JONIX

pure living

NON THERMAL-PLASMA (NTP)TECHNOLOGY

SUMMARY

1. DEFINITION

The word plasma means a blend of ionized gases composed of a large quantity of energized particles, such as ions and electrons, free radicals, molecules as well as neutral atoms.

Ionization occurs when an electron acquires enough energy to overcome the attractive forces of the atom's nucleus. When this result is obtained with processes generating a plasma in which the temperature of the ions and neutral atoms is significantly lower than the temperature of electrons, we are talking about cold plasma or Non-Thermal Plasma (NTP).

Cold plasma emits light with wavelengths in both the visible part and the ultraviolet part of the spectrum. Beside the emission of UV radiations, an important feature of the low-temperature plasma is the presence of strongly reactive high-energy electrons that create a number of chemical and physical processes such as oxidation, over-energizing of atoms and molecules, the production of free radicals and other reactive particles.

A plasma can be artificially generated by supplying a gas with sufficiently high energy by means of laser, shockwaves, electric arcs, electrical and magnetic fields, which means giving a gas energy so as to reorganize the electronic structure of the species (atoms, molecules) and produce over-energized species and ions.

One of the most common ways to artificially create and maintain a plasma is by using a gas electric discharge.

With regard to cold plasma, the so-called non-thermal discharges are used.

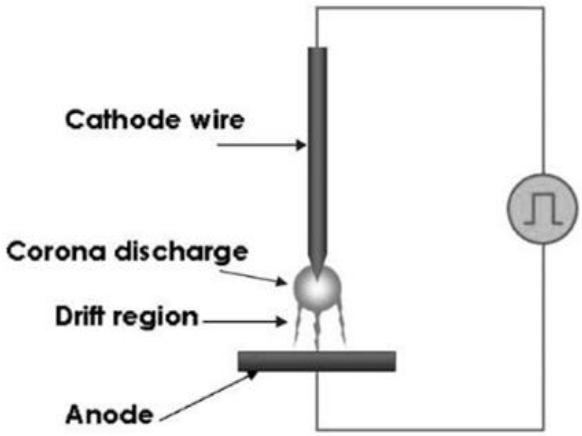
The two main types of non-thermal atmospheric pressure discharges are corona discharge and dielectric barrier discharge

Plasma with corona discharge

It occurs in a gas between an electrode having a small curvature radius, which is called active electrode, and an electrode with a large outer surface (passive electrode), between which voltage of a few kV is applied. In particular, the active electrode generates a sufficiently high electric field to produce free charges, whereas the external electrode, which is also called a passive electrode, primarily works as a charge collector.

The instrument is composed of a thread-like cathode from the current generator and anode composed of the component that is treated.

The electrode configurations that are commonly used to obtain a corona effect are cylinder-wire, tip-plane and wire-plane. The most commonly used electrode configuration is most likely the cylinder-wire since it guarantees almost even distribution of the discharge and is easily made in a system with gas flows.



Corona discharges are divided into two categories: continuous and pulsed. Continuous discharges are produced by low-frequency direct currents or alternating currents. A pulsed corona is obtained by applying a short voltage pulse to an electrode.

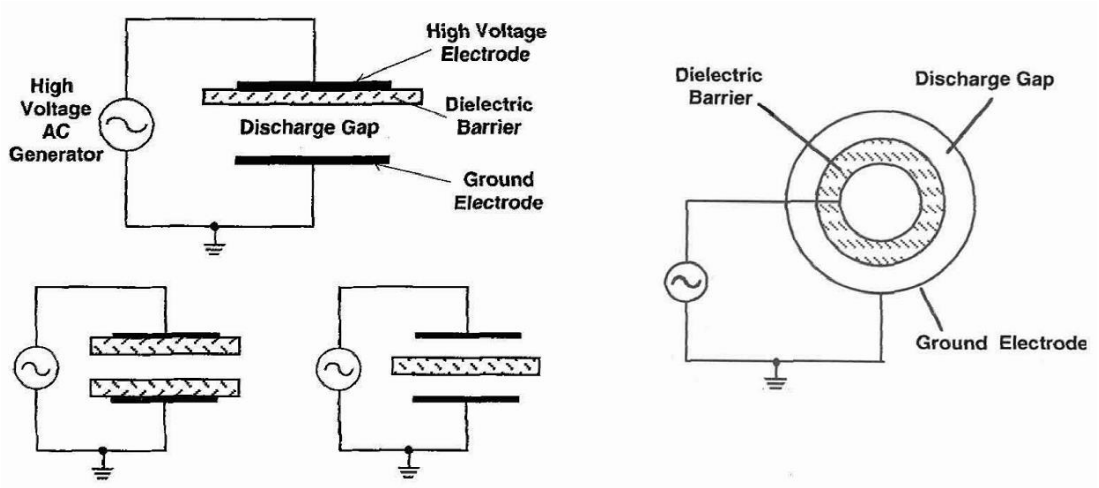
The two most important forms of discharge are the so-called flash corona and streamer corona (channel or filament discharges) Use one of these two discharge systems, which largely depend on the distance between the electrodes and the evolution in time of the voltage applied.

Plasma with dielectric-barrier discharge (DBD)

The gas generated from the plasma is made to pass between two metal electrodes, planar and parallel, between which there is dielectric material.

Discharge is generated as a result of sinusoidal or pulsed current that creates micro-arcs that develop due to an accumulation of electrons on the dielectric layer that covers one of the electrodes. The dielectric material prevents the development of high currents.

The configurations of the most common electrodes are planar with one or two dielectric barriers between flat electrodes. Most technical applications are also used with annular cavities between electrodes and cylindrical dielectrics.



The ionizing power and density of the charged species generated by the plasma with the corona discharge and the plasma with dielectric discharge (D) are shown in the following table, where the corresponding values for the other types of plasma are also visible.

Tecnologia JONIX

Sorgente	V (kV)	Densità (cm-3)
Low pressure discharge	0.2-0.8	10^{8}-10^{13}
Arch and plasma torch	10-50	10^{16}-10^{19}
Corona	10-50	10^{9}-10^{13}
Dielettric barrier discharge	5-25	10^{12}-10^{15}
Plasma Jet	0.05-0.2	10^{11}-10^{12}

2. JONIX DEVICES

JONIX devices fall under the category of the so-called air ionizers, which means systems that release negatively (and/or positively) charged particles in the air to treat. This air ionizing system is obtained by using cold plasma acquired by taking appropriate advantage of the corona effect. This effect is obtained as a result of an electrical field generated by voltages equivalent to approximately **3000 V** set on a metal mesh exposed directly to the flow of air to treat. In particular, the plasma is obtained via **dielectric barrier discharge (DBD)** created **by two metal planar and parallel electrodes** where the dielectric material is interposed.

Discharge is generated as a result of sinusoidal or pulsed current that creates micro-arcs that develop due to an accumulation of electrons on the dielectric layer that covers one of the electrodes. The dielectric material prevents the development of high currents.

3. GENERAL EFFECTS OF NON-THERMAL PLASMA

Some studies show that people should feel significant benefits from using an ionizer, which is based on producing cold plasma. Medical literature, in fact, indicates that the change in concentration and mobility of these ionic species has psycho-physiological benefits.

Cold plasma treatment also has an important **purifying and sanitising** effect. In fact, the ions created join airborne particles (dust, aromas, smoke, pollen) negatively (or positively) charging them. As a result, dust tends to bind with surfaces it meets (for example, walls in rooms) instead of remaining airborne. A similar procedure can also be attributed to cleaning of surfaces, not only the air in the environment.

Biological Effects

Hereunder is a demonstration on how a low-temperature plasma can have beneficial disinfecting and sanitizing effects against bacteria, spores, moulds, and other pathogens.

This antimicrobial action is mainly due to:

- UV rays
- Reactive particles carrying electric charges, among which the most important ones are the oxygen reactive species (for example atomic oxygen and ozone), which concentrate on the membrane surface causing its destruction.

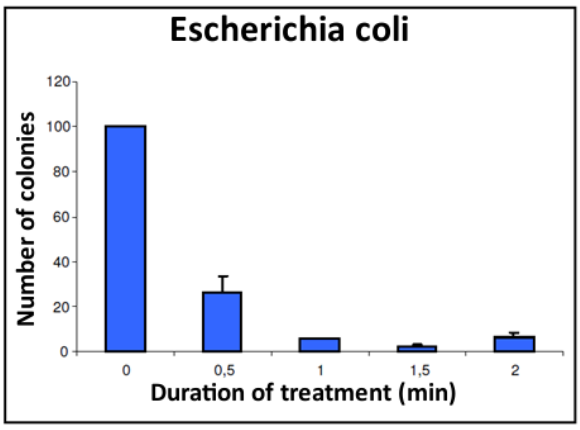
The hypothesis is that the microbiocidal action derives from a mechanism combined with active oxygen and UV rays, which are manifested in three phases:

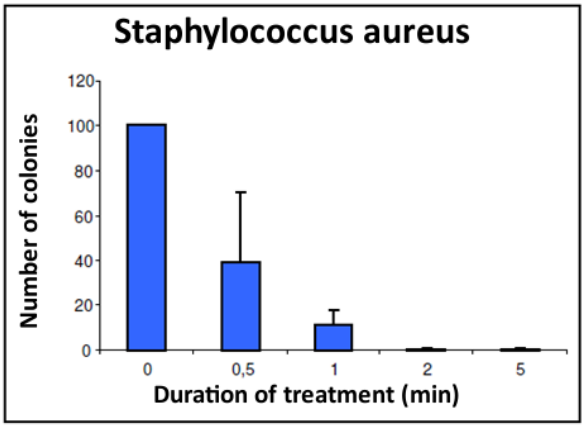
- Elimination of the genetic material of microorganisms by UV light
- Microbic surface erosion caused by reactive particles in synergy with UV
- Elimination of the non-protected genetic material by UV light

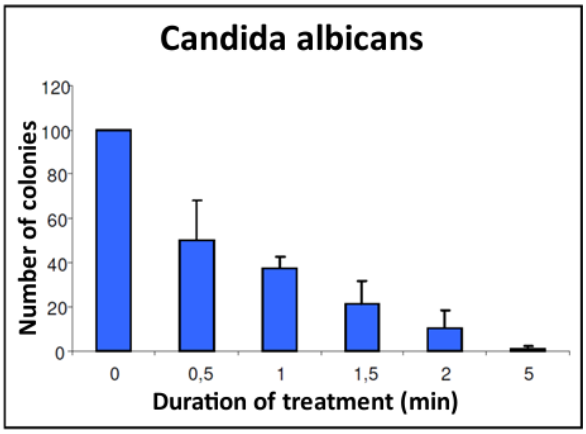
Hereunder is a report:

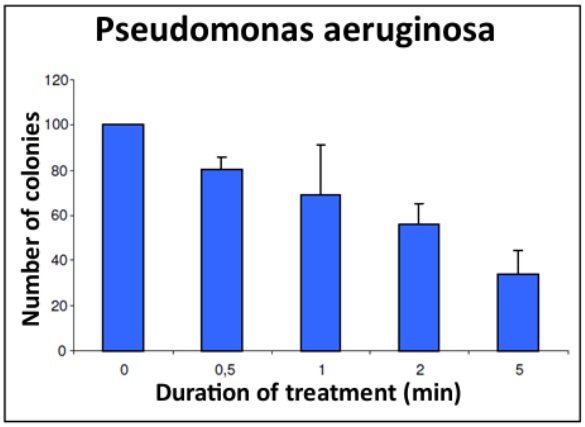
1. the performance of the number of bacterial colonies of different cultures subjected to a cold plasma treatment [Source: PhD thesis in Ocular Immunology by Velika Deligianni, discussed at the Bio-Medical University Campus in Rome on 15/03/2010]

2. photographic documentation attesting biocidal activity of NTP air (ionized air via Non Thermal Plasma) of different microbial strains, at different exposure times. The tests were carried out at ARCHA laboratories in Pisa.









With regard to the tests carried out at ARCHA laboratories, the microorganisms tested and which presented biocidal activity of NTP air, are as follows:

- Salmonella spp.
- E.Coli
- Listeria monocytogenes
- Staphylococcus aureus
- Pseudomonas aeruginosa

The photos show a comparison between contaminated Petri dishes exposed to different times (2.5 and 10 minutes) at ambient air flows or ionized air, for Salmonella spp., Escherichia coli, Listeria monocytogenes, Staphylococcus aureus and Pseudomonas aeruginosa.

From the photos, it is evident that even with short contact times (2 minutes), the biocidal activity of NTP air is total: the plates exposed to NTP air show no development of microbial strains tested, which, instead, are normally developed on plates just exposed to air

Salmonella spp.

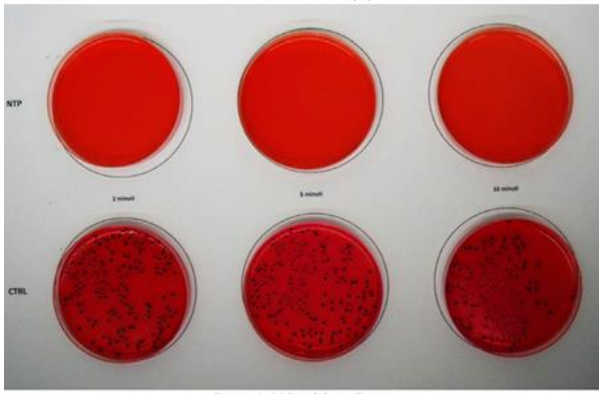


Foto 1 - Attività su Salmonella spp.

E.Coli

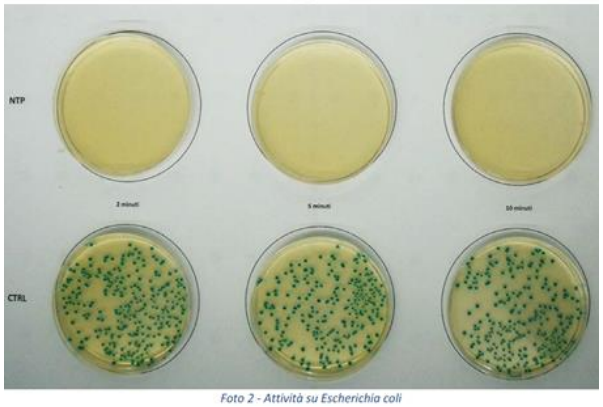


Foto 2 - Attività su Escherichia coli

Listeria monocytogenes

Foto 1 - Attività su Listeria monocytogenes

Staphylococcus aureus

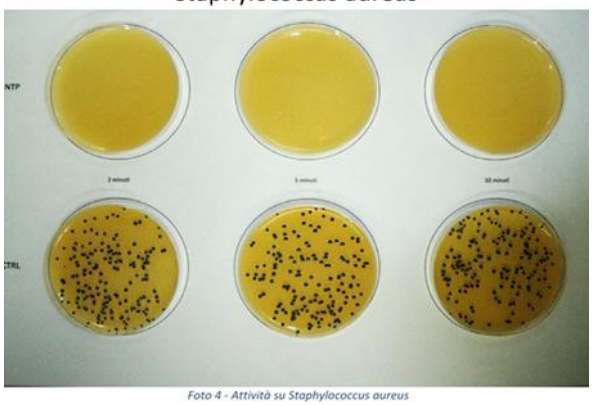


Foto 4 - Attività su Staphylococcus aureus

Pseudomonas aeruginosa

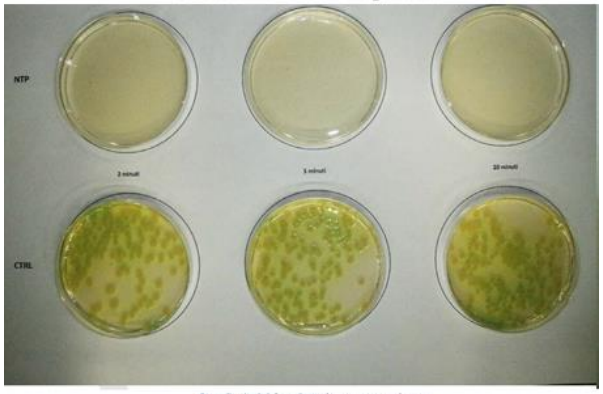


Foto 5 - Attività su Pseudomona aeruginosa

The following table summarises the average results obtained.

	Treatment time (minutes)						
Strain \ treatment	**0**	**1**	**3**	**5**	**10**	**15**	**30**
Escherichia coli \ air	~ 500	~ 500	~ 500	~ 500	~ 500	~ 500	~ 500
Escherichia coli \ NTP	~ 500	0	0	0	0	0	0
Candida Albicans \ air	~ 600	~ 600	~ 600	~ 600	~ 600	~ 600	~ 600
Candida Albicans \ NTP	~ 600	38	20	0	0	0	0
Staphylococcus aureus \ air	~ 300	~ 300	~ 300	~ 300	~ 300	~ 300	~ 300
Staphylococcus aureus \ NTP	~ 300	78	1	0	0	0	0

Table 1. Results of treatment tests

As shown in the photo, the NTP treatment seems effective from the first few minutes of use. In fact, after just 5 minutes, all species tested were completely eradicated from the surface of the plates. An additional element that positively characterises the success of the experiment consists in the fact that, contrary to what is foreseen by certain methods that envisage the execution of experiments on stainless steel surfaces, the tests described above were carried out in perfect conditions for microorganisms, both with regard to the ecological point of view (humidity, perfect pH, presence of nutrients, etc.) and for the presence of large amounts of organic substances, which are known to interfere with the classical biocides.

The biological effect of the cold plasma technology was then brought out by Laboratori ARCHA srl in certain practical applications reported hereunder.

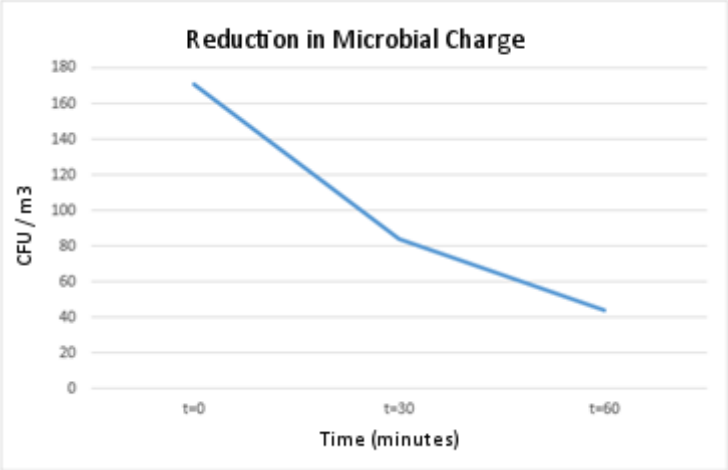
The use of NTP to eliminate odorous components generated by different types of waste

It has been demonstrated, at the laboratories of ARCHA in Pisa, that NTP technology has a positive effect in breaking down the species present in the gaseous flow generated by the different waste, with percentages varying between 26 and 40%. In particular:

- organic molecules are eliminated up to approximately 40% (elimination of the aliphatic and aromatic chains determined by GC-MS)
- odorous substances are eliminated up to 34% (determined by using an e-Nose)

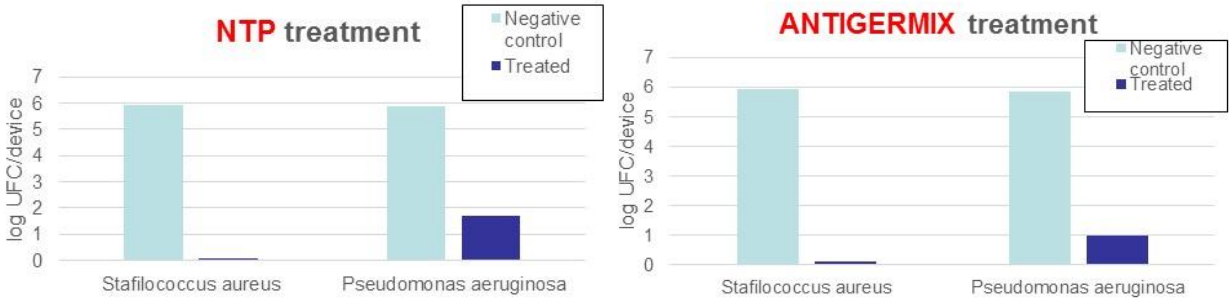
Creation of an NTP ionization chamber to assess the biocidal effectiveness in the gaseous phase of the air

Escherichia coli cultures were used to run the test to assess the effectiveness of the ionization chamber.
The following graph shows a reduction in the airborne microbial charge inside the cube after treatment with NTP.



Sanitisation of non-critical ultrasound probes

"Non-critical" ultrasound probe sanitisation tests were carried out using NTP AIR, compared to sanitisation carried out by commercial devices.
The tests have shown efficient NTP that is absolutely comparable to that of devices marketed for the purpose.
The figures below show the elimination of microbial species associated with NTP air and regarding commercial devices during the same disinfection procedure.



Use of NTP technology against bad odours associated with use of footwear

The effectiveness of NTP air was tested regarding the elimination of chemical molecules and regarding microbiological sanitization related to elimination of bad odours that are associated with use of footwear. In particular, NTP air resulted effective in eliminating the following species:

- Chemical molecules responsible for odours.
- Mircoorganisms responsible for producing odours.

With regard to the elimination of chemical molecules, the experiment conducted led to the conclusion that air treatments using NTP for sufficiently long times (from 6 hours onwards), they are EFFECTIVE and able to completely eliminate and destroy the molecules in question, as shown in the following table

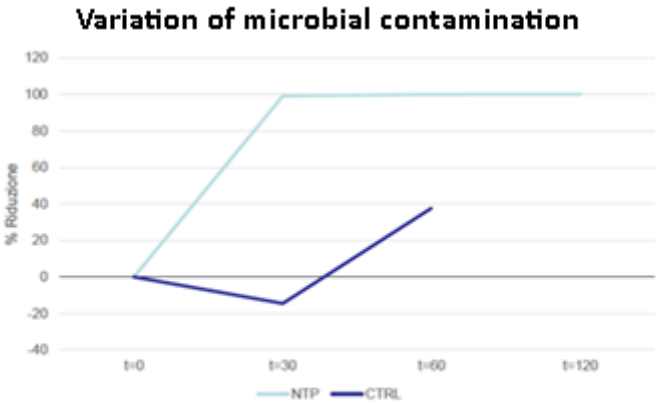
chemical molecules	Elimination % of molecules compared to the initial concentration, via NTP air		
	60 min	6 h	17 h

Acetic acid	69%	100%	100%
Propionic acid	45%	100%	100%
Isobutyric acid	31%	100%	100%
Butyric acid	21%	100%	100%
Isovaleric acid	0%	100%	100%
Valeric Acid	10%	100%	100%
Caproic Acid	6%	100%	100%
Caprylic Acid	6%	99%	99%
Caprylic Acid	6%	88%	95%

Sanitisation of rooms with JONIX™ mate

JONIX™ mate is a sanitisation system cabinet that uses NTP cold plasma technology to ionize the air. Use is focused on sanitising industrial environments, medical and outpatient clinics, and can also be extended to many other fields, amongst which the agri-food industry (cultivation and preservation of food).

Laboratori ARCHA srl has compared the spontaneous reduction in microbial contamination in workplaces with and without NTP treatment (respectively with MATE operating and non-operating). The results are in the graph below.



Comparison between spontaneous reduction of airborne microbial contamination (CTRL) and what is determined by the treatment (NTP). Negative values indicate an increase in contamination with regard to zero time (end of atomization)

From the graph, it can be seen how after 30 minutes of treatment with the device, the microbial reduction percentage is extremely close to 100%. This confirms the efficiency of the JONIX™ mate to sanitise living and working environments.

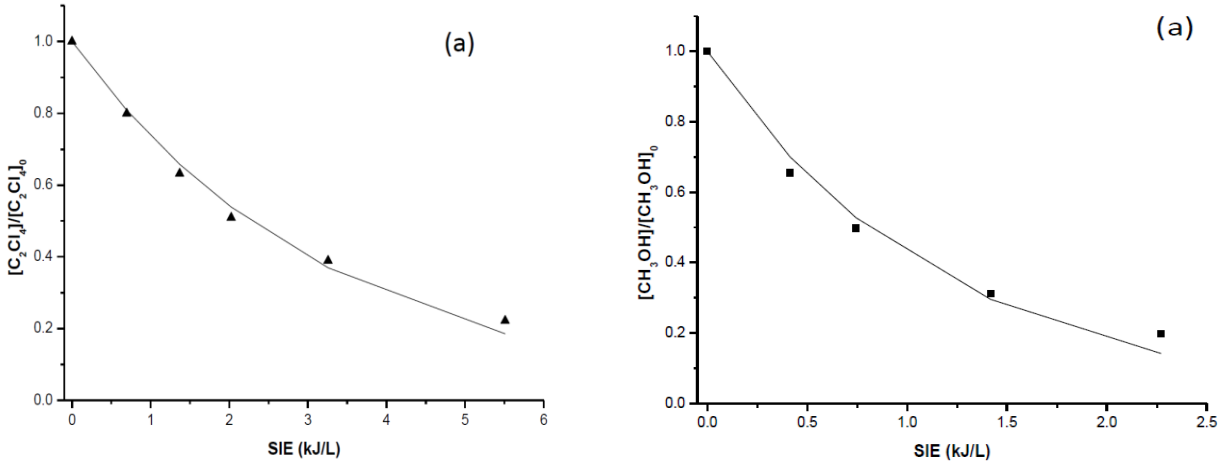
Oxidising Effects

Recent research in the field of air ionizing processes has obtained important results in neutralising odours, reducing volatile organic components (VOC) dispersed into the environment and elimination of fine particulate matter PM_x.

The ionizing process causes the development of small ions of air, including superoxide O_2-, ozone, OH radicals and atomic oxygen, defined as “reactive oxygen species” (ROS). These species participate in numerous oxide-reduction reactions both in gaseous and liquid phases. In particular, they quickly react to VOCs and fine particulate matter PM_x, leading to the destruction, transformation and elimination of particulate matter and potentially dangerous volatile organic compounds.

Based on use of non-thermal plasma at ambient temperature and pressure, the low-energy costs make the ionization process one of the most interesting advanced oxidation processes to purify water and air.

An example of the effectiveness of the technology, which is based on non-thermal plasma, is visible in the following diagrams, which show the decomposition of perchlorethylene (PCE) (a) and methanol (b) (500 ppm) in dry air according to specific energy in a non-thermal plasma produced for application of direct current discharge.



SIE (kJ/L)* = * Energy used to treat one unit volume of gas

[Source: C.Crema, Study of decomposition of tetrachlorethylene and methanol activated by non-thermal plasma in the air, Thesis discussed at the Faculty of Industrial Chemistry, University of Padua, 2011-2012]

Therapeutic Effects

Different studies have been carried out regarding the effects of negative ions on human health.

Decrease in stress caused by working at the computer

The levels of chromogranin A (considered as a biological indicator of stress) were measured on sample people during and after performing written work at the computer in order to assess the effects of negative ions on stress caused by working at the computer. The results showed a significant reduction in the increase in chromogranin A levels during the task and a rapid decrease in the level during the rest period. This shows a reduced stress effect of negative ions when working at the computer.

[Hideo Nakanea, Osamu Asamia, Yukio Yamadaa, Hideki Ohirab, "Effect of negative air ions on computer operation, anxiety and salivary chromogranin A-like immunoreactivity", *International Journal of Psychophysiology,* 2002*]*

Reduction of symptoms in people suffering from seasonal affective disorders

The effects of negative ions regarding depression symptoms were tested on groups of people affected by seasonal affective disorders. Using the SIGHSAD method to evaluate the severity of symptoms, the results show a reduction of more than 50% in depressive symptoms in at least half of the patients treated. As a result, a high density of negative ionization reduces depressive symptoms in patients with seasonal affective disorder.

[Terman M,Terman JS,Ross DC, "Bright light and high density negative air ionization reduced symptoms in seasonal affective disorder", *Arch Gen Psychiatry,* 1998]

Improvement in emotive states

Subjecting several depressed and non-depressed people to treatment with high density of negative ions has demonstrated, through the use of a special questionnaire to determine the severity of depression and the trend of the main mood conditions (anger, depression, vigour, tension, fatigue and confusion), the effect of negative ionization in reducing the rate of depression. This was already confirmed after 15 minutes of exposure to negative ions.

[NAMNI GOEL* AND GLENDA R. ETWAROO, "Bright light, negative air ions and auditory stimuli produce rapid mood changes in a student population: a placebo-controlled study", *Psychological Medicine*, 2006

Recovery of physiological responses after an exercise using moderate resistance

It has been demonstrated that exposure to negative ions causes beneficial effects on the recovery of the endocrine and cardiovascular system after an exercise using moderate resistance. In fact, compared to the absence of negative ions, we could see that exposure to these ions causes a reduction in diastolic blood pressure during the recovery period after exercise using moderate resistance. This is most likely due to the decrease in serotonin plasma levels, a neurohormone with important neurovascular, endocrine and metabolic effects, and partly responsible for vasoconstriction and vasodilation mechanisms. Therefore, it seems that after the exercise there is a lower level of blood pressure, which leads to a more rapid recovery of the conditions of rest.

[Tomoo Ryushi et al., "*The effect of exposure to negative air ions on the recovery of physiological responses after moderate endurance exercise*", Int J Biometeorol, 1997]

Effect on health and work production

A study carried out in 8 different localities in 1,159 places amongst offices, control rooms and call centres, shows that the combined effect of air ionization and filtration caused a substantial reduction in symptoms of illness, absenteeism and sick-building syndromes, with significant improvements in working productivity.

The results show a reduction of 57% of stress symptoms due to work environments, a reduction of 59% of 5 main respiratory stress symptoms and 71% of the cases of headaches, as well as reduction of 35% for sick leave. This led to an increase in productivity between 5 and 10%.

These effects were taken from a study of the following causes:

- normalizing effect of negative ions on blood levels of the hormone serotonin, stress index, electrical activity of the brain and on electrical activity of the heart;
- biocide effect of negative ions..

[John Jukes, Andrew Jenkins and Julian Laws ,"The Impact of Improved Air Quality on Productivity and Health in the Workplace", WESTRA (Workplace Environment Science & Technology Research Assoc.).

4. FIELDS OF APPLICATION

Food Industry

Within areas intended for food production, there are numerous sources of pollution (staff, production cycle, etc.); food that can compromise duration or health.
A considerable part of such contamination derives from the environment in which the product is made, in particular, from air circulation, which, if not appropriately treated, can represent an easy source for bacterial and fungal contaminants.
These contaminants compromise the product's duration, which is an essential requirement in the food industry.
The conservation and food processing is traditionally linked to proper use of low and/or high temperatures, following common procedures based on heat transfer. According to this approach, the temperature control phases (refrigeration until freezing) to slow down the deterioration and metabolic phenomena, are entrusted to chilling systems or the use of cryogenic gas (liquid nitrogen or carbon dioxide), whereas sanitisation requirements (reduction or elimination) are commonly carried out via heat exchangers (using water or overheated steam as a heating fluid) or of pasteurisation/sterilisation processes of ready-packed products.
However, the process times are the temperatures reached in the most disadvantaged (innermost) point of the product, which means the outer parts are undoubtedly "over-processed", often resulting in a decline in quality and/or high energy expenditure, without taking into consideration that, to date, transport of foodstuffs, such as fruit and vegetables, especially in the summer season or in any case with medium to high temperatures, often occurs in conditions with uncontrolled temperature, to the detriment of a good part of life quality of the products.

Use of cold plasma technology for sanitisation and improved conservation of foodstuffs represents and interesting technology since it may solve the aforesaid problems that characterise the so-called "thermal" techniques.

This is due to important properties of the ionising process:

- eliminating microbial charges and airborne dust and surface dust subjected to the treatment
- elimination of odours;
- sanitisation and improvement of Indoor Air Quality (IAQ)

The fields of application of cold plasma technology, which is based on the ionizing process, can be the following:

- microbiological decontamination of fresh and dried fruit;
- decontamination of dairy products;
- decontamination of meat, sausages and eggs;
- decontamination of grains and legumes.
- lengthening the quality of life of products.