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Forest Fire Net

Special issue with the proceedings of the teleconference:

"Short and long term health impacts of forest fire smoke on the firefighters and the exposed population"

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Prologue

The teleconference "Short and long term health impacts of forest fire smoke on the fire-fighters and the exposed population" took place on the 31st of May 2005. It was organized by the European Center for Forest Fires (ECFF), which operates in the framework of EUR-OPA initiative of the European Council. Forest fire smoke health impacts on population and firemen are priority issues of the ECFF agenda.

Coping with these safety issues entails a number of activities. This teleconference is considered as the first step. The aim of the event was to bring together scientists and operational people in order to define key aspects and to propose further actions needed. Participants from Cyprus, Greece, France, Morocco and Portugal and the European Council contributed with their knowledge and expertise in presentations and discussions, providing opinions, know-how and proposals.

The proceedings of the teleconference are prepared in a format which is expected to allow a better understanding of the key issues. The conclusions presented at the end of the proceedings should be considered as a catalogue of ideas and not, necessarily, as recommendations. Further elaboration on the relevant issues and the use of relevant tools is needed in order to have solid recommendations and guidelines.

The National Technical University of Athens (NTUA) is acknowledged for technically supporting the teleconference and for providing with the teleconference room.

Milt Statheropoulos

European Center for Forest Fires (ECFF)

“Short and long term health impacts of forest fire smoke on the fire-fighters and the exposed population”

teleconference of 31st of May 2005

European Center for Forest Fires

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1. Chemistry of Forest Fire Smoke

1.1. Introduction

Forest fire smoke (ffs) is a mixture of various compounds, such as water vapour, permanent gases *(e.g. Carbon Monoxide, Carbon Dioxide)*, Volatile Organic Compounds *(e.g. formaldehyde, acroleine, benzene, toluene, xylene)*, Semi Volatile Organic Compounds (e.g. Benzopyrene) and particulate matter, usually of very small diameter/ fine particles *(e.g. PM_{10}, $PM_{2,5}$, PM_1)*. Particulate matter, a mixture of both solid particles and liquid droplets, usually consists of Polyaromatic Hydrocarbons (PAHs) and/or trace elements *(e.g. Pb, Fe, Zn, S)*. Concentrations of particles are often measured in μg/m^3; other pollutants are measured in ppm *(parts per million)* or in μg/m^3.

Smoke is usually originated from the combustion of forest fuels. However, in some cases, the forest fire front may, possibly, expand and burn buildings, landfills e.t.c. In such case, forest fire smoke may also contain pyrolysis and combustion products of materials other than the forest fuel e.g.asbestos, glass, cement, waste, fertilizers.

1.2. Questions to be answered

The composition of forest fire smoke (ffs) is a subject of various chemical analysis, carried out by using bench-top instruments and field chemical analysis. Two issues are raised in today's approaches:

1) What is defined as ffs?
2) Is there a typical chemical composition of forest fire smoke (list of components)?
3) Are photochemical reactions possible for the components of forest fire smoke?
4) What are the combustion products originated from oher sources, that ffs can consist of?
5) Which properties of the ffs are important for health impact and safety issues?

1.3. Presentations

- **Chemical components of forest fire smoke: a new approach**
  (M. Statheropoulos, ECFF, Athens, Gr)

Forest fire smoke is product of the pyrolysis and combustion of forest fuels, consisted of gases, liquids and solids. The definition of forest fire smoke (ffs) needs to be reconsidered due to the following:

1) Depending on the fire-front expansion, different materials such as glass, cement, wastes etc, can be burned.
2) Ffs mixes with other types of pollutants *(urban, industrial)* and may be exposed for long time periods to sun radiation, causing possibly photochemical reactions.
3) Suppression methods *(e.g. sea water, chemical retardants)* may also contribute to the components of ffs. Due to strong winds and fire attack methods *(remove vegetation, digging fire-lines)*, soil particles are removed from the ground and mixed with ffs during the forest fire.

Consequently, forest fire smoke in a more operational view, may be considered as a complex mixture originated from the combustion of forest fuel, the possible combustion of others materials due to the expansion of forest fire front, the possible photochemical reaction products and airborne soil.

- **Forest fire smoke as an air pollutant**
  (A.I. Miranda, C. Borrego, Project Spread/ D262EVG1-CT-2001-00043, Uof AVEIRO, Aveiro, Pt)

Smoke from forest fires releases important amounts of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrogen oxides (NOx), ammonia (NH3), particulate matter (total particles, TP), particles with mean diameter lesser than 2,5 μm (PM2,5) and particles with mean diameter lesser than 10 μm (PM10)), non-methane hydrocarbons (NMHC), volatile organic compounds (VOC_S), sulphur dioxide (SO_2) and other chemical species. These air pollutants can cause serious consequences to regional and local air quality by reducing visibility, generating smog and threatening human health and ecosystems.

- **Factors which influence the chemical composition of forest fire smoke**
  (M. Stefanidou – Loutsidou, Medical School, Uof Athens, Athens, Gr)

The chemical composition of the combustion formed atmosphere and the concentrations of the individual constituents depend on many factors, such as:

1) The nature of the materials available for heating or burning
2) The phase of the combustion process
3) The potential for chemical and/or physical interactions between materials present in the fire atmosphere
4) The potential for additive or synergistic toxic effects
5) The temperature
6) The air flow and oxygen availability.

(Norris JC, Ballantyne B: Combustion Toxicology, In B. Ballantyne B, Mars T, Turner P Eds: General and Applied Toxicology, Vol. 3, MacMillan, London: 1309-1327, 1993, Hartzell GE: Overview of combustion toxicology. Toxicology 31: 115 (1-3), 7-23,1996)

- **Forest fire smoke components from sources other than the forest fuel**
  (M. Statheropoulos, ECFF, S. Karma, NTUA, Athens, Gr)

Forest fire smoke chemical composition depends on the forest fuel *(type, relative moisture content)* and the specific conditions of each forest fire *(meteorological data such as wind velocity, duration of flaming and smouldering phase)*. A list of some ffs components identified during three different forest fires is presented in Table 1. *(Muraleedharan, et al, "Chemical characterisation of the haze in Brunei Darussalam during the 1998 episode" Atmospheric Environment 34 (2000) 2725; M.Reh et al, "Health Hazard Evaluation Report No. 88-320-2176", February 1992 U.S Department of the Interior, National Park Service, Yellostown National Park, Wyoming http:// www.cdc.gov/niosh/hhe/reports; FIACTU/ NTUA unpublished results)*

In the same table, the concentrations of those components are also presented in relation to the distance from the fire-front.

However, as fire expands to constructions, landfills, waste disposals, it is usual the forest fire front to burn materials other than the forest fuel, such as glass, cement, plastics, asbestos, fertilizers, pesticides and wastes. As a result, the composition of ffs may become even more complicated, as long as emissions, such as Polychlorinated Dibenzo-p-Dioxines (PCDD)/Polychlorinated Dibenzo-Furans (PCDFs) and Polychlorinated Biphenyls (PCBs), are also produced. (Lemieux, et al, "Emissions of organic air toxics from open burning: a comprehensive review". Progress in Energy and Combustion Science 30 (2004) 1-32)

It should be emphasized that under sun radiation secondary products can be produced, such as ozon. VOCs and CO are described as precursors to ground level ozone, especially when NO_2 is present. In the follow the photochemical reactions of those pollutants are presented:

1) $CO + OH \xrightarrow{[O_2]} HO_2 + CO_2$

2) $VOC + OH \xrightarrow{[O_2]} RO_2 + H_2O$

3) $RO_2 + NO \xrightarrow{[O_2]}$ Secondary VOC $+ HO_2 + NO_2$

4) $HO_2 + NO \longrightarrow OH + NO_2$

5) $NO_2 + hv \longrightarrow NO + O$

6) $O + O_2 + M \longrightarrow O_3 + M$

An effort to register all the possible scenarios of a forest fire front expansion (e.g expansion to houses, landfills, waste disposals), is presented in Table 2 (Road –Map of forest fire flame and smoke front) together with the possible synthesis of ffs in such cases (Chemical & Engineering News, January 24, 2005, pg.26).

It should be pointed out, that in the various scenarios presented in Table 2 the smoke produced may be the additive or the synergistic result of all those products, which may turn ffs in a more hazardous and toxic mixture. It should be noted that Table 2 needs further elaboration in order to become a useful operational tool for crisis managers *(e.g. assessing the severity of the situation and take first response measures).* This map can also be used for assessing the possible health impacts (short and long term) of forest fire smoke, as well as, for safety issues.

Physical and chemical properties of forest fire smoke

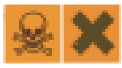
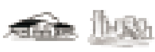
Depending on the type of components, their chemical and physicochemical properties can be proved very important for health effects. Among the physical properties are included: the size of particles and their ability to absorb chemicals, according to their surface area. The size of particles is important because the fine and aerodynamic particles can penetrate more easily the respiratory system and cause more severe health implications. Small particles are charcterized by a large surface area and they play double hazardous role: not only do they have health implications due to their size, but they also act as small matrixes, which absorb toxic compounds (e.g PAHs, Dioxines, Trace metals like Pb).

Among the chemical properties, alkalinity and acidity seem to be top priority for health reasons. When forest fire expands and burns buildings, (cement, glass, asbestos, e.t.c) the particles produced usually consist of $Ca(OH)_2$, $CaCO_3$, $CaSO_4$ and therefore have alkaline PH, which cause nose and chest irritation. It should also be noted that other properties (e.g. oxidation, photolysis) might be important. However, these are issues which need further investigation.

Table 1. ***Forest fire smoke components and their concentrations, in relation to the distance from the fire-front, measured in different forest fires incidents.***

Type of Compounds	Compounds	South East ASIA (24-h average measured during a time period of 5 days, in a 3,5 km distance from the fire front)	Yellostone Park USA (Clover Mist) (Area air sampling near the firemen crew)	Urban area Greece (NTUA experiments) (70 m distance from fire-front, 30 min sampling duration)
Volatile Organic Compounds	Benzene	0.4 – 24.8 μg/m³	64 μg/m³	696 μg/m³
	Toluene	2.1 – 15.5 μg/m³	Net Detected	436 μg/m³
	Phenol	0.14 – 0.41 μg/m³	Not measured	Not measured
	Naphthalene	2.1 – 15.2 μg/m³	2,74 μg/m³	182 μg/m³
	Styrene	Not measured	Not measured	657 μg/m³
	Ethyl Benzene	0.14 – 2.01 μg/m³	Not measured	17 μg/m³
	Xylene	3.7 – 28.7 μg/m³	Not measured	347 μg/m³
Permanent gases	Carbon dioxide	Not measured	700-750 ppm	500 ppm (max)
	Carbon monoxide	Not measured	3.9– 4.6 ppm	44 ppm(max)
	Nitrogen oxides	1.5 – 27.0 μg/m³	2 ppm<	Not measured
	Sulfur oxides	Not measured	1.8 – 1.9 ppm	Not measured
Particulate matter	PM 10	49– 372 μg/m³	200– 15.900 μg/m³	Not measured
	PM 2,5	Not measured	Not measured	49.484 μg/m³ (max)

Table 2. ***Road-Map for air-quality assessment during a forest fire: Decision tool for crisis managers (Prepared by NTUA-ECFF)***

Forest fire flame and smoke front (Scenarios)	Forest fire Flame front 	Rural Fields 	Rural or urban constructions 	Landfills 	Illegal Waste disposal	Forest fire Retardants 	Smoke front	Urban or Industrial areas 
Possible processes	Pyrolysis and combustion of forest fuel	Pyrolysis and combustion of agricultural fields, fertilizers, pesticides, e.t.c.	Pyrolysis and combustion of building materials, glass, cement, asbestos, plastic e.t.c	Pyrolysis and combustion of household waste, plastic e.t.c.	Pyrolysis and combustion of organic residues, lead-acid vehicle batteries, electric appliances, radioactive materials	Pyrolysis and combustion of commercial retardants (e.g Firetrol)	Mixture of gases, liquids & solids	Mixing of forest fire smoke with urban and industrial pollutants, possible photochemical reactions
Chemical components **1) Organic**	1) VOCs (H/C, Aldehydes, substituted furans, carboxylic acids, BTEX), SVOCs (PAHs)	1) VOCs, SVOCs (PAHs), PCDDs, PCDFs	1) Non polar VOCs (e.g BTEX, styrene), SVOCs (PAHs), PCDDs, PCDFs, PCBs	1) VOCs, chloro-benzenes, chloro-phenols, SVOCs (PAHs), Carbonyls, PCDDs, PCDFs, PCBs	1)PCDDs, PCDFs, Co-PCBs			1)Aliphatic H/C, VOCs, BTEX, Styrene, PAHs, Saturated hydrocarbons (PAR), mercaptans
2) Inorganic	2) CO, CO2, NOx,SOx, trace elements (e.g. S, Cl, K, Na, Mg,)	2) CO, CO2, CH4, HCl, SO2, NOx, POx, NH3, CS2, H2S, HCN	2) CO, CO2, metals (e.g.Ca, Mg, Ti, Al)	2)CO, CO2, heavy metals (e.g. PB, Cd, Cr, Cu, Zn)	2) CO, CO2, radionuclides (I-29, Cs-137, Cl-36)	2) NH3, SO2		2) CO, CO2, NOx, SO2, H2S, O3
Physical properties (particle size)	Coarse (PM10) & Fine (PM2.5)	Coarse (PM10) & Fine (PM2.5)	Coarse (PM10) & Fine (PM2.5)	Fine particles (PM2.5<)	no data	Coarse (PM10) & Fine (PM2.5)		Coarse (PM10) & Fine (PM2.5)
Chemical properties **1) Alcalinity** / acidity **2) Photo-chemical reactions**			1) alkaline PH					2)PAH photo-degradation Photo-chemical O_3

- **Background information**
  (C. Chrysiliou, Civil Defence, Ministry of Interior, M. Martin, Lemesos Municipality, S. Kleanthous, Department of Labour Inspection Ministry of Labour & Social Insurance, Lemesos, Cy)

Burning of wastes, domestic and industrial, is prohibited since it can produce air pollution. Specific methodologies have been developed for the estimation of these emissions from the Corinair and the EPA. However, in case of a fire, there are only a few data one can find to estimate the emissions.

Intentional or accidental fires can contribute to the pollution, depending on the materials burned. In case of a factory, everybody can realize that the emissions may include a great number of hazardous substances including dioxins. Fire Departments are normally aware of the risk depending on the fire hazard classification of the factory and may protect their crew with specific overalls and masks and also minimize the public health impact by evacuation. However, it is not a common practice for countries to take any measurements during the fires or even estimate the pollutants' emissions.

In forest fires on the other hand, especially the big ones, everybody can join the work of the Fire Department, since fires are considered as crisis, so many people are exposed to the fire-originated pollutants. According to Corinair Emission Inventory Guidebook *(SNAP CODE 110301-110302, Activities: OTHER SOURCES AND SINKS-Forest and other vegetation fires – Man induced – Other of 1999)*, the major products from biomass burning are CO_2 and water.

However, a large number of particulates and trace gases are produced, including the products of incomplete combustion (CO, NMHCs) and nitrogen and sulphur species that come from the vegetation and soil. MSA (methane-sulphonate), aldehydes and organic acids are present as trace gases. Furthermore, the emissions of H_2, COS and CH_3Cl which have been traced, can have stratospheric impact. Forest fires account for 0,2% of European NOx emissions, 0,5% of NMVOCs, 0,2% of CH_4, 1,9% of CO, 1,2% of N_2O and 0,1% of NH_3.

On the whole, forest fires appear to have a low contribution in the overall emissions in Europe, but "in some areas emissions might make appreciable contributions to ground level concentration, especially as fires occur over short periods of time". In hot Mediterranean countries, where fires can last for many days in summer time, large areas are completely burned out and the emissions are far more hazardous.

This is supported by an Italian study *(of Carlo Trozzi, Trita Vaccaro, Enzo Piscitello)*. The study shows that in Italy it has been estimated that forest fires have bigger contribution: up to 4,5% CO, 1% NOx and 1% NOx. While in regional level, forest fires can contribute up to 5% CO and 8% PM10.

1.4. Comments/ Discussion

S. Karma (NTUA, Athens, Gr) commented that there is a need to define target compounds as markers for monitoring air-quality during a forest fire. This becomes necessary due to the complexity of ffs. This will also facilitate quantitative chemical analysis procedures (e.g. determine type and quantities of internal standards).

C. Magnan (CEREN, Marseille, Fr) pointed out that among the compounds found in forest fire smoke there are carcinogenic elements, such as furans.

A.I. Miranda (Uof AVEIRO, Aveiro, Pt) mentioned that joint measurements of ffs components have been carried out during the ERAS project by CEREN, NTUA and Uof AVEIRO (EVG-CT-2001-00039)

2. Forest Fire Smoke: Medical and toxicological issues

2.1. Introduction

Exposure to ffs can cause short and long term health impacts on the fire-fighters and population. Sensitive groups, such as people with respiratory problems, children and elderly are more vulnerable. Generally, epidemiological studies which link particulate air pollution to human health impacts exist. However, the exposure to the components of ffs could be considered similar to the occupational exposure to these chemicals and in fact is, at least for the fire-fighters.

The conditions, the intensity and the duration of the exposure are different for the fire-fighters and the exposed populations and are essential for the determination of the final impact of this exposure on their health. The preventive measures that can be taken and could minimize the effects of the exposure are also different for each group. Fire-fighters are directly exposed to high concentrations of smoke and chemicals that are produced on site. Human and animal populations are exposed to chemicals produced elsewhere and transferred by the wind far away from the place of their emission. Haze, produced by biomass burning can cause lung and respiratory disorders and decreased function of the lungs e.g. acute respiratory irritation and acute exacerbation of asthma and chronic obstructive pulmonary disease, not only to fire-fighters but also to exposed nearby populations. The haze-related respiratory tract diseases may influence the morbidity and mortality of the exposed populations and lead to increased hospitalization and increased visits to emergency rooms.

Irritation of the eyes and the skin, some times severe, can also be observed. Further studies are needed for the identification and the evaluation of the short and long-term effects of the haze on human health and especially, on the health of sensitive populations like children, pregnant women, elderly people or people with preexisting respiratory problems. The evaluation of the carcinogenic, embryotoxic or teratogenic potential of this exposure needs also further evaluation.

Impacts of air pollutants from forest fires on human health are largely preventable and specific measures should be taken in first place for reducing the number and the severity of forest fires.

2.2. Questions to be answered

1) What is known about the toxicology of forest fire smoke?
2) What about the physiological responses after inhaling smoke?
3) Is there a need for a special protocol for medical examination, especially for firemen and population in case that exposure to ffs must be monitored? Can routine medical procedures be used?
4) What is known about the chemical analysis of expired air of firemen and population after their exposure to a forest fire?

2.3. Presentations

- **Toxicology of forest fire smoke components *(M. Stefanidou – Loutsidou, Medical School, Uof Athens, Athens, Gr)***

Introduction

Fire Toxicology is an important and complex field of Toxicology which deals with the nature and potential adverse effects of products resulting from the heating or burning of materials. Fire Toxicology predicts the nature of the combustion breakdown products, the severity and the time course of adverse effects produced upon exposure to fire-generated toxic substances, the composition of which varies at different stages of the fire. The characteristics and hazards of one fire may be entirely different from those of another fire *(Ellenhorn MJ, Barceloux, DG: Smoke inhalation, In Ellenhorn MJ, Barceloux DG Eds: Medical Toxicology, Diagnosis and treatment of human poisoning, Elsevier Science Publishing Company: 888-893, 1988).*

Fire dynamics is a complex and irreversible process involving flame, heat, oxygen depletion, smoke, toxic gases and climatological factors, including altitude and meteorology. Under ideal conditions, the burning of organic material is an oxidation process that primarily produces water vapor and carbon dioxide. Nevertheless, in natural and anthropogenic fires, combustion is incomplete due to an insufficient supply of oxygen *(Delmas, R., Lacaux, J.P., Brocard, D.: Determination of biomass burning emission factors: methods and results. Environmental Monitoring and Assessment, 38, 181-204, 1995).*

Smoke

Smoke is evolved when materials undergo vaporization or thermal decomposition. Smoke is a complex mixture of volatilized products of combustion, consisting of toxic gases and particulate matter that depend on fuel type, moisture content and combustion temperature *(Nelson GL: Regulatory aspects of fire toxicology. Toxicology 47:(1-2), 181-199, 1987).*

During a fire, the materials that burn are organic materials, of which the primary chemical element is carbon. When burned completely, carbon compounds evolve carbon dioxide and water. Combustion is seldom complete, even in furnacelike conditions; thus carbon monoxide is an ever present and ever expected toxicant. In almost all fires, dioxins can be found in the smoke and residues. Therefore, the combustion atmosphere formed and the toxicants present are based on material-specific chemistry and are totally dependent upon the specific conditions of smoke generation, conditions which change during a fire *(Nelson GL: Regulatory aspects of fire toxicology. Toxicology 47:(1-2), 181-199, 1987, Wittbecker FW, Giersig M: Fire and ecotoxicolo-gical aspects of polyurethane rigid foam. Rev Environ Contam Toxicol 170: 1-11, 2001).*

Factors contributing to the production of inhalation injury, due to smoke, in the fire setting depend on the following factors *(Ellenhorn MJ, Barceloux, DG: Smoke inhalation, In Ellenhorn MJ, Barceloux DG Eds: Medical Toxicology, Diagnosis and treatment of human poisoning, Elsevier Science Publishing Company: 888-893, 1988):*

1) Particle Size. Smoke particles, such as soot, act as vehicles to carry absorbed toxins into the respiratory tract. Particles measuring between 5 and 30 μm impact on the nasopharyngeal region, whereas particles of 1 to 5 μm penetrate the large airways of the trachea, bronchi, and bronchioles and particles smaller than 1 μm reach the alveoli.
2) Toxic gas and oxygen concentration.
3) Effectiveness of protective reflexes (e.g., cough, laryngospasm).
4) Respiratory rate. High minute volumes, such as those seen in fire-fighters, increase the volume of inhaled noxious gases.
5) Acidity/alkalinity of gas involved.
6) Preexisting cardiopulmonary disease.
7) Degree and type of respiratory protection.
8) Total amount of combustion products absorbed either acutely or chronically.

The most important airborne toxins included in smoke of forest fires are classified as follows (Hartzell GE: Overview of combustion toxicology. Toxicology 31: 115 (1-3), 7-23,1996):

Asphyxiants

- Carbon Dioxide
- Methane
- Carbon Monoxide

These chemicals produce hypoxia by displacing oxygen from the environment. A 17% inhaled oxygen content is the safe limit for prolonged exposure. A 5% oxygen content is the minimum compatible with life. Concentrations of 1% produce stupor and memory loss.

Respiratory Irritants

- Ammonia
- Acrolein/aldehydes
- Sulfur dioxide
- Formaldehyde

These compounds produce hypoxia by causing a chemical tracheobronchitis, pulmonary edema, upper airway obstruction, or pneumonia.

Systemic Toxins

- Heavy metals (lead, mercury and cadmium) coming from the environmental pollution.

Forest fires

The ecosystem's chemical and physical features combined with environmental parameters *(humidity, temperature, wind speed)* and the type of ignition, affect the combustion factor and combustion efficiency and therefore, the amount of biomass consumed, the composition of smoke emissions, and the rate of release of emissions *(Ward, D.E., Susott, R.A., Kauffman, J.B., et al.: Smoke and fire characteristics for cerrado and deforestation burns in Brazil: BASE-B Experiment. Journal of Geophysical Research, 97, 14601-14619, 1992).*

Exposure to combustion products can have potentially detrimental short and long term effects on human health. Persons at higher risk include those with preexisting cardiovascular and respiratory disease, infants, the elderly and pregnant women. Assessment of potential adverse health effects from the products of combustion is difficult, because of the multiplicity of thermolysis products and the variability of factors affecting the qualitative and quantitative nature of the products and the biological responses to them *(Malilay, J.: A review of factors affecting the human health impacts of air pollutants from forest fires: WHO, 1999, Health Guidelines for Vegetation Fire Events, Lima, Peru, 6-9 October 1998).*

After biomass fires many toxic agents are produced, such as, particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), carbon monoxide, aldehydes, organic acids, semi volatile and volatile organic compounds found in soils in remote areas, free radicals, ozone, trace gases and radio nuclides *(Malilay, J.: A review of factors affecting the human health impacts of air pollutants from forest fires.: WHO, 1999, Health Guidelines for Vegetation Fire Events, Lima, Peru, 6-9 October 1998).*

- Particulate matter (PM) is the solid component of smoke and PM increases respiratory and cardiovascular mortality and morbidity, including asthma and emphysema.
- Polycyclic aromatic hydrocarbons (PAHs) are organic compounds, between them the benzopyrene is considered the most carcinogenic.

- Carbon monoxide causes tissue hypoxia and it may cause death. Persons at higher risk include those with preexisting cardiovascular and respiratory disease, infants, the elderly and pregnant women.
- Formaldehyde and acrolein are aldehydes considered irritants of the mucous membranes and they are released during biomass burning, causing pulmonary lesions.
- Free radicals, produced during biomass burning, may react with human tissues.
- Ozone is not found in areas close to fires. It is formed photo chemically near the top of smoke plumes under high sunlight.
- Trace gases, particularly polychlorinated dibenzo-p-dioxins (PCDDs) are extremely persistent and widely distributed in the environment and they are found in soils in remote areas.
- Radionuclides, such as iodine-129, cesium-137 and chlorine-36 can be released into the atmosphere, soil and water with long-term consequences on health, with the possibility to cause cancer. Fires can mobilize radionuclides from contaminated biomass through suspension of gases and particles in the atmosphere or solubilization and enrichment of the ash.

Smoke emitted during the global annual combustion of about 2 to 3 billion metric tons of plant materials contains numerous toxic materials, some of which are herbicide residues and dioxins. Forest and brush fires are major sources of PCDDs (McMahon C.K. and Bush P.B.: Forest worker exposure to airborne herbicide residues in smoke from prescribed fires in the southern United States. Am. Ind. Hyg. Assoc., 53, 4, 265-272, 1992, Abelson, P.H.: Chlorine and organochlorine compounds (editorial). Science, 265, 1155, 1994a, Abelson, P.H.: Sources of dioxin (response to letter). Science, 266, 349-352, 1994b).

Wood combustion products are spread around the world and they can travel thousands of kilometers to heavily populated urban areas *(Sapkota A., Symons J.M., Kleissl J., Wang, L., Parlange M.B., Ondov J., Breysse P.N., Diette G.B., Eggleston P.A., Buckley T.J.: Impact of the 2002 Canadian forest fires on particulate matter air quality in Baltimore city. Environ. Sci. Technol., 1,39, 1, 24-32, 2005).*

According to the WHO bioregional meeting on health impacts of haze-related air pollution at Kuala Lumpur in 1998, it was concluded that the main constituent of the haze that adversely affects health is fine particulate matter *(WHO, 1999: Health guidelines for vegetation fire events, Lima, Peru, 6-9 October 1998).*

Occupational exposure of fire-fighters

Firefighting is one of the most hazardous professions, having an associated high level of morbidity and mortality. Casualties occur during, or as a consequence of exposure to a fire for various reasons, of which the following are the more important *(Norris JC, Ballantyne B: Combustion Toxicology, In B. Ballantyne B, Mars T, Turner P Eds: General and Applied Toxicology, Vol. 3, MacMillan, London: 1309-1327, 1993):*

- Direct physical trauma
- Flame and heat
- Oxygen depletion
- Factors hindering escape
- Toxic substances in the atmosphere, such as carbon monoxide.

Fire-fighters are often exposed to concentrations of carbon monoxide and particulate matter at levels near or higher than recommended occupational exposure limits and particularly in those cases when respiratory protective equipment was not used, due to the visual impression of low smoke intensity. Many of these materials have been implicated in the production of cardiovascular, respiratory, or neoplasmatic diseases *(Brandt - Rauf PW, Fallon LF, Jr, Tarantini T, Idema C, Andrews L.Health hazards of fire fighters: exposure assessment. Br. J. Ind. Med., 4:9, 606- 612,1988, Wexler P: Combustion Toxicology, In Wexler P Ed: Encyclopedia of Toxicology, Vol 1, Academic Press, New York: 360-374, 1998)*.

In addition to the most obvious external stress causes *(heat, humidity, O_2 decrement, CO_2 increment, emotional stress)* fire-fighters use heavy equipment and carry people or objects during firefighting, thus, the risk of poisoning by inhalation of toxic combustion gas of the fire atmosphere is probable *(del Piano M, La Palombara P, Nicosia R, Sessa R: Pathology in firemen.G Ital Med Lav, 5:5, 221-225,1983)*.

The most important health concerns of fire-fighters are traumatic, thermal, ergonomic, psychological, toxic, respiratory disease, cardiovascular disease, reproductive and carcinogenic hazards. Several studies have shown that exposure to a fire atmosphere produces acute changes in pulmonary function and may be a factor in the development of chronic lung disfunction, decrease in pulmonary function and a raised risk for emphysema. The FEV1 *(forced expiratory volume in 1 s) was decreased in the fire atmosphere, as well as the FVC (forced vital capacity)*. These indices changed in relation to frequency of exposure *(Beaumont JJ, Chu GST, Jones JR, Schenker MB, Singleton JA, Piantanida LS, Reiterman M: An epidemiological study of cancer and other causes of mortality in San Francisco fire-fighters. Am J Industr Health, 19, 357-372, 1991, Norris JC, Ballantyne B: Combustion Toxicology, In B. Ballantyne B, Mars T, Turner P Eds: General and Applied Toxicology, Vol. 3, MacMillan, London: 1309-1327, 1993)*.

To assess the types and levels of exposure encountered by fire-fighters during their routine occupational duties, it is necessary the monitoring during firefighting activities with personal, portable ambient environmental sampling devices.

Regulatory Fire Toxicology is dealing with the toxicity and the risk from fire. In the fire risk equation, ignition and growth terms dominate. Practitioners of emergency and occupational medicine, industrial hygienists and toxicologists, treating victims of fire, must keep in mind a wide range of potential combustion and pyrolysis products when dealing with clinical and regulatory issues in fire safety *(Orzell RA: Toxicological aspects of fire smoke-polymer pyrolysis and combustion. Occup Med, 8: 3, 414-429, 1993)*.

Toxicity assessment of fire

For the toxicity assessment of fire, information on the toxicity of combustion products derives from studies of combustion products in small-scale tests or individual fire gases. Although bioassays are needed for a full toxicity assessment, it is now possible to predict the toxic potency of materials to some extent from analytical data alone. The suitability of the small-scale test decomposition conditions is determined in terms of non-flaming or flaming behavior, temperature, CO_2/CO ratio and oxygen concentration.

Existing small-scale test methods provide reasonable models for materials under non-flaming oxidative and early flaming conditions, although the data base for the latter is poor. For the toxicity assessment of fire it is also indicated the use of laboratory animals for studying the fire conditions. The combination of these leads to the development of an empirical mathematical model to predict the toxicity *(Barillo DJ, Goode R: Fire fatality study - demographics of fire victims. Burns, 2: 2, 85-88, 1996)*.

- **Effects on health from forest fire smoke *(A.I. Miranda, C. Borrego, Final remarks/ Project Spread /D263 EVG1-CT-2001-0004, Uof AVEIRO, Aveiro, Pt)***

Atmospheric emissions from forest fires have considerable impacts on air quality and human health. Biomass burning is a major contributor of toxic gaseous and particle air pollutants and greenhouse gases throughout the world, in many instances resulting in human exposure to high levels of various air pollutants. But unlike some anthropogenic sources it is poorly quantified.

The nature of biomass burning is such that the combustion is not complete, and as a result a large number of pollutants are emitted. For example, particulate matter (PM), oxides of nitrogen (NOX), sulphur dioxide (SO_2) and carbon monoxide (CO) are among the air pollutants (or their precursors) that are often of most concern for general population exposures. The emission of e.g. sulphur- and nitrogen-based compounds depends both on the efficiency of the combustion process and the chemical composition of the vegetation burned.

After the emission, during transport, the combustion emissions undergo physico-chemical changes. While exposure to most airborne pollutants can potentially have detrimental health effects, recent scientific evidence indicates that airborne particles, especially those that are very small (aerodynamic diameters below 2.5 µm), could have the most significant health effects. These particles have very high probability of deposition in deeper parts of the human respiratory tract where they may lead to a range of health effects by virtue of their physical, chemical, toxicological or carcinogenic nature. The adverse health effects of small particles and their relative abundance in emissions are why particles receive more attention than other pollutants when considering exposure to smoke plumes from biomass burning *(WHO, Health guidelines for vegetation fire events, Geneva 1999).*

Work performed in the scope of SPREAD Project contributed to a better understanding of forest fires impacts on air quality and health. Personal exposures to NO2/SO2 measured during Gestosa, revealed that fire-fighters can be exposed to high levels of pollutants with adverse impacts on health. Due to the harmful effects of particulate matter, an effort will be made in the future in order to quantify fire-fighters' exposure to this pollutant.

For a fire event occurred in Lisbon, an estimation of the population exposed was performed based on demography data and estimated air quality concentrations. Obtained results pointed that entire populations could be at risk in areas where air quality impacts from forest fires are significant. Hence, forest fires should be considered as a major source of air pollutants emissions, including atmospheric pollutants affecting human health like particles, when quantifying causes of poor air quality, particularly in urban areas with high population density.

Research is still needed in this issue, aiming to improve the knowledge on population exposure associated with forest fires occurrence, and help on the establishment of recommendations and guidelines for human health protection.

- **Analysis of expired air of fire-fighters and exposed population as a tool for monitoring health impacts of smoke**
  (A. Georgiadou, A. Agapiou, S. Karma, NTUA, Athens, Gr)

The bulk matrix of human breath as we know is a mixture of water, carbon dioxide, nitrogen, oxygen and inert gases. A small fraction of this mixture encompasses of Volatile Organic Compounds (VOCs), which are found usually in the range of nmol/pmol. Recently, human expired air analysis has been focused on these volatile compounds since they can offer valuable informations about human status.

Thus, analysis of expired air has been used for several applications including toxicological, medical, forensic and biomedical applications. *(Philipp et al, "Medical applications of proton transfer reaction-mass spectrometry: ambient air monitoring and breath analysis, International Journal of Mass Spectrometry, Vol. 239, Issues 2-3, 2004, 221-226; Miekisceta et al, "Diagnostic potential of breath analysis— focus on volatile organic compounds, Clinica Chimica Acta, Volume 347, Issues 1-2, 2004, 25-39; Statheropoulos et al of "Preliminary investigation of using volatile organic compounds from human expired air, blood and urine for locating entrapped people in earthquakes, Journal of Chromatography B, Vol. 822, Issues 1-2, 2005, 112-117)*

The origin of most of those compounds is still unknown. Some VOCs originate as the end products of several metabolic pathways in human organism (endogenous), where others may be absorbed as contaminants from the environment (exogenous). The determination and quantification of endogenous compounds consists a part of a new area of research, called metabolomics, whereas exogenous volatile compounds levels nowadays have become of major concern for monitoring air quality in workplaces and external environment. Potential health risks exist due to the toxic nature of these components. Furthermore, due to their lipid solubility in the lung, the gastrointestinal tract and the skin readily absorb them. They may bioaccumulate in the lipid tissues of the body or they can eliminate from it with various rates.

Smoke and the resulting haze originated from forest fires are known source of volatiles, affecting primarily fire fighters and exposed population. Fire fighters are of primary concern since they are exposed for long time period to very smoky conditions.

In this presentation, a preliminary work involving expired air analysis from subjects exposed to forest fire smoke is described. It should be noted that similar work has also been carried out from FIACTU/NTUA group with normal, fasting and dead people, as well as, field chemical analysis of VOCs emitted from wastes and urban air.

Experimental Part

Prescribed burning of 1 ton of mixed forest fuels has been carried out in the area of the National Technical University of Athens, Greece. Two workers, remained in the fire-front throughout the burning process, in order to prevent any spread of the fire. At the end of the forest fuels combustion, the workers were asked to blow calmly air into 5 lt Tedlar bags by mouth, while inspiring from the nose. The VOC content of the air in Tedlar bags was immediately transferred to sorbent sampling tubes.

Sorbent tubes were thermally desorbed to an HP 5890/5972 GC/MS (Agilent Technologies) system, using an in house made thermal desorption unit (TDU). Chromatographic peaks were identified with the help of a mass spectrum library Willey 138, using similarity indexes above 80%.

Results-Discussion

In the following table qualitative results of expired air are presented.

Table: ***Indicative VOCs of 2 workers expired air analysis after inhalation of smoke produced during prescribed burning process of 1 ton mixed forest fuels.***

A/A	Substance
1	Acetaldehyde
2	Butane 2, methyl
3	Pentane
4	Isoprene
5	Acetone
6	Methane, dichloro-
7	Hexane
8	Furan, 2-methyl-
9	Cyclopentane, methyl-
10	2-Butanone, 3-methyl
11	Cyclohexane
12	Benzene
13	Cyclohexane, methyl
14	1-Heptene
15	Heptane
16	Acetic acid
17	Toluene
18	Ethene, tetrachloro
19	Xylenes (o, m, p)
20	Benzene, chloro
21	Benzene, ethyl
22	Styrene
23	Acetamide, N, N-dimethyl
24	Benzene, ethyl, methyl-
25	Alpha,-Pinene,(-)-
26	Camphene
27	Cyclohexanone
28	2-beta,-Pinene
29	Benzene, trimethyl
30	Benzene,(methyl ethenyl)
31	Cyclohexane, isocyanato-
32	1,8-Cineole
33	2 (5H)-Furanone, 3-methyl
34	Benzene, diethyl
35	Undecane
36	Phenol
37	Benzene, ethenyl ethyl
38	Ethanol,1-phenyl
39	Benzene, methyl butenyl
40	Naphthalene
41	Benzene, tetramethyl

The results presented here are a preliminary work and they should be interpreted in a careful way i.e. a larger number of subjects should be examined for verifying that the results are solid. However, they give an initiative approach and present a new methodology for monitoring health impacts of ffs on firemen.

- **Short-term Effects of Wood Smoke Exposure on the Respiratory System Among Charcoal Production Workers**
  (N. Tzanakis, Uof Crete, Crete, Gr)

The objective of the presentation is to present some facts for the short-term respiratory effects of heavy, occupational wood smoke exposure among traditional charcoal production workers *(N. Tzanakis, K. Kallergis, DE Bouros, MF Samiou, NM Siafakas, Short-term Effects of Wood Smoke Exposure on the Respiratory System Among Charcoal Production Workers, Chest. 2001 Apr;119(4):1260-5. PMID: 11296197).*

A total of 22 charcoal workers *(mean age, 41 years; 9 current smokers, 5 ex-smokers, and 8 nonsmokers)* were studied and compared with a control group of 35 farmers residing in Perama, Rethymnon, Crete. The charcoal workers were exposed to wood smoke for an average of 14 h/d during a mean of 23.7 days required for the burning of kilns. The workers under study were found to have significantly more cough (odds ratio [OR], 4.8; 95% confidence interval [CI], 1.2 to 19.7), sputum production (OR, 6; 95% CI, 1.4 to 26.5), wheezing (OR, 7.7; 95% CI, 1.4 to 41.5), dyspnea (OR, 28.7; 95% CI, 5.4 to 153), and hemoptysis (OR, 2.7; 95% CI, 0.7 to 55) than the control group.

The prevalence of respiratory symptoms such as cough, sputum production, wheezing and dyspnea in the charcoal workers was significantly elevated during the exposure period (OR, 5.4; 95% CI, 1.1 to 17.7; OR, 5.7; 95% CI, 1 to 31; OR, 9.8; 95% CI, 1 to 88; and OR, 36.7; 95% CI, 1 to 327, respectively). The mean ± SD percent of predicted values of FVC, FEV_1, FEV_1/FVC ratio and forced expiratory flow at 25 to 75% of FVC during the exposure period were significantly lower than those before exposure: 106 ± 10.8 vs 101 ± 11.9, $p < 0.01$; 104 ± 16 vs 97 ± 15, $p < 0.001$; 81 ± 9 vs 78 ± 8, $p < 0.001$; and 95 ± 27 vs 80 ± 25, $p < 0.01$, respectively. The mean ± SD value of peak expiratory flow at midday and in the evening during the exposure were significantly lower than before: 524 ± 131 L/min vs 548 ± 108 L/min, $p = 0.03$; and 521 ± 135 L/min vs 547 ± 131 L/min, $p = 0.02$, respectively.

The results suggest that wood smoke exposure in charcoal workers is associated with increased respiratory symptoms and decreased pulmonary function. Longitudinal studies are needed to determine potential long-term adverse respiratory effects.

Similarities between working conditions of charcoal workers and firemen, is a fact that should alert us about the effect of forest fire smoke on respiratory system.

2.4. Comments/ Discussion

M. Stefanidou - Loutsidou (Medical School, Uof Athens, Athens, Gr) commented that alkalinity/ acidity of gas involved in the smoke is a fact that contributes to the production of inhalation injury. The fuel type, the amount of burned biomass, the type of particular matter and the time of being exposed to smoke define the severity of exposure in ffs.

S. Athanaselis (Medical School, Uof Athens, Athens, Gr) agreed that the alkalinity of smoke is an important issue to be taken into account despite the fact that it has temporary consequenses. Furthermore the size of the particles and the time of exposure determine the nature of consequences. In any case strict standards should be established to prevent any severe impacts on firemen and civilians' health.

S. Karma (NTUA, Athens, Gr), mentioned that there are two main factors that define smoke hazardous impact; firstly the size of the particles (small diameters penetrate the respiratory tract) and secondly the chemical composition of fine particles, as long as they can act like matrixes which absorb toxic compounds, such as dioxines, PAHs e.t.c.

S. Athanaselis (Medical School, Uof Athens, Athens, Gr) emphasized on different impacts of different kind of fires e.g. forest fires, fires in houses, etc and the different danger that comes out from them. It should be kept in mind that the exact composition of smoke, the amount and time exposure are important factors. Furthermore, it should be noted that, radiation induced secondary products and their respiratory impacts. On a longterm basis, exposure to different incidents needs an overall toxicity evaluation.

M. Statheropoulos (ECFF, Athens, Gr) emphasized on concidering forest fire expansion and burning of buildings and landfills. Smoke can therefore mixe with other pollutants.

P. Balatsos (Ministry of Agriculture, Athens, Gr) pointed out that concentrations of pollutants and time of being exposed to them defines the dose in which a person is being exposed. That is why the chemical composition of smoke is important. There are several health effects and irritations such as cough and severest such as cancer. So there is a need for establishing permissible exposure levels or even more determing standards of duration on working to fire shifts.

Ch. Lembeye (CEREN, Marseille, Fr) emphasized that "even if we are able to measure short-term effects of the smoke, we don't know what the long term effects are, as soon as no follow-up is done afterwards on the firemen once they have retired".

Real case studies show that after long exposures (10 minutes) hospitalizations are sometimes required. After an oxygen treatment of 2 or 3 hours no sequel is observed but, as we already mentioned, this is only for the short term. No long term follow up being organized, we cannot be sure of the possible pathologies. It would be good to put such a follow up in place.

3. Exposure limits set by International Organizations-Air quality monitoring in the fire-front – Personal Protective Equipments (PPE)

3.1. Introduction

The third item of the agenda focuses on exposure limits to forest fire smoke as defined by health organizations and on air quality monitoring in the fire front, by using air quality indexes. The use of protective means and devices for fire fighters are also discussion topics.

3.2. Questions to be answered

1) Are there any International organizations that have set indexes for measuring exposure to chemical compounds during a forest fire?
2) If there are such indexes what are the permissible exposure limits for forest fire smoke?
3) Are there European standards, specifically for fire-fighters during forest fires and what practices are used for operational people?
4) What are the duration shifts of forest firemen?
5) Are there incidents of forest fires that population used personal protective means?
6) What are the possible air –quality indexes?
7) What are the devices and units needed for air-quality monitoring during a forest fire?
8) Is it possible to evaluate situation severity, regarding health impacts, by using air-quality indexes?
9) Is there a need to develop air quality monitoring stations especially for forest fires? Can existing urban pollution monitoring stations be used for on-line monitoring of forest fire smoke?

3.3. Presentations

- **Exposure limits to forest fire smoke components**
  (S. Karma, NTUA, Athens, Gr)

Various Health International Organizations have established exposure limits for compounds that are characterized suspected for causing health implications. The most well known health organizations and the respective limits are the ACGIH-TLV (American Conference of Governmental Industrial Hygienists-Threashold Limit Value), the OSHA – PEL (Occupational Safety and Health Administration-Permissible Exposure Limit) and the NIOSH- RELs (National Institute for Occupational Safety and Health- Recommended Exposure Limit). These limits have been established for occupational exposure of 8h or 24 h. In addition, for some compounds are given the Short Term Exposure Limits (STELs). In the following table the TLVs, PELs, RELs and STELs

However, there haven't been established so far official exposure limits especially for forest fires. It seems that these values have to be reconsidered in such case, not only for the exposed population, e.g. for the sensitive groups, but also for the fire-fighters of the front-line. For example, exposure limits for particles (PM10, PM2.5) are given for time exposure of 24h. During a forest fire, very high concentrations of particles at short time duration may be observed; that short-term peaks may cause some of the most significant health implications. According to the above, exposure limits to particles during a forest

Table: ***Occupational Exposure limits according to various Health Organizations for specific components of forest fire smoke***

Compound	TLV-TWA (Time -Weighted average assuming 8 h/day ACGIH)	STEL (Short Term Exposure Limit) ACGIH	PEL (Permissible Exposure Limit for General Industry, TWA (Time - Weighted over an 8-hour workshift) OSHA	STEL (Short Term Exposure Limit 15 min) OSHA	REL (Recommended Exposure Limit TWA Time-Weighted over an 10-hour workshift) NIOSH	STEL (Short Term Exposure Limit) NIOSH
Formaldehyde	-	0,3 ppm	0,75 ppm	2 ppm	0,016 ppm (8-hour)	0.1 ppm Ceiling (15 min)
Acrolein	0.1 ppm		0.1 ppm		0.1 ppm	0.3 ppm
Acetone	500 ppm	750 ppm	1000 ppm	-	250 ppm	
Benzene	0,1 ppm	2,5 ppm	1ppm	5ppm	0.1 ppm	1 ppm (15 min) (Ceiling)
Toluene	50 ppm	-	200 ppm	300 ppm Ceiling for 10 minutes	100 ppm	150 ppm
Phenol	5 ppm	-	5 ppm		5 ppm	15.6 ppm Ceiling (15 min)
Furfural	2 ppm		5 ppm		2.0 ppm	
Naphthalene	10 ppm	15 ppm	10 ppm		10 ppm	15 ppm
Styrene	20 ppm	40 ppm				
Ethyl Benzene	100 ppm	125 ppm	100 ppm		100 ppm	125 ppm
Xylene	100ppm	150ppm	100 ppm	-	100 ppm	150 ppm (15 min)
Ammonia	25 ppm	35 ppm	50 ppm	-	25 ppm	35 ppm (15 min)
Carbon Monoxide	25 ppm	-	50 ppm	-	35 ppm (8-hour)	200 ppm Ceiling
Sulfur Dioxide	5 ppm	5 ppm	2 ppm	5 ppm	2 ppm	5 ppm
Carbon Dioxide	5.000 ppm	30.000 ppm	5.000 ppm	30.000 ppm	5.000 ppm	30.000 ppm
PM 10	150 μg/m³ * *24-h*					
PM 2,5	65 μg/m³ * *24-h*					
PAHs	200 μg/m³					

* *US - EPA*

fire could be established for a time exposure of 30min, 1hour or 3 hours, depending on the total duration of the fire.

Especially for the fire-fighters and in order to assess their exposure to chemical compounds during a forest fire, critical indexes for air quality monitoring have to be established. It would be very useful operationally to monitor on – line one or two pollutants-indexes that can be correlated with the severity of the situation (e.g. CO or particulate mater), so as to facilitate decision making regarding protective measures. Indexes such as CO, PM, acroleine and formaldehyde have been reported in literature. *(Reinhardt eta al, "Baseline measurements of smoke exposure among wildland fire-fighters" Journal of Occupational and Environmental Hygiene, 2004, 593-606).*

Though, further investigation is needed in order to define critical indexes (by using empirical or mathematical equations) that will be used as a tool to estimate the air quality close to the flame front and decide on protective measures.

- **Exposure limits in regard to fire fighters shift duration and fire-fighters camping**
  (M. Statheropoulos, ECFF, Athens, Gr)

For various compounds, threshold limits of exposure have been set from various organizations e. g. OSHA, ACGIH, NIOSH in the framework of health and safety in the work. However, threshold limits of fire fighters for exposure to ffs components is an issue, which needs further study for two reasons:
1) Time duration of forest fire shifts is varying.
2) Distance of shift camping from fire-front is another parameter that sticks fire fighters to working area without giving the human organism time for recovering.

It is known that threshold limits established by various organizations are mostly applied for standard work shift (usually 8 hours/ day). In the case of forest fire there is a situation of an exposure in the field with concentrations ranges varying very broadly and dynamically. In addition, time duration of work shift can be as up as 16h depending upon the situation.

Firemen work shifts are usually camping close to the fire front, minimizing the possibility for the fire-fighters to recover. Camping in a distance from the fire and smoke front is a problem, especially in the case of forest fires in small islands. Dispatching means and personnel is already difficult in this case, especially with rough seas.

- **Exposure of forest firemen to Carbon Monoxide *(G. Koutoula, NTUA, Athens, Gr)***

Carbon monoxide, which is one of the basic components of ffs, is an asphyxiant that can cause hypoxia by displacing oxygen from the environment. This presesentation emphasizes on effects of exposure of forest firemen to Carbon Monoxide.

The reason of emphasizing in that issue is that levels of CO concentration, which are especially high during the smoldering phase of a forest fire can be correlated with specific health impacts in exposed firemen and population (Reh et al, 'Health Hazard Evaluation Report No. 88-320-2176, February 1992 U.S Department of the Interior, National Park Service, Yellostown National Park, Wyoming http://www.cdc.gov/niosh/hhe/reports). Inhalation of CO increases production of Carboxy-hemoglobin (COHb) in blood, whose concentration in normal levels is about 5%. If concentration levels of COHb exceeds 5% then various symptoms can be recorded *(tissues hypoxia that causes headache, dizziness, nausea)*.

It is important to be taken into account that in fire incidents concentartion levels of COHb can reach far above 5% causing various symptoms in firemen and exposed population. In the following table the %concentration of COHb in blood and respective symptoms are presented. If for example % COHb in blood is about 40% loss of consciousness is a possible symptom. It should be emphasized that loss of consiousness can be proved dangerous in fire events.

Table: Symptoms from % COHb in Blood

% COHb in Blood	Symptoms
0-10	No symptoms
10-20	Tightness across forehead, slight headache, dilation of cutaneous blood vessels.
20-40	Moderate to severe headache, weakness, dizziness, dimness of vision, nausea, vomiting, collapse.
40-50	Increased probability of collapse, loss of consciousness, rapid pulse and respiration
50-60	Loss of consciousness, rapid pulse and respiration, coma, convulsions, and Cheyne-Stokes (periodic decreased) respiration
60-70	Coma with intermittent convulsions, depressed heart rate and respiration, possible death
Greater than 70	Weak pulse, slow respiration, respiratory failure, death

The way to estimate the COHb level is to use the CFK (Coburn, Foster, Kane) equation. The equation takes into consideration variables such as the duration of exposure, the lung ventilation rate, the rate of endogenous CO production, the diffusion rates in the lung, the blood volume, the barometric pressure and the partial pressure of CO and oxygen in the lung. However, the CFK equation does not take into account the effects of altitude on CO exposure and COHb levels. Thus, NIOSH recommends that when exposures to forest fire smoke occur at altitudes above 5000, then the loss of the oxygen-carrying capacity of the blood should be taken into consideration.

Specifically, it has been calculated that with CO exposures of 23 ppm (for an altitude of 5000 feet) and 17 ppm (for an altitude of 10000 feet), 5% COHb levels would be reached. When concentrations exceeded 17 ppm at an altitude of at least 8000 feet above sea level, forest fire fighters may have been overexposed to CO (Reh et al, 'Health Hazard Evaluation Report No. 88-320-2176, February 1992 U.S Department of the Interior, National Park Service, Yellostown National Park, Wyoming http:// www.cdc.gov/niosh/hhe/reports ; Kelly, 'Health Hazard Evaluation Report No. 92-045-2260, October 1992 U.S Department of the Interior, National Park Service, New River Gorge National River, West Virginia http:// www.cdc.gov/niosh/hhe/ reports).

As it can be concluded, if CO exposures can be monitored in a fire incident then the estimation of the possible % COHb can be a possible index of the severity of the situation for firemen and exposed population.

- **Adjustment of Established Exposure Limits to Unusual Working Shifts**
  (S. Karma, G. Koutoula, NTUA, Athens, Gr)

During a forest fire, the environment close to the flame front is characterized very hostile and heavy due to the smoke produced. Fire-fighters and operational people of the front-line are exposed to very smoky conditions during their work-shift and usually during big forest fires they have to work extended schedules (14-16h or more).

CFK model presented before is used to estimate the exposure of fire-fighters to CO. Although, there aren't any official exposure limits especially adjusted for fire-fighters in the fire-front, OSHA has made a first approach and have developed two models for evaluating exposures to other chemical compounds, during unusual work schedules.

The models take into consideration parameters such as the toxicity and the biologic half-life (less or more than 12 hours) of the compound, as well as the number of hours of the work-shift per day or per week. (Reh et al, 'Health Hazard Evaluation Report No. 88-320-2176, February 1992 U.S Department of the Interior, National Park Service, Yellostown National Park, Wyoming http:// www.cdc.gov/niosh/ hhe/reports]

The idea is to use the OSHA-PEL or the ACGIH-TLV (whichever exposure limit is the more protective of the two) for the specified compound and calculate the new "adjusted-equivalent PEL" by using the proper OSHA model.

However, there are some compounds which considered potential human carcinogens, such as formaldehyde, and for that reason the exposures are recommended to be reduced to the lowest feasible level.

- **Personal Protective Equipment (PPE) for fire-fighters and population in Greece**
  (D. Vorisis, Forest Fire Fighting Dept., Fire Corps Headquarters, Athens, Gr)

Measurement of concentrations of specific compounds in the field (near the fire front or in a distance) will allow decision making regarding the exposure of fire-fighters and population. Novel techniques and instruments, especially designed to work in the field (field chemical analysis and technology) need to be used.

During a forest fire the issues of safety and health of the fire-fighters and operational people of the front-line are raised. Fire fire-fighters have to move very quickly to avoid flames, very high temperatures and smoke; for that reason their personal protective equipment has to be effective and easy to use.

For the protection from smoke and vapor, EU standards have been given for masks and filters. More specifically, the masks used are EN 136 (full-face masks) and EN149: 2001(half masks, FFP). Although full face masks offer better protection, as long as filters for particles and vapors (e.g. CO, VOCs) can be adjusted on them, they aren't usable enough for field use; they are heavy and not very comfortable (potentiality of heat-stress) if wearing them for many hours. On the other hand, half face masks are more flexible but they offer partly protection only for particles.

More specifically, EU filters for particles are the EN 143, used for full face and half face masks. The categories of those filters are the P1, suitable for solid phase (non-toxic dust), the P2, suitable for solids and liquids (fine toxic dusts, fibers & liquid based aerosols) and the P3, suitable for solids and liquids (very fine toxic dusts, fibers & liquid based aerosols).

The filters used for protection from gases are the EN 141 and can be used only for full face masks. The categories of those filters are Gases/Vapors <0,1 % (1.000ppm), Gases/Vapors <0,5 % (5.000ppm) and Gases/Vapors <1,0 % (10.000ppm).

As it seems, there is a need for a standard protection equipment for the fire-fighters, designed for specific use in the field during a forest fire and by taking into consideration all difficulties and limitations. Moreover, there is a need for first response protection measures for the exposed population to the smoke haze (e.g. specific type of mask, effective and low cost)

- **Air-quality monitoring during a forest fire: Portable units and devices**
  (A. Agapiou, NTUA, Athens, Gr)

"Field analytical chemistry" is defined as the comprehensive process of collecting and analyzing samples on-site, in order to produce near real-time information for solving specific problems that require rapid feedback information for their effective solution.

The analytical instruments used in the field for air quality monitoring are specially engineered for minimum size, weight, low power consumption and maintenance requirements in combination with speed, ruggedness and simplicity of operation. Their analytical capabilities include selectivity, resolution, sensitivity, low detection limits, precision and accuracy. The aim is to perform chemical analyses in-situ, on-site, and/or on-line. The field instruments can be categorized in the following three main groups: portable instruments, roving systems and mobile labs (H. L. C. Muezelaar, Field Analytical Chemistry and Technology 1(2) 1996, 109-111).

Sampling systems are classified as active and passive. Active systems directly effect with the sample, whereas passive operate at a rate controlled by a physical process. A further classification of the devices can be made according their distance performance; stand-off and point devices. Stand-off devices operate from a distance whereas point devices near the sample.

The identification of hazardous compounds released in case of forest fires direct in the field (on-site analysis) is essential for the correct assessment of possible risks to the population, environment and fire-fighters, as well. As known, the forest fire smoke is a complex mixture consisted of persistent, bioaccumulative and toxic compounds (e.g. VOCs, PAHs, PCDs, PCBs) and for that reason the direct monitoring of smoke plume is necessary for public health.

A variety of portable instrumentation is available for the on-line identification of volatiles evolved. The most popular detection devices employed by fire brigades around Europe include colorimetric detector tubes, photoionization detectors and electrochemical or infrared sensors. However, these devices have limitations regarding identification of unknown compounds and may be strongly affected by background interferences (cross-sensitivity), providing thus with false responses. Combined Gas Chromatography-Mass Spectrometry (GC/MS) addresses the above disadvantages providing both identification and quantification of organic compounds.

A mobile or a roving GC/MS with the appropriate procedures can perform sampling and analysis of complex mixtures released in a forest fire. Taking into consideration the stress of operators, the instrument will perform accurate measurements under rough environmental conditions, providing with high analytical results (G. Matz et al., Field Analytical Chemistry and Technology 1(4) 1997, 181-194). Other instruments involved in measuring forest fires emissions are particle analyzers for monitoring $PM_{2.5}$ and PM_{10} and Ion Mobility Spectrometers (IMS) for the identification of selective target compounds.

Furthermore, aircraft and satellite remote sensing methods have been applied for gathering emissions data (i.e. fire and smoke spread, optical density) through infrared spectrometers or radiometers. Ground based optical remote sensing methods, as well, using Fourier Transform Infrared (FTIR) and Light Detection and Ranging (LIDAR) have also been tested. Moreover, hyphenated analytical techniques (TG-bridge/MS) were developed for the on-line monitoring of combustion products (M. Statheropoulos et al., Fire Safety Science (13) 2004, 135-144) and can be used in the field.

Monitoring the air-quality of a forest fire is a critical issue, not only for the health impacts and safety issues, but also for the protection of the instruments and devices that perform the on-line monitoring. Forest fire smoke is considered heavy, hostile and aggressive. Thus, special design considerations and sampling procedures needed to be established. Novel techniques and instruments, especially designed to work in such heavy environment need to be developed. The instruments must respond dynamically in the rapid concentration changes occurred in forest fires and easily be decontaminated, afterwards. The special character of fire smoke (turbulence) should also be taken into consideration for their performance.

Field measurements carried out by FIACTU/ NTUA group in the fire front showed that these measurements have some special characteristics:

1) Measurements must be taken in time and space, following the concentration gradients of the smoke plume ("mapping" the sampling area). Static devices are difficult to work effectively.
2) Equipment should be portable, lightweight, energy independent and robust.
3) Special care should be taken for the protection of instruments from smoke tar and chemicals *(internal pumps can be destroyed from smoke compounds even when filters are used, other parts can be heavily contaminated).*

A mobile analytical unit (FIACTU/ NTUA) that has been developed for air monitoring includes:

1) Meteorological station
2) Particle analyzer
3) Portable detectors for permanent gases *(e.g. electrochemical CO detector)*
4) VOCs sampling system
5) Portable analytical instruments *(e.g. GC-MS or GC-IMS)*
6) Wireless communication
7) GPS
8) PPE *(Personal Protective Equipment)*

The introduction of methods and procedures of field chemical analysis and technology in environmental disasters is beneficial and essential for operational units for the acute estimation of the impact of forest fire smoke on population and environment. On-site and on-line measurements beyond their analytical difficulties can provide the real and authentic information needed by emergency forces for evaluating the situation. Further research is needed for the development of a new generation of detectors, the Second-Generation Detectors (SGDs), with specific design for addressing the dynamic phenomena that appear in hostile fields, such as the fire incidents.

3.4. Comments/ Discussion

F. Giroud (CEREN, Marseille, Fr) pointed out that in France exist urban air quality monitoring systems but none specific for forest fires. There are no pre-existing criteria for evacuation. It is decided upon the assessment of each situation.

It would be good to put in place biometrological measurements through blood and urine analysis before, during and after the fire on the fire-fighters but this needs financing which could be obtained by a European project.

C. Picard (CEREN, Marseille, Fr) commented on the personal protective equipment for fire fighters and population. In France no standards for masks specific to forest fires exist. The specification requirements for the masks are not the same for population and fire-fighters. The masks for the population can be heavier and thinner whereas the ones for the fire fighters need to be light. These masks have limitations, as they are "escape masks" and not intented to be used during the fight itself or to extend exposure times.

A. Agapiou (NTUA, Athens, Gr) concluded that measurement of concentrations of specific compounds would allow decision regarding the exposure of fire-fighters and population. Novel techniques and instruments, especially designed to work in the field need to be used. The instruments used should be portable and need special care.

4. Crisis management in general - Cross border transfer of forest fire smoke

4.1. Introduction

Crisis management of forest fire smoke is important because smoke affects not only the population in the vicinity of the fire but also the populations who live in a short or long distance from it, as long as the haze can travel long distances.

Air quality monitoring can be used to assess the severity of the situation during a forest fire. For that reason indexes of air quality are needed. The idea is to measure on-line in the field those indexes, so as to have a quick estimation. Data from the on-line measurement of specific pollutants could be directly transferred to civil protection center and decide, if necessary, for protective measures of population.

However, it is important to consider using stable air pollution stations, allocated in specific sites for monitoring urban air pollution, in order to monitor also air pollution in case of a forest fire.

4.2. Questions to be answered

A number of questions have to be answered on these issues:

1) Is there any experience on evacuation criteria for copying with short-term health impacts of forest fire smoke?
2) Is there any experience in copying with cross border forest fire impacts?
3) What are the possible evacuation procedures?
4) Do operational emergency plans include coping with forest fire smoke?

4.3. Presentations

- **Hazardous assessment of forest fire smoke – draft review**
  (G. Koutoula, NTUA, Athens, Gr)

The hazardous consequences of the forest fire smoke, a complex mixture of chemicals, could be the additive, synergistic or antagonistic result of all the smoke components. In order to assess the exposure to the multiple chemicals of forest fire smoke a useful practical tool should be used. The idea is to find correlation of the concentration profiles among hazardous chemicals; for example three or four chemicals are measured on-line by field chemical analytical methods and then results can be combined, providing thus the total hazardous impact factor.

To evaluate the level of combined exposure to organic compounds, an assessment criterion (Em) for multiple organic compounds can be given by the following equation (Ikuharu Morioka et al, "Evaluation of Organic Solvent Ototoxicity by the Upper Limit of Hearing" Archives of Environmental Health, Sept 1999):

$$Em = C1/T1 + C2/T2 + ... + Ci/Ti .... + Cn/Tn,$$

Where:

Ci represents concentrations of the respective substances and

Ti represents threshold limit value of the respective substances

According to the American Conference of Governmental Industrial Hygienists (ACGIH), if Em exceeds 1 it is not of an acceptable level (Ikuharu Morioka et al, "Evaluation of Organic Solvent Ototoxicity by the Upper Limit of Hearing" Archives of Environmental Health, Sept 1999). The above equation has been used in order to estimate the additive mixture exposure criterion Em in a forest fire. The compounds used as quality indexes were acroleine, formaldehyde and PM 3,5.

Moreover, the interpollutant linear regressions measured between acroleine, benzene, formaldehyde, PM 3,5 and carbon monoxide was sufficient, enabling estimation of exposure to multiple pollutants in smoke from measurements of a single pollutant, such as carbon monoxide. (Reinhardt et al, "Baseline measurements of smoke exposure among wildland fire-fighters" Journal of Occupational and Environmental Hygiene, 2004, 593-606).

In addition, a default methodology for assessment of exposure to chemical mixtures has been recommended in literature, for use in emergency planning and for evaluating exposures to multiple chemicals. To facilitate application of the methodology, a matrix of chemicals and target-organ toxicities, in terms of health code numbers, has been developed (Craig et al, "Recommended Default Methodology for Analysis of Airborne Exposures to Mixtures of Chemicals in Emergencies", Applied Occupational and Environmental Hygiene, Vol.14 (9): 609-617, 1999)

It would be very interesting if this methodology was applied for hazard evaluation of forest fire smoke, maybe after making proper adjustments. It seems that further investigation and elaboration on air quality indexes for hazardous assessment of forest fire smoke is needed, so as to develop concrete emergency plans and procedures.

- **Evacuation criteria**
  (M. Statheropoulos, ECFF, Athens, Gr)

Evacuation of areas in case of a large scale forest fire is very important issue, as long as such a decision means fast transfering of a significant number of population in "safe" place. Definatelly, more elaboration is needed for establishing evacuation criteria. However, this is an interesting example of how to cope with forest fire smoke severe incidents.

More specifically, evacuation for coping with ffs impacts needs establishing of criteria and indexes, regarding air quality during forest fire incidents. In Table 1 a set of evacuation criteria are presented as a case study. More elaboration is needed for having criteria in different countries and different incidents. Short – term averages (1-hr to 3-hr) have been correlated to recommended actions for Public Health Officials. (Wildfire Smoke: A guide for Public Health Officials, U.S. EPA and University of Washington, 2001)

Table 1. ***Recommended actions for Public Health Officials***

Categories	$PM_{2.5}$ or PM_{10} Levels (μg/m³ 1-hr to 3-hr)	Recommended Actions
Good	0-40	If smoke event forecast, implement communication plan
Moderate	41-80	- Issue public service announcements (PSAs) advising public about health effects/symptoms and ways to reduce exposure - Distribute information about exposure avoidance
Unhealthy for sensitive groups	81-175	- If smoke event projected to be prolonged, evaluate and notify possible sites for clean air shelters - If smoke event projected to be prolonged, prepare evacuation plans
Unhealthy	176-300	- Close schools (possibly based on school environment and travel considerations) - Consider canceling public events, based on public health and travel considerations
Very unhealthy	301-500	-Close schools -Cancel outdoor events (e.g. concerts and competitive sports)
Hazardous	Over 500	-Close schools -Cancel outdoor events (e.g. concerts and competitive sports) -Consider closing workplaces not essential to public health -If PM level projected to continue to remain high for prolonged time, consider EVACUATION of sensitive populations

Visibility reduce can also be used as a baseline for assessing the severity of the situation and for evacuating areas. Since particles from smoke has a size range near the wavelength of visible light (0,4-07 μm) they scatter light and reduce visibility. For that reason, if monitoring of PM continuously is not possible, an estimation of smoke levels can be extracted from visibility assessment, as it is presented in Table 2. (Wildfire Smoke: A guide for Public Health Officials, U.S. EPA and University of Washington, 2001)

Table 2. Estimating PM concentrations from visibility assessment

Categories	Visibility in Miles	PM levels (1hour average, μg/m³ $PM_{2.5}$ or PM_{10})
Good	10 miles & up	0-40
Moderate	6 to 9	41-80
Unhealthy for sensitive groups	3 to 5	81-175
Unhealthy	1 ½ to 2 ½	176-300
Very unhealthy	1 to 1 ¼	301-500
Hazardous	¾ mile or less	Over 500

In addition, for estimating air quality during a forest fire and decide on evacuation, other "criteria" pollutants according to National Ambient Air Quality Standards (NAAQS, U.S Environmental Protection Agency) are Ozone and Sulfur dioxide (Table 3).

Table 3. National Ambient Air Quality Standards

Pollutant	Standard value	Standard type*
Carbon Monoxide (CO)		
8-hour average	9 ppm (10 mg/m³)	Primary
1-hour average	35 ppm (40 mg/m³)	Primary
OZONE (O_3)		
1-hour average	0,12 ppm (235 μg/m³)	Primary & secondary
8-hour average	0,08 ppm (157 μg/m³)	Primary & secondary
Sulfur Dioxide		
3-hour average	0,50 ppm (1300 μg/m³)	Secondary

* *Primary: limit to protect public health, including the health "sensitive" populations (children, the elderly)*
Secondary: limit to protect against decreased visibility

- **Cross border transfer of forest fire smoke (M. Statheropoulos, ECFF, Athens, Gr)**

Until recently, the common belief was that incidents of natural disasters were strictly related to the incident's scene. However, nowadays the concept of a cross border transfer of natural disaster results seems to be confirmed.

Forest fire smoke plumes can travel very long distances and cross borders. In big forest fire incidents, the air quality of areas situated in a long distance from the incident can be disturbed as long as pollutants released from forest fires can travel thousands of kilometers to heavily populated urban areas. The significance of trans-boundary air pollution and the need for studies that assess the public health impacts, associated with such sources and transport processes, is highlighted by the following examples that examine transport of forest fires plumes far from the incident's scene.

According to a recent study (A. Sapkotta et al, Impact of the 2002 Canadian Forest Fires on Particulate Matter Air Quality in Baltimore City, Environ. Sci. Technol., 39 (1), 24-32, 2005), the result of a significant source event (forest fires during July 2002 in the province of Quebec, Canada) affected the PM levels of an urban center (Baltimore), located hundreds of kilometers from the source. Time- and size-resolved PM was evaluated at three ambient and four indoor measurement sites using combination instruments such as laser, time-of-flight aerosol spectrometer, nephelometer and an oscillating microbalance. The transport and monitoring results of the survey identified a forest fire related PM episode in Baltimore, that occurred the first weekend of July 2002 and resulted in as much as a 30-fold increase in ambient fine PM.

These results are significant in demonstrating the impact of a natural source thousands of kilometers away and potential exposures to air pollution within an urban center.

The results of the previews study compensate with those of a study announced recently (Wildfire emissions totaled, Chemical and Engineering news, July 11, 2005, pg 27). According to the latter study, the enormous wildfires of acres in Alaska and the Canadia Yokon, during the 2004 summer, generated among else huge plumes of carbon monoxide and other pollutants and affected large areas of the Northerne Hemisphere with higher ground-level ozone levels. It is estimated (Geophys. Res. Lett.2005, 32, L11809) that the wildfires generated more than 30 million tons of carbon monoxide, an amount roughly equivalent to the manmade emissions in the continental U.S. over the same time period. Furthermore, the ground level ozone concentrations, which are affected from NOx and VOCS (wildfire emissions), were found to be increased as much as 25% in the fires' vicinity and 10% over Europe.

In conclusion, forest fire smoke can generate trans-boundary air pollution. Consequently, the severe forest fires that took place in Europe the last three years can possibly affect the whole Europe and even other continents. This perspective generates the need for studies that assess the trans-border public health impacts, for research projects that would cope with impacts of forest fire smoke and methods to cope with them.

4.4. Comments/ Discussion

C. Picard (CEREN, Marseille, Fr) indicated that in France there have not been fire incidents lasting over long periods of time. The initial attack phase usually lasts around 4 hours. Due to this, forest fire smoke does not threaten the population much and even if there is a risk, the population is evacuated. The duration of the work shifts in France varies from 6 to 8 hours and when their work shift is finished, the fire-fighters leave the site. The only time when camping is arranged is when they are called as reinforcements on other fires; in this case the camping is a long distance away from the fire front.

5. Guidelines and directives-International experience

5.1. Introduction

To our knowledge, no specific quidelines or directives exist on the issue. However, various organizations in U.S.A , Canada, Australia and Europe have shown interest in forest fire smoke health impacts. Some studies have been reported by various teams, regarding animal toxicology of biomass smoke, medical protocols for monitoring fire-fighters exposure and exposure limits of smoke components. (Dawud, "Smoke episodes and assessment of health impacts related to haze from forest fires: Indonesian Experience" WHO 1999, Lima, Peru, 6-9, 1998, 313-333; J. Malilay, " A review of factors affecting the human health impacts of air pollutants from forest fires", WHO 1999, Health Quidelines for Vegetation Fire Events , Lima, Peru, 6-9, 1998, 255-270; C. T. Flower, "Human Health Impacts of Forest fires in the Southern United States : A literature Review", Journal of Ecological Anthropology, Vol.7 (2003) 39-59; Slaughter et al, "Association between lung function and exposure to smoke among fire-fighters at prescribed burns" Journal of Occupational and Environmental Hygiene, 1: 45-49, 2004).

There is a significant number of projects funded from the EC that have to do with forest fire prevention, forest fire and smoke plume early detection and smoke dispersion modeling (e.g. FOMFIS, DEDICS, INFLAME, AFFIRM). However, it seems that the issue of forest fire smoke chemical composition and the possible health impacts has not been extensively studied. Only in project SPREAD there was an effort to deal with health impacts of smoke, but further work needs to be done.

As a result, there is a need for research on forest fire smoke health impacts, considering forest fire smoke as a complex mixture with a chemical composition depended on the fire front path and the materials burned together with the forest fuel. Moreover, there is a need to improve knowledge on population and fire-fighters exposure to forest fire smoke, as well as to establish recommendations and guidelines for their protection.

5.2. Questions to be answered

1) Is there a need to develop special guidelines and emergency plans for copying with forest fire smoke?
2) Is there a need to develop early warning system for health smoke impacts during a forest fire?

5.3. Presentations

- **Prevention for coping with forest fire smoke** ***(M. Stefanidou - Loutsidou, Uof Athens, Gr)***

Since injury or death caused by fire is frequent and largely preventable, measures have been taken to reduce the number of fires and to reduce fire severity. The decrease of the toxic substances that are produced during a fire remains very essential for the prevention of a significant number of poisonings related to it. Fire prevention efforts should concentrate on children, the elderly and sensitive population groups. Furthermore, the population must be educated to confront fire incidence, to take preventive measures and to escape from the fire scene (Decker WJ, Garcia-Cantu A: Toxicology of Fires-An Emerging Clinical Concern.Vet Hum Toxicol 28:5, 431-433, 1986, Nelson GL: Regulatory aspects of fire toxicology. Toxicology 47:(1-2), 181-199, 1987).

Regulatory authorities should take fire prevention measures; the approval of these measures by the responsible authorities will contribute significantly to the protection of Public Health. Finally, all of us must not forget to keep the equilibrium in nature, by protecting not only the forests, but also the birds and the animals that live in the forest.

- **Forest Fire Smoke: Suggestions**
  (C. Chrysiliou, Civil Defence, Ministry of Interior, M. Martin, Lemesos Municipality, S. Kleanthous, Department of Labour Inspection Ministry of Labour & Social Insurance, Lemesos, Cy)

Cyprus suggests preparation of a strategic plan that will include:

1. Set-up
   1.1 Formation of a Committee from all interested parties: Fire Department, Forest Department, Civil Defence, Department of Labour Inspection, District Administration, Local Authorities.
   1.2 Mapping of countries that will show the different types of vegetation and the location of fire hazard establishments.
   1.3 Estimation of the emissions for each type of vegetation using all available information from Corinair and EPA.
   1.4 Classification of the different areas depending on the materials present, i.e. Asbestos roofs in farms.
   1.5 The above information may contribute to re-design the fire-fighting action plan for forest fires (if it exists).

2. Prevention measures
   Prevention measures can be taken, e.g. vegetation-free strips around high-risk establishments and follow up. Prevention measures should be accompanied by public awareness campaigns.

3. Protection measures during fires
   3.1 Fire fighters & volunteers.
   3.2 The public.

4. Air Sampling Measurements
   Actual measurements will assist the Dpt of Labour Inspection to revise the plan and make improvements.
   4.1 Fire engines
   Purchase and place equipment for the sampling of air during fires on the fire engines. This equipment can be used for all fires in order to examine not only the pollution during forest fires but also during fires in buildings.
   4.2 Fire fighters
   Fire fighters may carry small samplers on their overalls.

5.4. Comments/ Discussion

Delegates of C. Picard, C. Magnan, Ch. Lembeye, (Marseille, Fr) commented that recently in France a safety officer is appointed for each fire. Guidelines could be developed for safety on the fire front linked to smokes, and be checked by each officer. It would be good to put in place biometrological measurements through blood and urine analysis before, during and after the fire on the fire-fighters, but this needs financing which could be obtained by a European project. Why not have a European project on biometry on the fire front.

M. Statheropoulos (ECFF, Athens Gr) proposed future work to be done in using analytical methods and running measurements in the field. It was emphasized that monitoring of the air quality with portable devices may provide accurate evaluation of the situation. It was recommended that it is necessary for the population to be educated in that matter and for scientists to keep in mind the nature equilibriums.

6. Conclusions (A catalogue of ideas)

Comments, observations and suggestions, made by the participants of the teleconference were summarized as a catalogue of ideas, with the prospect of a future work. These are the following:

1. Forest fire smoke is a complex mixture of chemical compounds produced from combustion of forest fuel. However, as fire expands, it may burn constructions, landfills or crops. Asbestos, glass cement and combustion products of plastics, pesticides, insecticides can potentially be found in forest fire smoke. Data need to be collected regarding this concept.

2. Forest fire front is characterized by dynamic phenomena. Very rapid changes in compounds concentration profiles are observed in space and time. Temporarily, extremely high concentrations of chemical compounds and particles can be observed in the fire-front (e.g. PM 2,5 as high as 50.000 μg/ m^3, CO at 44 ppm have been observed and benzene at 700 μg/ m^3). Firemen have to be well aware of this situation. On-line monitoring is possible with small, portable devices, e.g. for particles and CO.

3. Forest fire smoke plumes can travel very long distances (even continents) and cross borders. In big forest fire incidents, the air quality of areas situated in long distance from the incident can be disturbed. Trans-border management may be needed.

4. Surveillance and monitoring the air quality in the fire front, as well as, in a distance from the forest fire is necessary. However, present generation of sensors (mainly for monitoring light gases), of instruments (for monitoring VOCs and SVOCs) and of particle analyzers are not designed for surveying a heavy, hostile (for humans and devices) environment and for measuring on-line in the field. More research is needed towards this direction.

5. Prioritization of forest fire smoke components is needed in regard to safety and health impacts to firemen and population. Studies and workshops can be the potential framework for deciding on these issues.

6. The synergism of various compounds and materials found in forest fire smoke and the possible photochemical reactions, which may occur and be responsible for surface level ozone increase, need to be investigated.

7. Exposure limits for firemen need to be established, taking into consideration the complexity of smoke, the dynamic phenomena which occur during a forest fire, the nature of firemen's work, the duration of work shifts and the site of the shift camping. Research and studies, with strong operational components, might be the way for providing solutions.

8. Existing PPE (Personal Protective Equipment), as simple as a surgical mask and as complicated as operational masks, needs to be benchmarked with careful experimentation.

9. Exposure limits of population, especially of infants, elderly people, pregnant women, persons with pre-existing cardiovascular and respiratory diseases, to smoke components have to be set and criteria of evacuation need to be considered. Evaluation of existing or similar studies need to be carried out.

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