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BIOLOGICAL DECONTAMINATION SYSTEM

PROJECT STATUS
DEVELOPMENT

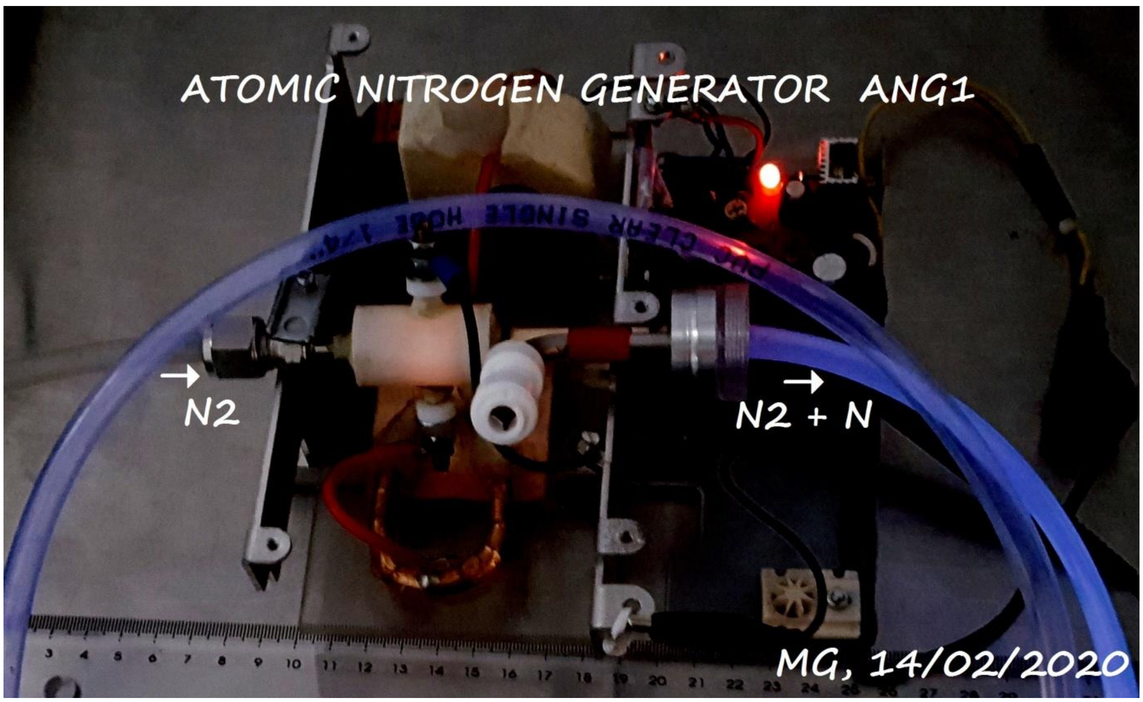
PROJECT NAME
BIOLOGICAL DECONTAMINATION SYSTEM

GENERAL PURPOSE
TO DEVELOP MAXIMUM OPTIMUM DECONTAMINATION PROCESS, FOR CITIES AND EXISTING SYSTEMS, FOR BIOLOGICAL THREATS

Trains, schools, stations, airplanes ,supermarkets, hospitals, food production areas, hotels, factories, restaurants, movie theaters, airports, etc.

READ FIRST

ATOMIC NITROGEN GENERATOR



Abstract

The decontamination by using atomic nitrogen was already tested on contaminated small surfaces. For the decontamination of larger surfaces we propose the use of "brushes" with atmospheric pressure molecular nitrogen containing atomic nitrogen. We believe that it can also use as ecological viral disinfection, since the active substances by which atomic nitrogen has a decontaminating effect (OH, O_3, O, NO, etc) in different states of excitation are natural and molecular nitrogen is not toxic. All the active species involved are also produced naturally during a lightning storm. What we are actually doing is to reproduce part of the effects, due to lightings, but at the right place and in the right proportion. However, lightings don't produce them at those locations, where these species can be useful in fighting the virus spread through a complementary disinfection method.

Introduction

Among plasma methods used to inactivate microorganisms those based on atmospheric pressure discharges and remote exposure are numerous, because of the practical simplicity and thermo-sensitive medium preservation.
A nitrogen afterglow at atmospheric pressure has recently been described as able to transport active species over long distances in small diameter tubes, with a biocide effect .

or a discharge gas composed of either high purity nitrogen or a mixture of nitrogen with some controlled ppm of oxygen, survival curves are presented in and fundamental or excited states of atomic or molecular species of parent gases are detected and evaluated.
Two types of microorganisms have been used for surface decontamination tests: E. coli bacteria and B. stearothermophilus spores.
The device under study (Fig. 1) appears to be efficient in the decontamination of the inner surface of tubes. A correlative study on medical catheters demonstrated no significant degradation of the polyurethane wall surface. The analysis of post discharge spectra (Fig. 2) allowed us the determination of the activated molecular nitrogen of ~ 300K .
The societal importance of the decontamination subject makes welcome any and all progress towards a solution, even as a step towards an eventual decontamination process.

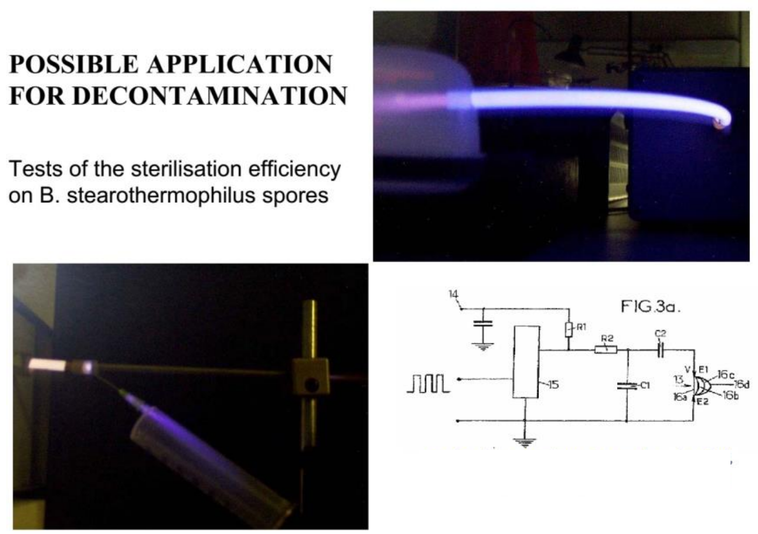


Fig. 1: Device under study that appears to be efficient in the decontamination of the inner surface of tubes

Long distance transport of active species that are not chemically or thermally aggressive to polymeric material but with a proven biocide effect constitutes one such solution.

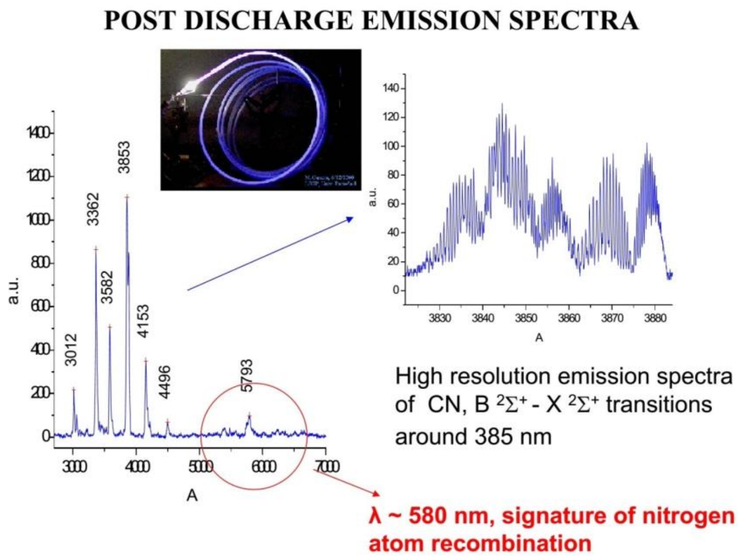


Fig 2: High resolution post discharge emission spectra

For the determination of the concentration of atomic nitrogen at atmospheric pressure and temperature, chemical titration with molecular oxygen has been studied by spectroscopic experiments and chemical simulations
2005] The formation of oxygen atoms (by the reaction between nitrogen atoms and molecular oxygen) leads to the rapid production of ozone which can be easily observed and quantified using its strong ultraviolet absorption.
The method might therefore be interesting for nitrogen atom diagnostics in decontamination or industrial processes at atmospheric pressure, particularly because of potential difficulties related to the classical method of NO titration used at lower pressures (for example to achieve a homogeneous mixture in the characteristic time of the reaction). Furthermore, NO is a toxic and corrosive substance that is much more difficult to handle than molecular O_2.

Project

Good to

to preserve and develop the skills in the generation, transport and use of atomic nitrogen, with a much higher decontaminating effect than ozone and with the potential to penetrate into hard-to-reach areas. It is certainly a more expensive process, than the use of ozone but can have beneficial complementary effects .

We are thinking that the most important channel of decontamination, by using atomic nitrogen, is the formation of OH following the N interaction with O_2 and H_2O from the microorganism's surface or very low amount of O_2 and H_2O in the decontaminated zone.
The green (557.7 nm) emission emerging when small amounts of molecular oxygen are added to the nitrogen stream containing also atomic nitrogen is a clear evidence of the formation of the metastable oxygen that leads to the dissociation of water molecules and the formation of two OH molecules. A recent article -

In Fig 2 we see very well the signature of the transition $O(1S)N_2$ to $O(1D)+N_2$ (emission in green at 557.7 nm) which is subsequently responsible for the formation of OH: $O(1D) + H_2O = 2\ OH$. In Fig.3 (a) the discharge is in pure molecular nitrogen (the emission in blue is due to the fluorescence induced by the de-excitation of CN molecules from nitrogen organic impurities) while in (b) a small amount of molecular oxygen gets added into the nitrogen flow which also contains atomic nitrogen.

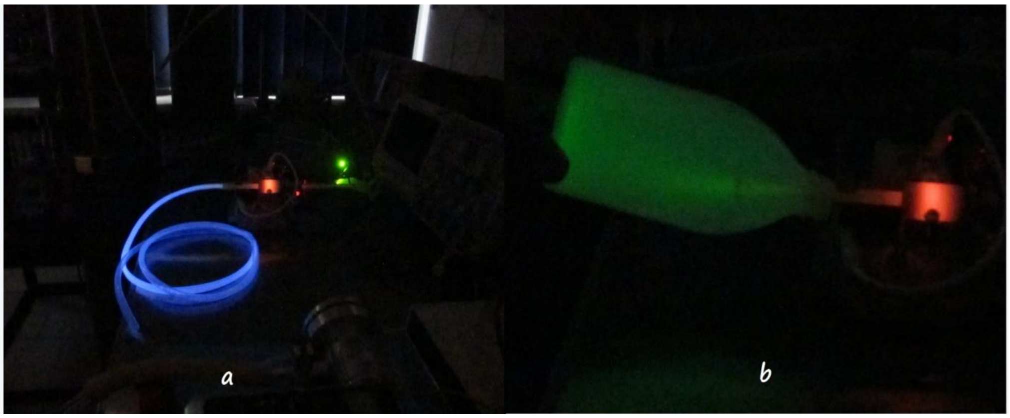


Fig. 3: (a) the discharge in pure molecular nitrogen (the emission in blue is due to the fluorescence induced by the de-excitation of CN molecules); (b) green light emission at 557.7 nm when a small amount of oxygen gets mixed with the post discharge nitrogen, which also contains atomic nitrogen.

The important role of OH is well described in EP 2211915 B1

1. OH radicals can be used to cause irreversible damage to cells and ultimately kill them;

2. The threshold potential for eliminating micro-organisms is ten thousandths of the disinfectants used in dor and outdoors;

3. The biochemical reaction with OH is a free radical reaction and the biochemical reaction time for eliminating microorganisms is about 1 second, meeting the need for rapid elimination of microbial contamination, and the lethal time is about one thousandth of that for current disinfectants;

4. The lethal density of OH is about one thousandth of the spray density for other disinfectants - this will be helpful in eliminating microbial contamination efficiently and quickly in large spaces, e.g. bed-space areas;

5. Finally, the OH mist or fog drops oxidize the microorganisms into CO_2, H_2O and micro-inorganic salts. The remaining OH will also decompose into H_2O and O_2, thus this method will eliminate microbial contamination without pollution.

Some additional details about the physics involved in making our relatively simple Atomic Nitrogen Generator, can be found in our patent

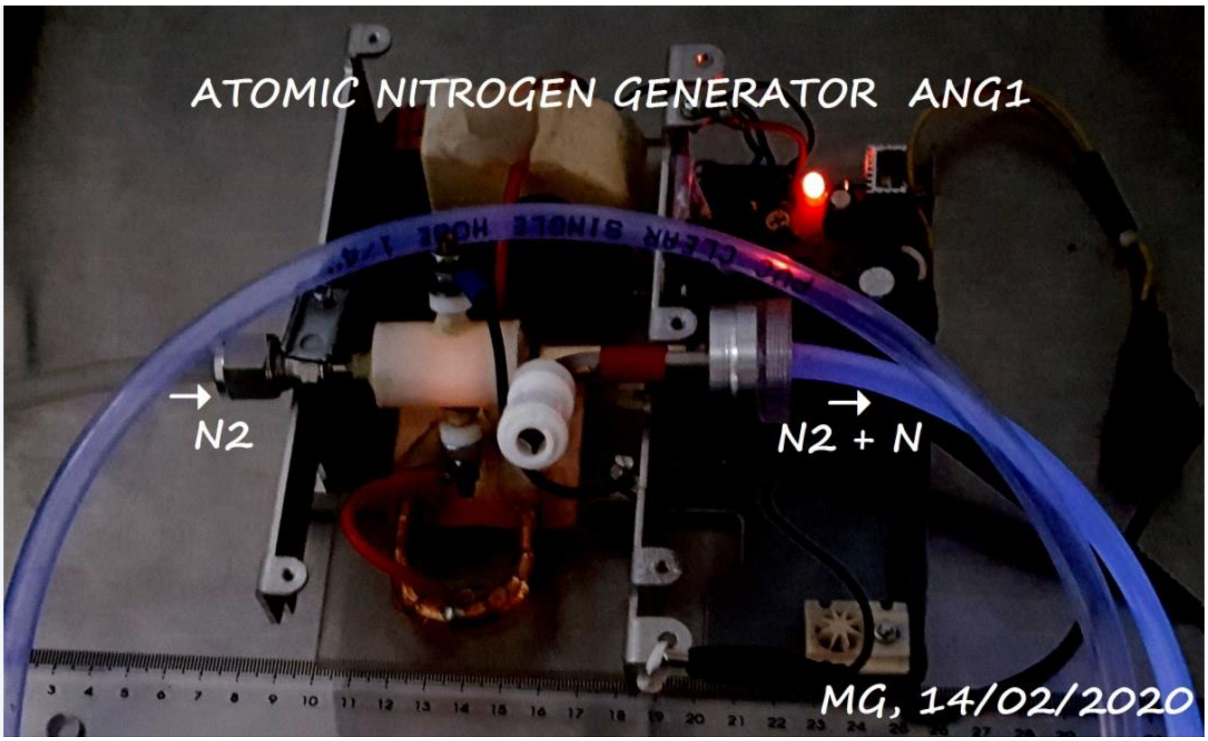


Fig. 4: Overview of a new Atomic Nitrogen Generator.

Specific to the developed Atomic Nitrogen Generator (ANG) are the discharge configuration and the applied electrical pulses, with amplitude, frequency and transferred charge which must be adapted to the gas flow. The performed studies were for a gas flow of 20-50 l/min at atmospheric pressure and a temperature of ~ 300 K. Additional details can be found in our patent [M.Ganciu et al, 2004].

At least the discharge tube structure could be realized by RAPID 3D structure printing. All the electronics can be compacted and only the high voltage transformer should be produced by a specialized company. The gas distribution part, in different geometries, adapted to the applications envisaged, can also take advantage of 3D printing.

A discharge spectrum emitted between the two point electrodes of an ANG under optimal discharge conditions is given in Fig 5. A comparison is made with the spectrum of a dielectric-barrier discharge (DBD) using the same electrical pulse generator.

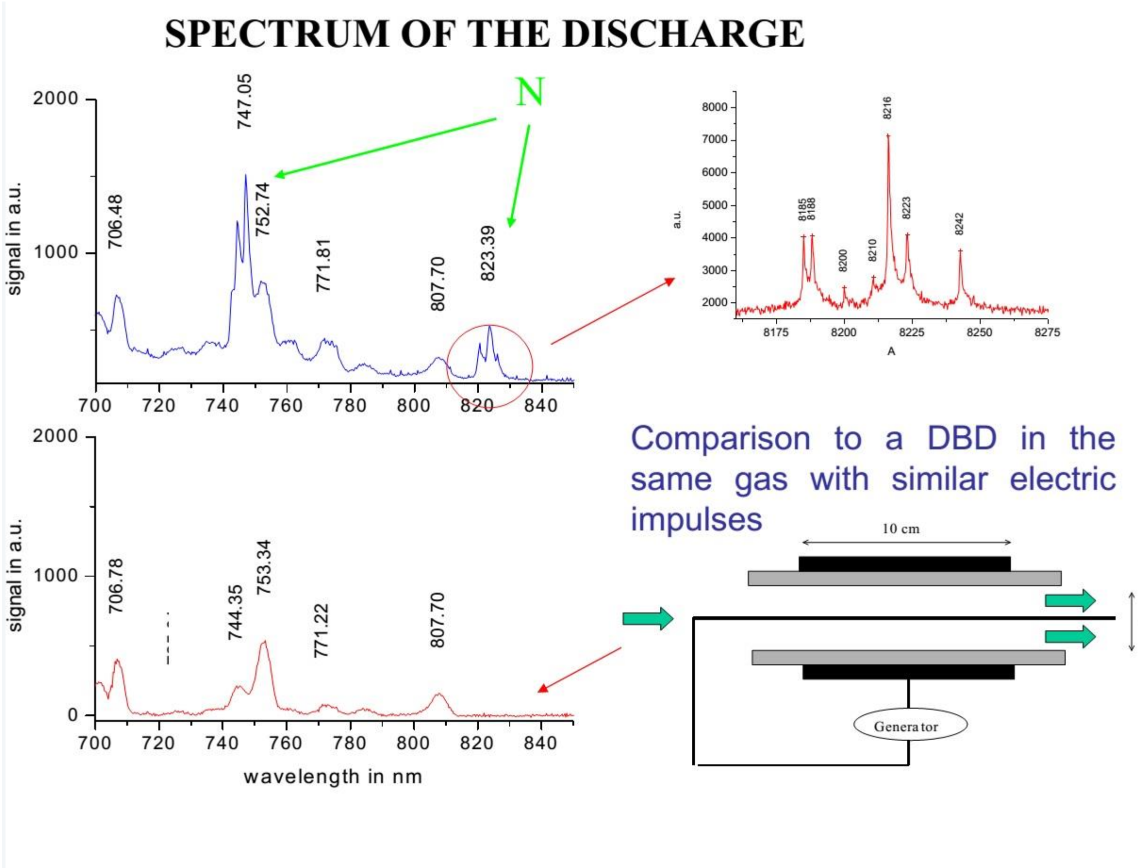


Fig. 5: Discharge spectrum emitted between the two point electrodes of an ANG under optimal discharge conditions; comparison with the spectrum of a dielectric-barrier discharge (DBD) using the same electrical pulse generator.

The viral disinfection effect of nitrogen plasma was analysed in [Sakudo A, Toyokawa Y& Imanishi Y, 2016]

The channel involving OH from the $O(^1D) + H_2O = 2\,OH$ reaction is missing, which we now consider to be very important.

The decontamination by atomic nitrogen was initially tested on contaminated small surfaces [A.-M. Pointu, et al., 2008] . For the decontamination of larger surfaces we propose the use of "brushes" with atomic nitrogen. We believe that it can also be used for hand disinfection, since the active substances by which atomic nitrogen has a decontaminating effect (OH, O_3, O, NO) in different states of excitation are natural and molecular nitrogen is not toxic. In addition, nitrogen can be easily stored as a non-flammable gas.

All the active species involved are also produced naturally during a lightning storm, like in Fig.6. What we are actually doing is to reproduce part of the effects due to lightnings but at the right place and in the right proportion. The active species produced when applying this method are actually in very small quantities when compared to what results from a lightning during a storm. However, lightings don't produce them at those locations, where these species can be useful in fighting the Coronavirus through a complementary disinfection method.

Fig 6: Lighting storm- (Schutterstock credit)

Conclusion

1. Atomic Nitrogen has an antiviral effect and can be used at least for air conditioning decontamination and for closed areas. Atomic nitrogen is transported by molecular nitrogen and can enter areas where disinfectants in solution do not reach. The active species with decontaminant role (OH, NO, O, O_3, etc.) are produced following the plasma-chemical reactions induced by the atomic nitrogen where it arrives.
2. At least on cruise ships, trains, buses, subways and lifts, the use of additional disinfection with atomic nitrogen would have reduced the spread of the virus.
3. The atomic nitrogen based decontamination method can provide complementary disinfection that slows the spread of the virus, thus saving time until the weather warms up, and the spread of the virus is inhibited.
4. The viral disinfection by ozone has been used for over 50 years:

   but it also has many drawbacks related to a relatively long life of ozone and, to be effective on viruses, significant quantities are necessary making it toxic to humans too. An area disinfected with ozone must be subsequently aerated for over an hour. The validation of viral disinfection by ozone implies also the validation of viral disinfection by using atomic nitrogen in molecular nitrogen flux.
5. Ozone is the final compound after atomic nitrogen generates other compounds much more active than ozone. If oxygen is used instead of nitrogen, ozone is obtained directly. If needed, only compressed air can be used which leads mainly to ozone generation but also to nitrogen oxides which should be rather avoided.
6. A demonstration of great effect would be the disinfection of an airplane. We can start with a smaller one. It would take about a bottle of nitrogen. I could already think of a generator adapted for this application. It would be the nitrogen bottle, a hose finished with a cylinder with a volume of 2 litres (high power Atomic Nitrogen Generator).
7. A robotic system that transports the atomic nitrogen generator together with the associated nitrogen cylinder would be very useful at least inside airplanes. Activated nitrogen must be released near the decontaminated areas (it reacts with residual O_2 and H_2O) or the aircraft must first be filled with molecular nitrogen and then atomic nitrogen is introduced. This will reduce the amount of ozone that has a long life.
8. It can be made even simpler by using atomic nitrogen from the beginning during few minutes, after which the plane is aerated for several hours to remove ozone (ozone is also good for disinfection)
9. Aviation companies would certainly be interested in this if the situation gets complicated. It is sufficient for one to apply this method and then to start the other in avalanche.
10. We want to specify that the method does not solve everything but it can be complementary to other methods, increasing the sterilization efficiency. However, the gaseous effluents also penetrate the hidden places.
11. At least the discharge tube structure could be realized by RAPID 3D structure printing. All the electronics can be compacted and only the high voltage transformer will be produced by a specialized company.

12. The gas distribution part, in different geometries, adapted to the applications envisaged, can also take advantage of a 3D printing.

Conflicts of interest

The authors declare no conflict of interest. The funders had no role in the design of the study, in the collections, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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