Bi-Polar Ionization using Non-Thermal Plasma through Dielectric Barrier Discharge

Introductory Definitions:

An **atom** is a basic unit of matter containing a nucleus (having both protons and neutrons), surrounded by electrons.

Protons are positively charged; **neutrons** are neutral; and **electrons** are negatively charged.

A **molecule** is a group of two or more atoms held together by covalent bond(s), which is when atoms share electrons. Generally molecules, by definition, are neutral.

An **ion** is an atom or molecule that has either a positive or a negative charge.

A **charge** is created when the total number of electrons is not equal to the total number of protons, such that there is a net difference of charge.

Bi-Polar Ionization (BPI) is the term used when generating both positive and negative ions in the air. These ions are able to use their unique properties to break down chemicals and agglomerate particles.

Plasma is the fourth fundamental state of matter, after solids, liquids, and gases. It is similar to a gas without a definite shape or volume; however has very different properties. Plasma is electrically neutral, overall, but is composed of positively and negatively charged particles. Plasma is used in many applications, including neon lights, and in semiconductor fabrication processes. Plasma also exists in many natural forms, including lightening, the 'Northern Lights', and in space such as in comet ion tails.

Non-thermal Plasma (NTP) (aka cold plasma) is loosely the term for plasma that is created near room temperature. In actuality the gas, or ion temperature, is low; however, the electron temperatures within the plasma can be several thousand degrees Celsius. NTPs and plasmas in general can be generated in many ways, including through dielectric barrier discharge.

A **dielectric** is a material that is non-conductive, thus preventing current from flowing through or across the material. AtmosAir uses a composite as the dielectric material.

Dielectric Barrier Discharge (DBD) is the technique used by AtmosAir to generate plasma. A typical DBD system generates an electric field by applying a potential difference across a dielectric material.

AC Current is alternating current, typically produced by changing the direction of the current flow many times a minute, such as 60 times per second when using a 60 Hz power supply. Typically this follows a sinusoidal path, though this is not always the case.

DC Current is direct current, which provides a steady current in one direction.

Overview:

AtmosAir is a Bi-Polar Ionization (BPI) technology that can be characterized as using dielectric barrier discharge (DBD) to generate non-thermal plasma (NTP) on the outside of its tubes. This generated plasma interacts with the air surrounding the tube to generate ions in the air that are able to interact with chemicals and particles to purify the air.

Plasma Generation:

AtmosAir generates plasma by sending a high voltage AC current to the two electrodes on either side of the dielectric glass. Because the glass is a dielectric material, the current (i.e. electrons) cannot flow across the tube; instead a build-up of charge develops on one side of the dielectric, with the opposite charge building up to balance this charge on the other side of the dielectric. When the voltage reaches a high enough energy for the specific dielectric material, the charge build-up on the outside of the composite begins a discharge of 'lightening bolts', which is the creation of charged ions that form the plasma. Due to the nature of electrons and charged particles, an initial impact between an electron and a neutral atom results in an avalanche of ions being generated such that millions of ions are created in an extremely short amount of time.

Ion Formation in the Air:

AtmosAir technologies require a flow of air over the tubes for proper ionization. As the air flows over the tubes, the interaction between the air molecules and the plasma causes electrons to be exchanged between the air molecules and the plasma, generating ions. The same electron avalanche can occur when generating ions in the air; however, the overall concentration of ions in the air will not reach the same levels as in the plasma. Because AC current is used, this process reverses (the current flow and charge build-ups occur in the opposite direction, on opposite sides of the dielectric) several times a minute, according to the high voltage frequency. This use of AC, instead of DC, is how AtmosAir creates both positive and negative ions. The ions generated through BPI closely mimic naturally occurring ions created from falling water such as breaking surf and waterfalls, through the plasma of lightning bolts during thunderstorms, and those found in clean mountain air.

Ions and Air Purification:

Bi-Polar Ionization (BPI) can purify the air through chemical reactions and through electrostatic/physical attraction.

BPI uses ions and electrons as a way to catalyze reactions (make reactions happen more quickly) because they are able to reach the required activation energy for a specific reaction more easily compared to neutral molecules. Ions have high electron energies because they do not 'like' being in the non-neutral state. The activation energy, specific to each molecule, is the first and highest energy level that needs to be reached in order to break the molecule's bonds and create new ones. Basically this means that ions are more reactive

than neutral molecules and can initiate chemical reactions more quickly, and in many cases where no chemical reaction would occur with a neutral molecule.
The exact mechanism for how ions break down molecules is unknown because ions are difficult to measure as a group and difficult to identify as individuals; and because mechanisms can be tricky to determine for 'normal' chemical reactions.

Ions are effective in purifying the air, despite their low relative concentrations in the air, because they are so reactive, AND because the charge from an ion is conserved (unless there is a path to neutralize it such as a conductive material or opposite charge). Thus, an ion can participate in a reaction and survive in a modified form to participate in another reaction. In such a manner, an ion (or rather the ion's charge) can participate in thousands of reactions, very quickly. Due to this reactivity, chemical reactions with ions can 'go to completion'. This means they will keep reacting until the chemical is in its simplest form. What this means for most volatile organic compounds (VOCs) is that they get broken down to a small amount of carbon dioxide along with water vapor.
This chemical reaction allows chemicals to be broken down into less odorous and less toxic substances, thus purifying the air.

The second mode of operation ions use to clean the air involves the use of electrostatic attraction and physical removal of particles. Ions in gas-phase (in the air) reactions attract particles in the air and agglomerate them together through electrostatic attraction. This agglomeration of the particles allows them to become heavier / larger in size and causes them to drop out of the air; they will either be cleaned through normal housekeeping duties, or get filtered out through the return air system filters. This allows air filters to perform at higher standards, as more small particles can be removed when they are agglomerated.

Ions are very effective in improving indoor air quality through removal of dust particles from the air stream, and by breaking down odors and contaminants into less offensive molecules.