

## **Applied plasma physics and atmospheric chemical principles in odour removal**

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Dispersion and dilution was the mainstream pre-1980s philosophy in pollution control. In the 70s discussions on human released chlorinated compounds emerged, and the potential of these activities to significantly alter the chemical composition of the different layers of the atmosphere, as well as affecting animal life. The growing awareness gave the scientific community momentum in digging deep to look for and understand the very complex chemistry and physics involved in releasing compounds to the atmosphere. The scientists followed a tradition started up by among others the French multi-scientist Fourier, whom first introduced the world to carbon dioxides impact on the atmospheric energy balance back in the 1820s, and many years later in 1896, Arrhenius opened an article stating that great deal has been written on the influence of the absorption of the atmosphere upon the climate. At that time the discussion were coupled to a genuine concern about a near coming ice-age, therefore Arrhenius sat down and did some enormous calculations on the impact of scenarios of altered carbon dioxide concentrations. Those calculations, although principally wrong, ended up in pretty good agreement with present top class geophysical global models, and already by the beginning of the 20<sup>th</sup> century he introduced us to the connection between solar activity and mistiness/clouds. During the 1990s, even chemical computer models of the atmosphere were constructed for calculating the fate of volatile organic compounds, and the complexity of such models are colossal.

These days we have a rather good understanding of the chemistry of the atmosphere. Compounds have their lifetime in the atmosphere depending on different loss/removal terms. The path for removal of pollution is either by precipitation or by reaction to some intermediate, which will have the same two possibilities as its fate. Atoms may change, and also find new atom partners, but they never disappear, and in some combinations they might even smell good. In this paper we will focus on these two important natural mechanisms, precipitation and reactions in air.

### **1. Natural removal of pollutants**

Precipitation and reactions are the two main mechanisms by which pollution is removed naturally. This may take sub-seconds for some compounds whilst others may use hundreds or even thousands of years to be removed the natural way, in fact some compounds are not even ever removed, but rather in the end dispersed into the oceans,

and may or may not end up in sediments, but for most compounds, nature has its own ways of processing them.

### **1.1 Natural precipitation**

Precipitation of compounds by attachment to particles such as on droplets or dust is one main mechanism of removing pollution from air. This is why even vacating a heavy polluted city may feel as good as a vacation on the countryside minutes after heavy rain. However, in the boundary layer between earth and atmosphere, direct precipitation of pollution on the ground, in the oceans, or on vegetation, is important and we probably also receive our part of the direct precipitation on our skin and through our noses. Although not necessarily feeling good, pollution ending up in our nose is by far not its most common fate as seen from a molecules perspective.

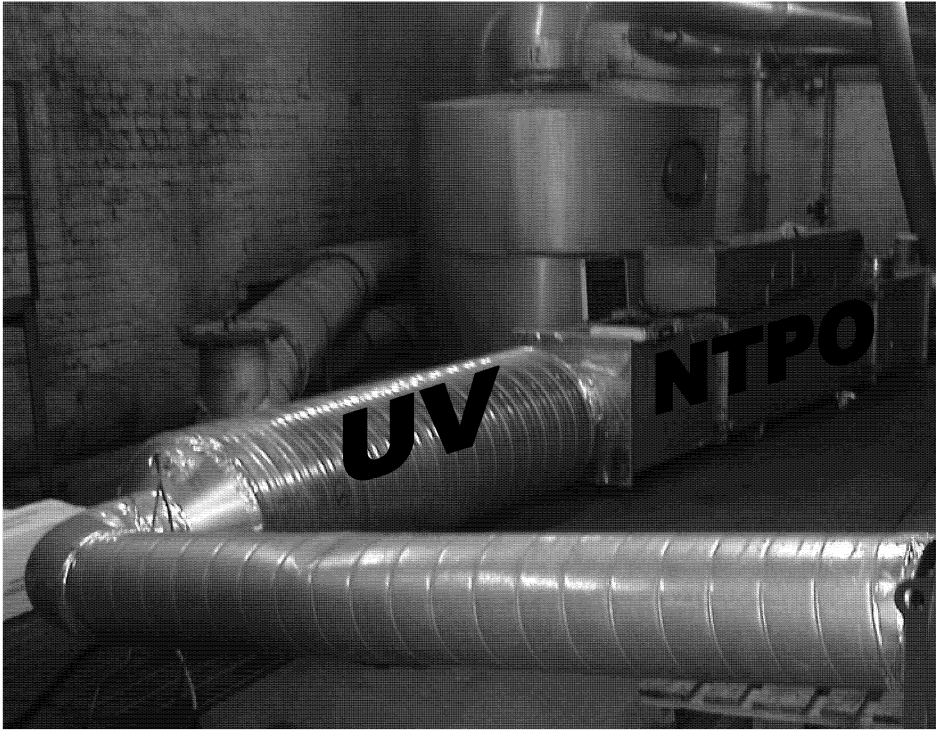
### **1.2 Atmospheric reaction mechanisms**

Several reaction pathways are possible in air, e.g. reaction on/in particles (heterogenous chemistry) or reaction initiated by light (photochemistry) or simply regular chemistry, however, the latter is normally slow in vapour phase. Nevertheless, radical reactions take place in gas-phase. It has long been acknowledged that in the atmosphere the most important reactions in the atmosphere take place during daytime by reactions by the OH radical. One useful computer model for understanding the chemistry of the atmosphere is the Master Chemical Mechanism (MCM) of Jenkin et al.

## **2. Plasma physics and advanced oxidation for removal of odour**

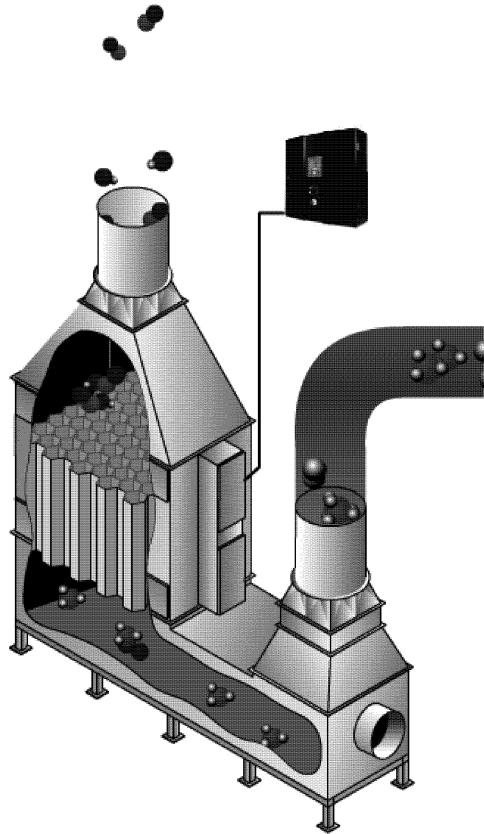
A direct non-thermal plasma oxidation reactor (NTPO) works on the same chemical principles as that of the atmosphere. We can divide the plasma systems into several different approaches and technical solutions, but that is in parts a separate topic. However, the two important principles we focus on are precipitation and chemical reactions.

In the plasma zone molecules are bombarded by electrons creating ions and charged material. The primary created ions may generate secondary radicals, of which oxygen atom radicals and hydroxyl radicals (HOx) are the most important. Further, the initial ions may also self-decompose, or work as a nucleation centre for creating condensates. Even more important, if the emission passes directly through the reaction zone of the plasma reactor, it may function as an electrostatic precipitator. In short, such a plasma system will boost the natural chemistry by generation of radicals, and it can actively precipitate charged condensates. In other words, a direct non-thermal plasma system works as a “turbo-atmosphere” where removal of chemistry is enhanced and works by natural means.



**Figure 1 A Combined Non-thermal plasma oxidizer and UV test pilot capable of treating up to 2000 m<sup>3</sup> h<sup>-1</sup> emission volumes.**

There is some computer modelling available for the main chemistry of a plasma system; however, the precipitation terms are difficult to model. Nevertheless, modelling can approach the chemistry, and the usefulness of the direct NTPO technology on different chemicals can with advantage be elaborated. On odour removal, which by itself is very complex, many important chemical compounds can be present and have difficult interactions, as well as affecting the oxidative capacity of the plasma system. Nevertheless, the only way to comprehend odour thoroughly, will have to go through a proper understanding of the chemistry involved. With a better understanding of the chemistry of an odorous emission, it will be possible to adequately combine a plasma system with combinations of other abatement methods. We have had success in combining two dry removal stages, non-thermal plasma in combination with UV. The combination works by further increasing the oxidative capacity by UV interaction with plasma-generated intermediates, and boosts odour removal performance. Also the small footprint of the plasma system can be maintained in such a combined plasma-UV system. Combining pilot test sessions, as seen in Figure 1 with chemical analysis and modelling, gives a good understanding on the odour removal mechanisms involved.



**Figure 2 Industrial non-thermal plasma treatment equipment**

Commercial system solutions based on this type of combinations, with odour removal efficiencies above 90% are available for a wide range of industrial applications. Further an EC reference document, 2006, on Best Available Techniques (BREF) in the Food, drink and milk industries lists such a system as the best available technique for end-of-pipe air treatment, see figure 2.

### **3. References**

Jenkin ME, Saunders SM, et al., 1997, "The tropospheric degradation of volatile organic compounds: A protocol for mechanism development." *Atmospheric Environment* 31(1), 81-104. (<http://mcm.leeds.ac.uk/MCM/home.htm>)

Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Food, Drink and Milk Industries, EC, August 2006