Equipment for Diluting Air Pollution

Alex Nemes, Helga Kovács, Arpad B. Palotas
University of Miskolc, Dept. of Combustion Technology, 3515 Miskolc-Egyetemvaros, Hungary
tuznemes@uni-miskolc.hu, tuzkh@uni-miskolc.hu, arpad.palotas@uni-miskolc.hu

Abstract - The quality of air we breathe determines our general health and comfort. Even though this fact is well known, people get used to the effects of the urbanized lifestyle with all its toxic implications. Air pollution includes all contaminants found in the atmosphere, which comes from – amongst others – transportation, industry, and domestic heating. In addition, atmospheric dispersion and chemical transformation conditions as well as topographic location have great influence on the ambient air concentrations. Heavy smog clouds can form when solid air pollutants are trapped in the lower troposphere, near the ground. This behavior of the ambient air is caused by a weather phenomenon so called the inversion, which prevents the polluted air to move out from the ground level. This paper presents a small-scale demonstration using an equipment capable of diluting the ground level pollution. To realize our goal, a long tube was designed in which the contaminated air from ground level is transported above the inversion-layer. An open field experiment was carried out with a test tube at the University of Miskolc, Hungary. The test equipment was made of lightweight fabric. During the experiment, the tube was attached to Helium filled balloons, which held the setting above the ground. By generating enough lift inside the tube, the contaminated air can vent into the higher part of the troposphere. It is important to know the location of the inversion in order to define the height of the tube, therefore several measurements will be conducted in the next period. The aim of this project is to develop an advanced version that can vent the most polluted areas of heavily polluted cities.

Index Terms - smog, inversion-layer, City Chimney, air pollution

1. Introduction

Increase in the concentration of CO, NO_x, SO_2, O_3, fine particles (PM10 and PM2,5) and other pollutants can cause severe smog situations. Regulating the emitting sources could be difficult or undesirable, since the major sources are usually domestic heating, transportation and the industry. Limitation on the operation of these sources can cause public discontent or economic depression. Still, in most countries there are national limits for air pollutants and public awareness is increasing about the toxics that people breathe. Air pollution is closely related to health issues, such as respiratory and cardiovascular diseases [1]. Although the medical implications are clear, people living in big cities seem to have no choice when the heavy smog sets in.

2. Smog types

According to the location and weather two types of different smogs can be distinguished. These are the London-type and the Los Angeles type smog.

The London-type smog is reductive, and is mostly created by the emission of burning fossil fuels. The main constituent of London-type smog is soot; however, this type of smog also contains large quantities of fly ash, sulfur dioxide, sodium chloride and calcium sulfate particles. If concentrations are high enough, sulfur dioxide can react with atmospheric hydroxide to produce sulfuric acid [2]. Soot, and fine dust particles acts like a carrier of other liquid and gaseous pollutants.

The Los Angeles type smog is also called the photochemical smog. The three main ingredients needed to form a photochemical smog are: nitrogen oxides (NO_x), hydrocarbons, and energy from the sun in the form of ultraviolet light (UV). There are dozens of chemical reactions between the chemical compounds of the smog, but the first thing that starts the chain of events is the emission from fossil fuels, mainly from transportation.

Photochemical smog can cause eye irritation and poor visibility. Strong oxidants such as ozone can damage the lungs. The oxidants irritate the linings of lungs. Damage to the lungs may stress the heart. Health damage is worse for people with existing lung and heart conditions. Other health implications may include loss of immune system function, increased susceptibility to infections, and fatigue. The damage can be caused by exposure to large amounts of the pollutant over a short time span, and also by chronic exposure to small amounts over long periods of time. Oxidants can kill plant cells, causing leaves to develop brown spots or drop off the plant, reduce plant growth, and make plants more susceptible to damage from other causes. Oxidants such as ozone can also corrode and destroy many materials such as rubber, nylon, fabric, and paint [3].

Fig. 1.: Heavy smog in Beijing, China, August, 2005

Table 1.:Air pollutants in Beijing, China, 2012.08.30.

Air pollutant	2012.08.30.	Min.*	Max.*
PM2.5	**247**	**72**	**352**
PM10	**139**	**27**	**171**
NO_2	**13**	**10**	**38**
SO_2	**32**	**5**	**36**

*in the previous three days

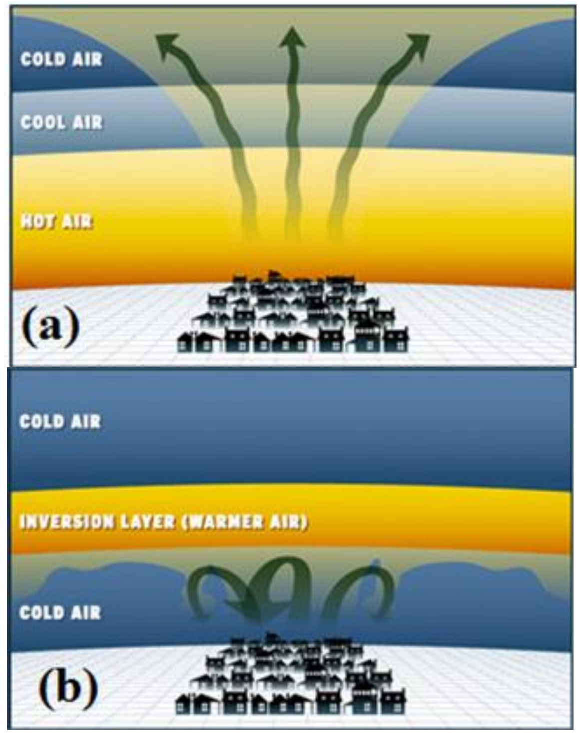

Fig.2 : Temperature gradient depending on the altitude in normal situation (a) and during temperature inversion (b)

3. Inversion-layer

In general, air pollutants are diluted by mixing in cleaner air. Geography and meteorological conditions, such as wind properties also have great effects on the dispersion [4]. Pollutants dilute fast in the case of heavy wind while form a toxic ground level clouds in the absence of wind. Contamination level can be changed through chemical and physical processes such as pollutant formation and sedimentation of larger particles.

Smog formation is usually associated with a certain weather phenomenon called the inversion-layer. The lower-atmosphere is heated from below by indirect solar radiation that is absorbed by the Earth's surface, which in turn then warms the layer of the atmosphere directly above it by convective heat transfer. Therefore air usually cools with increasing height in the lower-atmosphere, with the average thermal gradient 0,65 ℃/100m [5]. However, sometimes a warmer packet of air can be trapped above a lower one and this situation is called an inversion. Inversions often form on clear, calm nights when the ground cools rapidly [6]. The inversion layer acts like a lid, and traps air contaminants underneath. Inversion layers are usually dispersed by wind or by warm air rising as the ground heats up [7]. But if the inversion layer stays in place for a long time pollutants can build up to high levels. Fig.2 shows the lower atmosphere during normal situation and when inversion layer occurs. Air contaminants build up when inversion layers form close to the ground (low mixing depth).

An inversion can suppress convection by acting as a „cap”, therefore the air contaminants trapped by this boundary-layer can cause health and nuisance effects. An inversion will linger until wind or a storm front comes through. The "typical" period is from a few days to a week, although there have occasionally been inversions which have lasted two to three weeks.

4. Equipment for Venting Contaminated Air

The purpose of our research is to develop an equipment that can help diluting the air pollution, by breaking through the inversion-layer and moving the most polluted air upwards. To realize this goal, a long tube was designed in which the contaminated air from ground level is transported above the inversion layer. This equipment is basically a light weight, modular, mobile set of tubes with the necessary accessories and gears to keep it standing. The base of the tube has to be in the most polluted area while the top of the tube has to reach above the inversion layer, where (in the case of enough lift) the contaminated air can leave the lower atmosphere. Basically the „chimney” sucks out the smog from the most polluted area and is replaced by cleaner air from the adjacent – less polluted – parts of the city. Since the weather situation can change suddenly, the equipment should be deployable or dismountable quickly.

As a first step, an open field experiment was carried out with a test tube at the University of Miskolc, Hungary. The test equipment was made of lightweight fabric. The “chimney” was composed of five different segments, each 10 m in length and 2 m in diameter. The base of the tube was connected to a cone in order to help the injection of the ground level air. The segments were fastened to each other with karabiners and velcro. During the experiment, the set of tubes was attached to Helium filled balloons that were capable of generating enough lift to keep the whole instrument in the air.

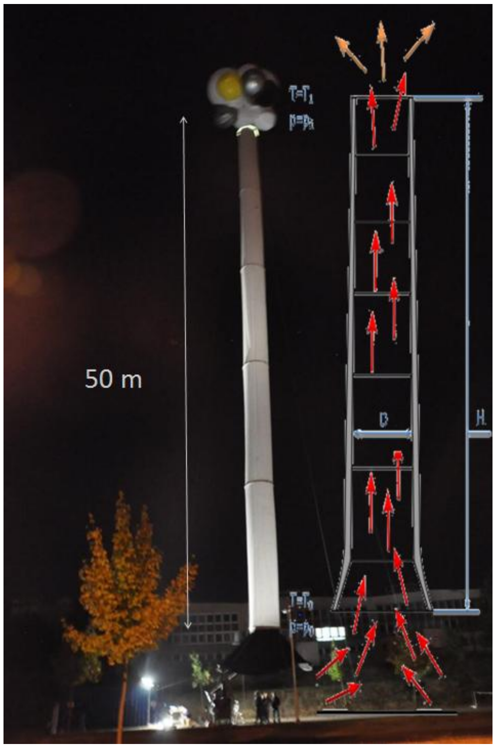

Fig. 3: „City Chimney" experiment at the University of Miskolc

The experiment was conducted three times in the Fall of 2011. These first experiments aimed at demonstrating our capability to deploy the mobile and modular equipment in a timely manner and at testing how the "chimney" behaves in low wind situations. At the time of the experiments the inversion layer was considerably higher than the length of the test chimney, thus no natural convection was experienced. As an additional test, an axial fan as well as a furnace was used to test how one can generate an airflow in the absence of the natural chimney effect. The results are not yet conclusive and are to be repeated in the Fall of 2012. The determination of the necessary minimum length for a successful experiment must be based on a series of temperature and pressure gradient measurements in the lower atmosphere. These measurements are on going presently.

5. Conclusions

Initial experiments demonstrated our capabilities to deploy a lightweight, modular and mobile "chimney" in a timely manner and keep it in the air in a functional manner for an extended period despite of light wind. Since the emerging wind would destroy the inversion layer and consequently solve the actual smog problem, there is no requirement for the chimney to withstand any considerable wind. Once the topology of the local, representative inversion layer is determined, the next level of experiments is to be performed. In optimum case the chimney is tall enough to reach above the inversion layer, thus the polluted air can dilute in the higher atmosphere. If there is no natural lift in the tube, auxiliary aids can be used in moving the polluted air into higher portion of the atmosphere. These aids can be fans, turbines and heat generation, such as mobile burners or their combination. The final goal of this project is to develop an advanced version of the equipment that can help in reducing the air pollution considerably by venting the most polluted areas of heavily polluted cities.

Acknowledgment

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