicon precursor that is often used in the synthesis of silica-based materials for photocatalysis.
4. Silica-Titania Composites [22]: These composites combine the advantages of both silica and titania, offering improved photocatalytic performance.
5. Dye-Sensitized Silica Materials [23]: These materials are sensitized with dyes to enhance their light absorption capabilities, thereby improving their photocatalytic activity.

6. Silica-Supported Metal Oxides [24]: In these materials, metal oxides are supported on a silica matrix, which can enhance the stability and photocatalytic performance of the metal oxides.
7. Silica-Supported Metals [25]: In these materials, metals are supported on a silica matrix, which can enhance the stability and photocatalytic performance.

This research presents Silica-Platinum composites as an innovative photocatalytic material. Official testing has confirmed its rapid and effective virus inactivation capabilities.

5. Diverse applications

The primary emphasis is on antiviral textiles. The binder plays a crucial role in maintaining the suspension of platinum nanoparticles in the spray, ensuring an even coating on the fibers. This results in a durable inactivation of viruses not only on fabrics but also on a variety of surfaces such as glasses, metals and any surfaces. In essence, it provides a comprehensive and enduring protection against viruses across multiple surfaces.

This paper highlights the importance of sustainability in ICUs and hospitals, where special infection protection is crucial. Obitková et al. recommended replacing the HEPA nanotextile monolayer three times, with a replacement interval of approximately 33 h, which imposes a significant burden [2]. The proposed technology alleviates this burden by eliminating the need for frequent replacements and enhancing sustainability through the instantaneous inactivation of viruses. This innovation not only extends the lifespan of the filtration system but also contributes to a more efficient and environmentally friendly solution for maintaining clean air and safe environments in medical settings.

Medical textiles: Washable and reusable surgical instruments, gloves, face masks.

Household items: Cutting boards, utensils, dishes (providing long-term antiviral protection).

However, the true potential lies in the versatility of the spray format. Here's a glimpse into the exciting possibilities:

Personal items: Toys, sports equipment (facilitating easy disinfection on the go).

Public surfaces: Doorknobs, light switches, elevator buttons, touchscreens (providing long-term antiviral protection in public spaces).

Transportation: Seats, handrails on buses, trains, airplanes (enhancing hygiene and passenger safety).

Food service industry: Tables, menus, trays (promoting sanitation in restaurants).

Eyewear: Glasses, goggles (offering an additional layer of antiviral protection).

Electronics: Keyboards, phones (facilitating disinfection of frequently touched surfaces).

Further research is crucial to explore the effectiveness and safety of the spray on various materials applicable to plastics, metals, ceramics, glass, and composites. However, this innovation holds immense promise for creating a new generation of antiviral products for everyday use, fostering a cleaner and healthier environment.

6. Conclusion

This study demonstrates a significant breakthrough in rapid virus inactivation technology through the novel application of platinum nanoparticles with photocatalytic binders. The research achieved unprecedented viral reduction rates of 99.97 % against Influenza A virus (H3N2) and 99.9 % against Feline Calicivirus within just 15 s, marking a substantial improvement over existing methods that require minutes to hours for effective virus inactivation.

The key to this remarkable performance lies in the uniform distribution of platinum nanoparticles on textile surfaces, facilitated by the photocatalytic binders. This uniform distribution, confirmed through microscopic analysis, enables efficient catalytic inactivation of viruses through the formation of reactive oxygen species (ROS). The significantly reduced contact time of 15 s, compared to the previous minimum of 5 min reported in literature, represents a major advancement in antiviral technology.

These findings have broad implications for various applications, from healthcare settings to everyday protective materials. This technology shows promise as a versatile solution for rapid inactivation of enveloped and non-enveloped viruses, with further research needed to confirm efficacy against other pathogens.

Consent to participate

Not applicable.

Ethics approval

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

Not applicable.

Code availability

Not applicable.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.micpath.2025.107965.

Data availability

No data was used for the research described in the article.

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