The use of cold plasma technology in the surface disinfection system

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Abstract. The work is devoted to the presentation of the system analysis results of hierarchical processes of the viral pandemic and development, based on the use of cold plasma, of technical means to counteract viral threats. The main place is occupied by the description of the application of cold plasma technologies for the purpose of viral disinfection and counteracting the spread of viruses in various environments. The results of practical field experiments are presented.

1. Introduction
At the end of 2019, the COVID-19 pandemic, (now known as SARS-CoV-2, previously under the temporary name 2019-nCoV), a new, possibly most dangerous in human history, type of coronavirus broke out. COVID-19 began to spread unusually quickly to almost the entire world. Millions of people have died, and hundreds of millions are infected [1,2]. The World Health Organization warns that the worst-case scenarios for the spread and impact of COVID-19 are very real.

From the point of view of virology and epidemiology, the new type of coronavirus COVID-19 (figure 1), has special epidemiological characteristics:

• multiplies very quickly and has a wide range of distribution;
• under normal conditions of the atmosphere and temperature, it retains an increased, long survivability on the surface of objects and in the air;
• attacks the human respiratory system, causes severe pneumonia, cardiovascular, can lead to rapid death.

The number of calls is very high and they are dangerous. The situation is completely new. Analogs are viewed with great difficulty. A comparison is possible with the Medieval Plague, which destroyed most of the population of Europe.

From the analysis of the existing problems, it became completely clear that it is necessary to create completely new technologies and systems of devices that have not existed so far to counter virus threats.

The available methodological and hardware resources in no way provide a solution to the problem of combating the existing and possible, expected in the near future, the number and content of challenges and threats.

Thus, ideologically new methods, as well as the development and application of specialized technology should be built on new principles with special requirements for the non-use of chemicals...
that are harmful to humans and the environment. This is extremely important, since the means of combating COVID-19 are mainly used in confined or confined spaces, in cities and towns, in social, residential, transport, industrial, educational, special medical centres, etc.

Research and development of scientific and technological systems capable of quickly disinfecting different types of surfaces under normal conditions and destroying the coronavirus are very urgent tasks in order to prevent the spread and continuation of the outbreak of the COVID-19 pandemic.

2. Systematization of the problem

From the standpoint of modern system analysis of the phenomenon, the appearance and spread of viral megapopulations on a global scale can be characterized by the following levels and characters of influence:

1. The level of all Nature, the level of everything that exists and lives on Earth. Many thinkers assume that all cataclysms, natural disasters, pandemics, occur due to a violation of harmony with nature and a hostile attitude.
2. The level of individual countries and world regions. It is distinguished by the presence of obstacles in the penetration of virus populations due to the existence of borders, controls and restrictions on the movement of goods and human flows.
3. The level of individual economic and social entities within level 2 - cities, districts, etc. This is the level of spread of viral populations on a mega scale, which is determined by infrastructure facilities and can be regulated by administrative decisions within the entire education. Together with the regulation of interaction with other entities of this level, especially neighbouring ones.
4. The level of direct, local manifestation of the activity of viral populations, within groups of people located within various infrastructure facilities - settlements, social, industrial and transport facilities, etc.
5. The level of direct infection and exposure to the organisms of individual people. This level is crucial and crucial in the overall problem of viral danger.

The mechanism of influence of the viral population of this level is the direct penetration of the virus into the human body, which occurs mainly by airborne droplets or through tactile contacts.

The virus tries to enter the cells of the attacked (host) organism and start using cellular material. To enter the cell, the surface proteins of the virus bind to specific surface proteins of the cell. Attachment, or adsorption, occurs between the viral particle and the cell membrane. A hole is formed in the membrane, and the viral particle or only the genetic material gets inside the cell, where the virus will multiply.
Then there are the processes of mass reproduction of viruses and the destruction of the cell itself. The consequences are damage to the body of the affected organism, the occurrence of various diseases, which can lead to a fatal outcome and has severe long-term consequences.

A huge amount of work has been devoted to the problem of the life cycle of the COVID-19 virus and its introduction into the human body. We note the works [1-7] and the analysis of experimental data conducted by Shi Nguyen-Kuok [3-5].

Currently, a fairly large number of expert systems and systems for mathematical, analytical and simulation modelling of the processes of the origin and this life cycle of COVID-19 have been developed and are being used [6-14].

3. Cold plasma technology

Scientists and engineers from the Vietnam VinIT Institute of Technology (VinIT), led by prof. Shi Nguyen-Kuok, successfully researched and created a prototype of a plasma disinfection system, surface sterilization and destruction of various bacteria, microbes, viruses, including COVID-19 coronaviruses, for industrial, transport, civilian facilities, which is especially important, hospitals and specialized medical centres. Currently, a group of Russian engineers and researchers is involved in the work, led by prof. Bolnokin V.E.

A new technology, proposed in VinIT, has been developed for creating a cold plasma flow in processing chambers (technological spaces) with high efficiency of disinfection and sterilization at atmospheric pressure [1,14].

The flow of cold plasma has a low atomic and ionic temperature of several tens of degrees Celsius, a high electron temperature above 10000 K, an electron density of $10^{12}$-$10^{13}$ cm$^{-3}$, charged particles and ions due to ionization of air and argon gas ($\text{Ar}^+$, $\text{N}_2^+$, $\text{N}_2^-$, $\text{O}_2^+$, $\text{O}_2^-$...), various active ingredients $\text{O}^-$, $\text{OH}^-$, $\text{O}^*$, $\text{O}_2^*$, $\text{O}_3^*$, $\text{NO}_x$, ultraviolet radiation (wavelength 180-400 nm), has a high bactericidal, fungicidal and virucidal effect. The scheme of generation and supply of a cold plasma flow is shown in figure 2.

![Figure 2](https://via.placeholder.com/150)

Figure 2. Generation and supply of a cold plasma ion flux.

This flow is well suited for disinfecting surfaces and killing viruses, bacteria and germs at atmospheric pressure.

In general, plasma technology in surface disinfection and antiviral system combines 08 bactericidal mechanisms, including: high temperature; ultra-violet rays; charged particles and electrons; $\text{H}_2\text{O}_2$; $\text{O}^-$; $\text{OH}^-$; $\text{O}^*$, $\text{O}_2^*$, $\text{O}_3^*$, $\text{O}_5$; $\text{NO}_x$. 

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The scheme of the effect of the cold plasma flow on the populations of bacteria, microbes and viruses is shown in figure 3.

![Scheme of the effect of plasma flow on populations of bacteria, microbes and viruses.](image)

**Figure 3.** Scheme of the effect of plasma flow on populations of bacteria, microbes and viruses.

Compared to conventional disinfection and sterilization methods, plasma technology has the following advantages:

1. A wide range of viruses, bacteria and microbes affected by plasma;
2. Fast action in vivo at atmospheric pressure, ambient temperature and humidity;
3. Not affected by environmental factors;
4. Absolute safety: treatment of surfaces and cavities without the use of chemicals, without the use of toxic substances; fire and explosion safe;
5. There is no harm to the materials used, metal tools, technological rubber and plastic;
6. The effect lasts a long time on the surface of the processed objects;
7. Simplicity and versatility of use;
8. The processing process is carried out without unpleasant odor, which is especially important when working in confined spaces;
9. Ability to quickly clean different types of surfaces;
10. High energy and economic efficiency.

Based on its theoretical and experimental studies, the VinIT Institute of Technology has developed prototypes of a surface disinfection system and the destruction of viruses, microbes, bacteria and fungi. The developed prototypes of disinfection systems were handed over to specialists of specialized medical institutions for experiments and practical use.

**4. Experimental work**

Experimental work on testing prototypes has shown their high efficiency in practical use. Tables 1 and 2 show some important results of experiments to test the effectiveness of using cold plasma technology to destroy various populations of viruses, microbes, and bacteria.

We see that the results of the experiments are very encouraging. Tables 1, 2, the degree of reduction in the number of bacteria and fungi reaches about $10^8$ times ($7\log_{10} - 7.7\log_{10}$). That is, out of hundreds of millions of bacteria units, after processing, only a few remain in the volume. Note that the processing time is only from 40 s to several minutes.

At room temperature (the temperature of atoms and ions in the autoclave is practically equal to room temperature, and the electron temperature is more than 10,000 K) and atmospheric pressure. The degree of processing reaches $7\log_{10} - 7.7\log_{10}$, which is in the zones not even disinfection, but sterilization (more than $6\log_{10}$).

At the same time, it should be noted that the degree of sterilization can be even higher, since, during the experiments, populations of microbes, bacteria and viruses were used at a much higher concentration than in natural conditions.

In comparison, other more expensive sterilization methods usually take much longer (up to an hour)
to achieve the same degree of sterilization than the proposed plasma method.

It should also be noted the universality of the proposed mechanism for the destruction of viruses, microbes, bacteria and fungi by ionic gases, carried out from different plasma sources of cold plasma. Ionic gas acts as an extremely effective and useful disinfection tool.

Since individual ions have a certain charge, they easily adhere to proteins with opposite charge signs located on the surface of viruses, microbes, bacteria and fungi of various types, changing and neutralizing their molecular structure, which leads to their destruction.

**Table 1.** The results of processing bacteria in a plasma autoclave system.

| Bacteria   | Distance to plasma jet / Treatment time / Decrease in the number of bacteria after treatment in logarithm, log10 | Required rate |
|------------|----------------------------------------------------------------------------------------------------------------|--------------|
|            | 3 cm | 7 cm | 12 cm | 40 s | min | 1 min | 1.5 min | 2 min | 3 min | 40 s | min | 1 min | 1.5 min | 2 min | 3 min |
| M. luteus  | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | 7.63 | >3     |
| B. subtilis| 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | 7.06 | >2     |
| P. fluorescens | 2.4 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | >3     |
| M. extorquens | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | 7.13 | >3     |

**Table 2.** Results of treating fungi in a plasma autoclave system.

| Fungi    | Distance to the plasma jet / Treatment time / Reduction of the number of fungi after treatment in logarithm, log10 | Required rate |
|----------|----------------------------------------------------------------------------------------------------------------|--------------|
|          | 3 cm | 5 cm | 10 cm | 15 cm | 20 cm | 5 cm | 10 cm | 15 cm | 20 cm | 5 cm | 10 cm | 15 cm | 20 cm | >3     |
| C. albicans | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | >3     |
| A. niger  | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | 7.29 | >3     |

Shown in figures 4, 5 photographs demonstrate the results of experimental tests of plasma technology, and also show the high efficiency of processing bacteria and fungi in a plasma autoclave using ions from a jet of cold plasma.

**Figure 4.** The result of processing bacteria M. extorquens in a plasma autoclave; processing time - 40 s; distance to plasma jet - 12 cm.
Figure 5. The result of processing the fungus C. albicans in a plasma autoclave: processing time - 5 minutes; distance to plasma jet - 3 cm.

In the left Petri dish, bacteria were grown in room conditions, in the right dish - the same, but after processing in a plasma autoclave, in the middle - a dish without bacterial growth (for testing and determination of experimental noise).

In the left Petri dish, the fungi were grown in room conditions, in the right dish - the same, but after processing in a plasma autoclave, in the middle - a dish without fungal growth (for testing and determination of experimental noise).

5. Conclusion
Note that the most important achievement of the VinIT team is the creation of systems with adaptive tuning properties for various types of viruses and bacteria. This allows these systems to be used in a wide range of virological conditions.

Currently, work is underway to create a wide range of technical manipulation systems for disinfection of arbitrary surfaces and internal cavities using cold plasma technologies.

Under the leadership of Professor Shi Nguyen-Kuok, a group of VinIT scientists are also working on the development of a new system of ionized water, which has great importance and application in medicine, agriculture, ecology and environmental protection. Many of VinIT's unique developments based on thermal and cold plasma are ready for commercial implementation and deserves the attention of the scientific world and business for implementation.

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