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Preventing the Spread of Coronavirus on Surfaces

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ABSTRACT

The evolution of new and reemerging virulent strains of respiratory viruses from animal reservoirs and among the population is a significant threat to human health. Respiratory viruses are responsible for more deaths globally than any other infectious agent. The recently discovered Coronavirus (COVID 19) is responsible for a devastating illness with a high death toll [1]. In the absence of proven therapeutics, most emphasis has to be put on prevention e.g., distancing, decreased public contacts, masks, handwashing with soap and hot water [2]. Immunisations if they reach herd immunity could contribute to contain the illness [3]. However, the major achievement of the immunisation is the prevention of a severe course of the disease and death as even immunised persons might still spread the virus [4].

Introduction

Early studies suggested that SARS-CoV2 is transmitted directly through respiratory droplets from infected individuals [5]. Human-to-human transmission is the main route of infection, presenting a substantial threat of rapid spread of the virus throughout the community. It is documented that also persons with mild or clinically unapparent disease can spread the virus. However, as a greater understanding of the virus is achieved, the routes of transmission have been widened by the WHO to include possible human-human contact, droplet, airborne, fomite, fecal-oral, bloodborne, mother-to-child and animal-to-human transmission [6]. Increasing concern of contact transmission during outbreaks has been cited. Viruses are spread by droplets expelled by coughs and sneezes, which can contaminate surfaces. Ample evidence in the literature indicates that pathogenic human coronavirus contaminate the environment 2 m to 6 m away, respectively [5], and a single droplet may easily contain an infectious dose.

Viral pathogens are surviving on a surface if epithelial cell material is contained in the droplets for an extended period of time [7]. There are reports of a human lung cell culture model show persistence of infectious viral particles at least 5 days of on a range of common nonbiocidal surface materials, including polytetrafluoroethylene (Teflon; PTFE), polyvinyl chloride (PVC), ceramic tiles, glass, silicone rubber and stainless steel [8]. It has been shown in the literature that several factors are pertinent to the antiviral activity of sanitising agents. Numerous compounds have been recommended [9]. Alcohol-based agents cause dissolution of the lipid membrane and denature proteins, thereby disrupting the virus membrane and inhibiting metabolism. The concentration of alcohol in hand-cleansing products, the volume used, contact time, degree of soiling, product formulation and use of excipients are some of the critical factors that affect the efficacy of alcohol against viruses.

Lipid membrane dissolution and protein denaturation are key mechanisms of the antimicrobial action of ethanol, leading to the disruption of membrane and inhibition of metabolism [10]. The outermost membrane of SARS-CoV-2 comprises of lipids bound together by an alkane chain of hydrophobic fatty acids. Alcohols are amphophilic compounds, as they possess both hydrophilic and lipophilic (hydrophobic) properties that facilitate their entry through the viral envelope. Contact of the virus with alcohol leads to alteration in its membrane fluidity. The antimicrobial mechanism of alcohol against enveloped viruses is similar to that for bacteria as both have a lipid-rich outer membrane. Non-enveloped viruses are relatively more resistant to this mechanism due to the lack of a lipid membrane. Raising the ethanol content may address this issue to some degree but increases the risk of tissue toxicity and lowers the flash point. At present, only one formulation with broad

virucidal activity exists with an ethanol content of 95 vol% [9]. The 70% ethanol control group was unable to completely inactivate SARS-CoV-2 after 15 seconds of contact but was able to inactivate the virus at 30 seconds of contact.

Efforts were made to reduce the ethanol content without reducing the virucidal activity to decrease the flash point and increase skin tolerance and compliance. As a result of these efforts, a synergistic combination was developed with an ethanol content of 55% (w/w) in combination with 10% (w/w) propan-1-ol, 5.9% (w/w) propan-1.2-diol, 5.7% (w/w) butan-1.3-diol and 0.7% phosphoric acid [10]. The crucial problem of alcoholic disinfectants however is the lack durability and a lasting efficacy-within 60 minutes the alcohol is evaporated and the activity vanishes. Also, povidone iodine (PVP-I) oral antiseptic preparations rapidly inactivates SARS-CoV-2 virus in vitro. The virucidal activity was present at the lowest concentration of 0.5 % PVP-I and at the lowest contact time of 15 seconds [10]. PVP-I oral antiseptic preparations rapidly inactivated SARS-CoV-2 virus in vitro. The virucidal activity of PVP-I oral antiseptic solution was present at the lowest concentration of 0.5 %, and at the lowest contact time of 15 seconds.

This important finding warrants the use of preprocedural oral rinsing with 0.5% PVP-I for patients and health care providers. This solution serves as an adjunct to personal protective equipment for dental and surgical specialties during the COVID-19 pandemic. Hand hygiene by washing hands with soap and water or with alcohol-based hand sanitisers are primary preventive measures against the spread of SARS-CoV-2 [11]. "Benzalkonium chloride, along with both ethanol and isopropanol, is deemed eligible by the FDA for use in the formulation of healthcare personnel hand rubs. However, available evidence indicates that benzalkonium chloride has less reliable activity against coronavirus than either of the alcohols [12]. At the same time, a dramatic increase in the number microorganisms with multiresistant activity against antibiotics has been observed [13].

Also, alcohol tolerant microorganisms have been observed by the use of benzalkonium chloride. The use of quaternary ammonium disinfectants e.g. benzalkonium chloride was identified as the cause of this phenomenon by rapidly inducing efflux pumps eliminating every antibiotic from the cell [14]. The development of germ-free surfaces - the correct term is "selfsanitizing surfaces" - was offered as the solution. The presence of polar oxygen atoms weaken the lipophilic interactions between the non-polar residues, and increase the internal affinity of the membrane for water, thus destabilising and denaturing the protein structure [15]. Mutants the so-called 'super-spreading events' emerged recently mandating additional efforts to contain the spread of the virus [16]. Preventive measures such as social distancing, quarantine, cough etiquettes, proper hand washing, cleaning and decontaminating the surfaces are the mainstay for curbing the transmission of this virus [17-20].

Therefore, there is an urgent need to continue to search for innovative and ambitious new therapeutic and preventive modalities, which may be at least as effective also against multidrug resistant bacterial microorganisms. It is mandatory for limiting the transmission by decontamination of surfaces. In addition also the development of selfsanitizing surfaces which eradicate viral pathogens on a surface. The requirements of self-sanitizing surfaces for application in hospitals, public transportation, the food industry etc. are extraordinarily high.

a) Intensive and broad antimicrobial activity, against Gram-positive, Gram-negative microorganisms, irrespective of their antibiotic susceptibility, fungi, legionella, moulds, virus documented by the RODAC plate method

b) Fast eradication of microorganisms i.e. minimum 5 log 10 reduction within 1 hour

c) Activity against a high inoculum size of 109 CFU on an area of $3cm^2$

d) No induction of resistance

e) Nontoxic, skin and soft tissue compatibility, no allergenicity, sbD (safe by design)

f) Long lasting/permanent antimicrobial activity

1. water-, acid-, alkaline-, alcohol insoluble, UV Light stabile

g) Cleanable with detergents

h) Uncomplicated technical processability, heat stabile up to 400°C, non corrosive

i) Physical stability, activity irrespective of sweat, grease, blood, pus

j) Not flammable, smoke reduction

k) BP authorisation by the European commission on biocidal products.

l) Favourable cost/benefit analysis

Rapid inactivation of human coronavirus occurs on brass and copper nickel surfaces at room temperature (21°C) has been found [20]. Brasses containing at least 70% copper were very effective at inactivating HuCoV-229E and the rate of inactivation was directly proportional to the percentage of copper. Copper surfaces however oxidize rapidly and require frequent cleaning. Also, the optical appearance is not acceptable. In the past decades, accumulated scientific findings confirmed also the role of additional antimicrobial modes e.g. free radicals damage in respiratory virus infection [21]. The occurrence of electrostatic repulsion forces between similar types of electric charge was described; their origin in FDS emulsions can be explained by ionization and adsorption mechanisms. This suggests the mechanisms of antimicrobial activity of nanoscaled particles. Classical explanations suggest that

an electric double layer is formed by the diffusion of counterions and coions towards the surface and near-surface positions.

The DLVO theory describes the interactions between two liquid droplets or particles at distances around 30-40 nm; however, at smaller distances, when atomic electron clouds are superimposed, strong boron repulsion occurs. Finally, for very small separations, non-DLVO forces must also be taken into account when studying the change in potential energy. The antimicrobial activity of nanoparticles is explained in part by the formation of reactive oxygen formation (ROS). Alternatively electrostatic attraction between metal nanoparticles and microbial cells which disrupt metabolic activities has been detected as well [22].

The endowment of surfaces with nanoparticles however is not practical:

a) Nanocoatings are difficult to implement on surfaces:

Antimicrobial technologies using nanomaterials e.g. chitosan, cellulose etc. must be incorporated into nanorods or nanomats. It is extraordinary difficult to fix these compounds stabile on a surface and preserving their antimicrobial activity. .

b) Nanoparticles incorporated into polymers loose their antimicrobial efficacy

c) Nanocoatings are generally not heat resistant, difficult to manufacture

d) Nanotechnologies are subject to approval by the Biocidal product regulation (BPR) of the European Union. The requirements of biocidal product regulation for nanotechnologies are time consuming and expensive. Nanoparticles can not achieve antimicrobial activity if incorporated into polymers. None of the nanoproducts passed the biocidal regulation up to this point in time.

e) Expensive

These properties and more can be achieved easier by in situ generated biocides. Investigation of additional modes to eradicate coronavirus from surfaces disclosed that an acid environment, free radicals e.g. oxygen radicals but also hydroxyl radicals and positive electrostatic surface properties are able to eradicate the coronavirus and don't induce the emergence of multiresistant bacterial microorganisms. Various metal oxides which act as catalysts have different physico-chemical properties and also different antimicrobial activity. Metal oxides function as in situ generated biocides and remain in the composite material or in a coating. By electron transfer they transform ambient water into the formation of acidic surfaces (analogous to the acid coating of the skin) the formation of free radicals such as oxygen radicals and hydroxyl ions and a positive zeta potential. The crucial requirement of these in situ generated biocides is a hydrophilic surface with a contact angle of 30° or less.

This can be achieved by addition of various hydrophilising agents e.g. glyzerin stearate, sorbitol ester, aerosil or substances like crodamol, fleroxacin, lubrophos etc. Molybdenum oxide is active against a variety of bacterial microorganisms and fungi just as the 5% oxygen deficient tungsten blue oxide. The difference between these is the water solubility (0.003 mol/l at a pH value > 7.55) of Molybdenum oxide in contrast to tungsten oxide which is entirely water insoluble. In addition molybdenum is also not UV light stabile and contains a light blue color on a surface. This can be overcome by the use of Zinc Molybdate where the Molybdenum oxide is incorporated into a Zinc oxide crystal structure [23]. The mechanism of activity is similar to molybdenum and tungsten blue oxides. Zinc Molybdate has a white color, is UV light stabile, water and alcohol insoluble and shows broad antimicrobial activity including influenza virus (influenza, bird flu and swine flu).

Submicron particles (Lambda half) provide a transparent surface of glass and plastic surfaces. Investigations to overcome the water solubility of molybdenum oxide have been performed. In this project Polyoxometallates (POMs) have been manufactured by combination of equimolar concentrations of ammonium dimolybdate (NH4)2Mo2O7 (ADM) and ammonium metatungstate (NH4)6[H2W12O40]· $3H_2O$ (AMT) in the same crystal structure. This is easily achieved as both substances exhibit similar ion radius. These compounds are of interest in the fields of catalysis, electronics, magnetic materials and antimicrobial activity [24]. POMs are formed. By the incorporation of molybdenum blue oxide into the tungsten crystal lattice a number of favourable properties have been achieved e.g. water and alcohol insolubility. The antimicrobial activity of polyoxometallates also based on in situ generated biocides by incorporation of transition metal oxides into composite materials or coatings.

However a number of additional properties have been observed. POMs exhibit strong antimicrobial activity against virtually all bacterial microorganisms regardless of their resistance to antibiotics and disinfectants in addition to fungi, molds (Aspergillus spp.), enveloped and nonenveloped virus based on a strong Zeta potential. Moreover, POMs were shown to exhibit biological activities in vitro and in vivo, such as antitumor and antidiabetic activity. Last not least also a strong antifouling activity has been documented. Astonishingly very few medical professionals mention the crucial role of free radical damage in COVID-19. The crucial pathogenic role of free radical damage in respiratory virus induced pneumonia suggest an antioxidative therapeutic strategy for COVID-19 [25,26]. The potential anti-SARS activity (severe acute respiratory syndrome) of the POMs [alpha-PTi(2)W(10) O(40)](7-) isomers was investigated. The SARS 3c-like protease, namely SARS 3CL(pro), is the key function of the protease for both viral replication and transcription and can therefore be considered as one of the main targets for the development of anti-SARS drugs.

Affinity/Insight II was used to study possible binding sites for the interaction of POMs/3CL(pro). The charges in the POMs were determined using the method of density functional theory (DFT). The results show that POMs bind with 3CL(pro) in the region of the active center with high affinity; POMs are more susceptible to binding with 3CL(pro) than with some organic compounds; for the POMs/3CL(pro) complex, OTi(2) in POMs is the crucial element for the electrostatic interaction, and the electrostatic binding energy is strong enough to keep the complex stable. The activity against coronavirus is based also on electric charges by the polyoxometallates (POMs) which were obtained from density-functional theory (DFT) method. The results show that POMs bind with 3CLpro in the active site region of coronavirus with high affinity; POMs are more prone to bind with 3CLpro than with some organic compounds; for the POMs/3CLprocomplex, the OTi2 in POMs is the element for electrostatic interaction, and the electrostatic binding energy is strong enough to keep the complex stable.

Different combination of Molybdenum oxide and tungsten oxide of POMs have been created with similar antimicrobial activity. POMs with incorporation of Molybdenum oxide into the tungsten crystal lattice show an exceptional strong Zeta potential responsible to the superior fast antimicrobial activity resulting in a 7 log 10 reduction of microorganisms in less than one hour. The potential anti-SARS activity (severe acute respiratory syndrome) of the POMs [alpha-PTi(2)W(10)O(40)](7-) isomers was investigated. The SARS 3c-like protease, namely SARS 3CL(pro), is the key function of the protease for both viral replication and transcription and can therefore be considered as one of the main targets for the development of anti-SARS drugs. Affinity/Insight II was used to study possible binding sites for the interaction of POMs/3CL(pro). The charges in the POMs were determined using the method of density functional theory (DFT). The results show that POMs bind with 3CL(pro) in the region of the active center with high affinity; POMs are more susceptible to binding with 3CL(pro) than with some organic compounds; for the POMs/3CL(pro) complex, OTi(2) in POMs is the crucial element for the electrostatic interaction, and the electrostatic binding energy is strong enough to keep the complex stable.

The SARS 3c like protease, namely the SARS 3CLpro is the key function protease for virus replication as well as transcription and thus can be taken as one of the key targets for anti-SARS drug design. Affinity/Insight II was used to explore possible binding locations for POMs/3CLpro interaction. The broad antimicrobial efficacy of the polyoxometallates is based on the synergistic effectiveness of 3 mechanisms which leads to a rapid elimination of viral and bacterial microorganisms and fungi in situ on surfaces. Because the active substances of this technology do not integrate the antimicrobial into the metabolism of the microorganisms, there is no induction of resistance and a permanent antimicrobial effectiveness (proven for at least 10 years). These metal oxides have a broad antimicrobial spectrum of activity against Gram positive and Gram negative microorganisms regardless of resistance to antibiotics and numerous viruses.

The antiviral efficacy is especially described for polyoxometalates as enveloped viruses such as hepatitis B, hepatitis C, influenza viruses, herpes viruses, Epstein Barr viruses. It was therefore obvious and of particular interest in the present situation to investigate the antiviral effectiveness of polyoxometallates in plastics or in coatings in surfaces against corona viruses. As surfaces can be colonized by infected/contaminated persons with corona viruses and harbour infection-prone viruses for over 72 hours. Surfaces that can neutralize corona viruses on a surface within a short period of time as "self-sanitizing surfaces" are highly desirable for containing the spread of pathogens. As in situ generated biocides, polyoxometallates have an antibacterial efficacy against a multitude of bacterial microorganisms, fungi and Aspergillus spp. but also against a number of enveloped viral pathogens such as hepatitis B, hepatitis C, enveloped viruses such as herpes viruses as well as vaccinia virus.

In the literature an activity of polyoxometallates with a titanium doping in a surface against corona viruses is described. POM's [alpha-PTi(2)W(10)O(40)](7-) titanium is used to form an electrostatic potential at the surface and free radicals such as oxygen radicals to enhance the effectiveness of polyoxometalates. This is also the basis for its effectiveness against viruses. Hu et al. also describes the effectiveness of various acids such as free fatty acids, glucuronic acid, galacturonic acid against viruses including corona viruses. Antiviral effectiveness has also been described by lipid peroxidase, and nitric oxide radical scavenging assays. As a better alternative, several other polyoxometalates have been prepared using a combination of tungsten oxides with molybdenum oxides, which have a strong zeta potential. The formula is paramolybdotungstate [H2Mo6W6O42].

Polyoxometalates can also be incorporated into various polymer surfaces or into a transparent coating e.g. liquid polyurethane, liquid silicone and other coating materials such as paints, which can be applied within one hour. The duration of effectiveness of such surfaces against bacterial microorganisms is at least 10 years and has been confirmed by appropriate tests. The effectiveness is not affected by detergents, alcohol and water.

The Technology of Polyoxometallates:

2% polyoxometallate 2:1 Mo:W in combination with 1% zinc molybdate to maintain the electrostatic charge of the surface was produced and can be applied to various composite materials e.g. polyimines and thermoplastic polyurethanes.The surface must be hydrophilic with a contact angle of < 30°.

Production of Polyoxometalates Mo:W 2:1,

The production of polyoxometalates has been established and is protected by patents. Also, the antimicrobial activity zinc molybdate

(incorporation of molybdenum oxide into the orthorhombic and monocline zinc oxide crystal structure) has been documented. The production of polyoxometalates was first carried out on an extended laboratory scale in quantities of 25 kg. At present the polyoxometalate as well as the zinc molybdate can be produced commercially in unlimited quantities. The coating material is silicon dioxide - water glass, silicium dioxide, liquid polyurethane, liquid silicone and also transparent melamine resins which dry on a surface within 20 minutes and results in a transparent layer. Polyoxometalates have broad antiviral efficacy. The surface, equipped with submicron particles of polyoxometalates Mo:W 2:1, meets a number of essential requirements, which are listed in the following table.

a) Wide antiviral effectiveness against a wide range of viruses Hepatitis B, C, herpes virus and the enveloped virus. Other pathogenic viruses as well as multi-resistant bacterial microorganisms including moulds and algae are covered by the spectrum of activity of polymetatungstate.

b) Rapid elimination of the pathogenic viruses on a contaminated surface, within 30 minutes.

c) No induction of resistance

d) Permanent effectiveness over years. Documented activity of 10 years for bacteria and fungi. No elution of the polyoxometallates from the surface has been observed. Polyoxometallates are insoluble in water, alcohol and detergents.

e) No loss of effectiveness after 1000 cleanings with detergents

f) No toxicity

g) Heat stable up to 400°C

Ti-containing alpha-keggin-polyoxometalates (POMs) have been described with properties against both tumors and HIV (Human Immunodeficiency Virus). The potential anti-SARS activity (severe acute respiratory syndrome) of the POMs [alpha-PTi(2) W(10)O(40)](7-) isomers was investigated in a study using a molecular modelling method [27-31]. The SARS 3c-like protease, namely SARS 3CL(pro), is the key function of the protease for both viral replication and transcription and can therefore be considered as one of the main targets for the development of anti-SARS drugs. Affinity/Insight II was used to study possible binding sites for the interaction of POMs/3CL(pro). The charges in the POMs were determined using the method of density functional theory (DFT).

The results show that POMs bind with 3CL(pro) in the region of the active center with high affinity; POMs are more susceptible to binding with 3CL(pro) than with some organic compounds; for the POMs/3CL(pro) complex, OTi (2) in POMs is the crucial element for the electrostatic interaction, and the electrostatic binding energy is strong enough to keep the complex stable. Polyoxometalate (POM) shows broad-spectrum inhibition, high efficiency and low toxicity. In a publication by Hu, the binding mechanisms of five isomers of di-Ti-substituted polyoxotungstate, [α-1,2-PTi2W10O40]7- (α-1, 2), [α-1,6-PTi2W10O40]7- (α-1,6), [α-1,5-PTi2W10O40]7- (α-1,5), [α-1,4-PTi2W10O40]7- (α-1,4) and [α-1,11-PTi2W10O40]7- (α-1,11). Up to five subtypes of influenza virus A neuraminidase (FluV-A NA) were investigated in aqueous solution using molecular docking and molecular dynamics studies.

The results show that the isomer α-1,2 is superior to other isomers as a potential inhibitor of neuraminidase. The positively charged arginine residues around the active site of NA could be induced to adapt by negatively charged POM and could form salt bridge interactions and hydrogen bridge interactions with POM. The free binding energies of POM/NA complexes range from -5.36 to -8.31 kcal mol-1. In a publication by Hu, the binding mechanisms of five isomers of di-Ti-substituted polyoxotungstate, [α-1,2-PTi2W10O40]7- (α-1, 2), [α-1,6-PTi2W10O40]7- (α-1,6), [α-1,5-PTi2W10O40]7- (α-1,5), [α-1,4-PTi2W10O40]7- (α-1,4) and [α-1,11-PTi2W10O40]7- (α-1,11). Up to five subtypes of influenza virus A neuraminidase (FluV-A NA) were investigated in aqueous solution using molecular docking and molecular dynamics studies. The results show that the isomer α-1,2 is superior to other isomers as a potential inhibitor of neuraminidase. The positively charged arginine residues around the active site of NA could be induced to adapt by negatively charged POM and could form salt bridge interactions and hydrogen bridge interactions with POM.

The free binding energies of POM/NA complexes range from -5.36 to -8.31 kcal mol-1. Electrostatic interactions are considered to be the driving force during the binding process of POM to NA. The conformational analysis shows that POM tends to bind mainly with N1 and N8 at the edge of the active pocket, causing the conformational change of the pliers structure consisting of rest 347 and loop 150. On the other hand, the active pockets of N2, N9 and N4 are perceived as more spacious, which allows POM to penetrate directly into the active pockets and anchor firmly. This study shows that a negatively charged ligand like POM could induce the reorganization of the active center of NA, and highlights POM as a promising inhibitor of NA despite the ever-increasing number of mutants of NA. POMs are composed of (MOx)n-polyyhedra; as a metal, only transition metals such as vanadium, molybdenum, tungsten, as well as niobium and tantalum are found in POM species in high oxidation states.

Regarding the additive it has been shown, that the molybdenum doped polyoxometallate paramolybdotungstate [H2Mo6W6O42]10- has the highest zeta potential and positive electrostatic property, which is of primary importance for the antiviral property and a high concentration of free radicals and H3O+ ions on the surface. The decisive factor, however, is in addition a hydrophilic, i.e. wettable surface with a contact angle of 30° or less.

This is achieved by adding glycerine stearate 1%, sorbitol ester or other hydrophilising agents e.g. aerosil. Catalyst in redox processes (e.g. the oxidation of aldehydes to carboxylic acids or the oxidation of methane), dehydrogenation (e.g. in the formation of alkenes) or the splitting of water into oxygen and hydrogen and many others. Highly selective inhibition of enzymes has been observed as well as antitumoral and antiviral effects both *in vitro* and *in vivo*.

Also, excellent activity against algae has been documented. The primary goal of these investigations, which have been ongoing since 2002, was the prevention of hospital-acquired infections, which are responsible for numerous deaths.

Polyoxometallates With Anti-Corona Virus Activity

Investigation of Antiviral Activity

The product passed the EN14476(liquid disinfectant test) in 2 hours with a 4log reduction. The treated surfaces killed 88% more than the control surface in 2 hours. However, these samples showed a less sufficient hydrophilicity with a contact angle of 52°. This is not sufficient as a hydrophilic surface with a contact angle of less than 30° is required. Therefore, additional tests with samples with sufficient hydrophilicity and a contact angle of 26° by addition of various hydrophilising agents e.g. sorbitol alcohol, aerosil have been performed and virtually a complete eradication of the corona virus load in comparison with a non treated surface has been achieved within 2 hours.

Summary

Coronavirus survives 2-4 days in inert surfaces and is still contagious. The elimination of COVID 19 from contaminated surfaces is desirable by alcoholic solutions containing at least 65 % alcohol. The duration of alcoholic solutions is approximately 4 hours, it has to reapplied again. Numerous other technologies have been investigated with insufficient results preventing the application of these Surfaces with long lasting activity against coronavirus can be provided. However new and innovative technologies e.g. acidity of a surface, formation of free radicals like oxygen radicals and hydroxyl radicals and electrostatic surface charges have to be used. The in situ generated biocides can be achieved by transition metal oxides. Polyoxometallates show a high zeta potential and eradicate Coronavirus, bacterial microorganisms and fungi within a few hours from a surface. Additives are not toxic and legitimately on the market. The technology is highly cost effective.

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