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RECENT RESULTS AND UPDATING OF SCIENTIFIC AND TECHNICAL KNOWLEDGE

HEALTH RISKS OF AIR POLLUTION FROM BIOMASS COMBUSTION

Report by the Task Force on Health[1]

I. INTRODUCTION

1. This report comprises the results of the discussion on biomass combustion related health risks and provides a summary of other topics of the Task Force meeting, and is presented here in accordance with item 3.8 (b) of the 2009 workplan for the implementation of the Convention (ECE/EB.AIR/96/Add.2) adopted by the Executive Body at its twenty-sixth session in December 2008.

[1] The Joint Task Force on Health Aspects of Air Pollution of the World Health Organization (WHO)/European Centre for Environment and Health (ECEH) and the Convention's Executive Body.

2. The twelfth meeting of the Task Force on the Health Aspects of Air Pollution was held on 25 and 26 May 2009 in Bonn, Germany. Twenty-four experts from 21 Parties to the Convention attended the meeting. An observer from the Oil Companies' European Organization for Environment, Health and Safety (CONCAWE) and staff of WHO attended the meeting. Mr. M. Krzyzanowski (WHO/ECEH) chaired the meeting.

II. HEALTH IMPACTS OF BIOMASS COMBUSTION

3. The Task Force reviewed the draft report on biomass combustion prepared by its experts. The report comprised available scientific evidence on the health risks of air pollution created by wildfires, the agricultural burning of biomass and the combustion of biomass to produce energy for domestic needs (see summary in annex). Most of the available evidence came from short-term studies, with little data on the effects of long-term exposures. Biomass combustion was becoming more important, especially due to the consideration of wood burning as a source of renewable, carbon-neutral energy. Switching to biomass combustion, especially in the low-income levels of the society, was also associated with growing market prices of fossil fuels. The Task Force noted that the emissions from burning biomass, mostly wood, constituted a substantial part (20–40 per cent) of total national fine particulate matter ($PM_{2.5}$) emissions in several developed countries. It was thus more important than fossil fuel combustion. However, precise estimation of these emissions and their contribution to PM concentrations remained uncertain, since they were mostly due to residential combustion, which is one of the most uncertain emission sources.

4. The Task Force concluded that, according to the present knowledge, particles emitted from biomass combustion could not be considered differently with respect to health effects than particles emitted from other combustion sources. In addition, volatile organic compounds (VOCs) emitted during combustion contributed to ozone (O_3) formation. Biomass burning under some conditions might form carbon monoxide (CO) and reach hazardous levels indoors.

5. The Task Force noted that smoke from forest fires and agricultural burning is associated with increased respiratory hospital admissions and emergency room visits. There is some evidence with respect to increased respiratory symptoms and medication use during such episodes. Especially asthmatics and persons with chronic obstructive pulmonary disease (COPD) are susceptible to the respiratory effects.

6. The Task Force noted that residential wood combustion was associated with the exacerbation of respiratory diseases, especially asthma, COPD and cardiovascular health. There was strong evidence linking biomass combustion with acute lower respiratory infections (ALRIs) in children and COPD in women, especially in low-income countries and in regions where poorly constructed stoves were used.

7. Available data indicated that emission factors ranged over several orders of magnitude for the main pollutants, which were produced by various types of biomass combustion devices.

Well-designed and operated district heating plants using wood chips might achieve emission levels as low as oil burners when measured as per megajoule of energy produced. Small stoves emitted 10–700 times more $PM_{2.5}$ and CO. The emissions depended also on the burning conditions, type and/or humidity of biomass.

8. While the hazardousness of the pollution from biomass burning was well recognized, studies enabling quantification of health risk were still needed. In particular, the contribution of emissions from biomass combustion to population exposure must be clarified. Improved emission data and studies focusing on exposure assessment were required. Further epidemiological studies providing concentration-response data specific to biomass combustion were needed to establish if – and how – they differed from the effects of pollution from other sources.

9. The priority in risk prevention strategies should be on the reduction of long-term exposure, mainly due to domestic biomass combustion. High exposure peaks due to seasonal agricultural biomass burning or accidental wildfires should be avoided. These contributed to the long-range transported pollution and could affect susceptible populations far from sources.

III. PARTICULATE MATTER AND OZONE

10. The Task Force discussed recent evidence on health impacts of PM and O_3. These studies confirmed and, in general, strengthened earlier observations summarized, inter alia, in the *WHO Air Quality Guidelines, Global Update 2005*.

11. The Task Force took note of several studies on effects of long-term exposures. In particular, the following observations provided new insights of public health significance of $PM_{2.5}$:

(a) A study based on data from 211 areas in the United States indicated that a decrease of PM levels in the 1980s and 1990s was significantly associated with an increase in life expectancy. The reduction of air pollution accounted for as much as 15 per cent of the overall increase in life expectancy in the study areas (Pope, A.C., M. Ezzati and D.W. Dockery 2009, “Fine-particulate air pollution and life expectancy in the United States”, *New England Journal of Medicine* 360: 376–386);

(b) A recent analysis of the data from extended follow-up of the “Harvard Six Cities Study” confirmed the linearity of the link between $PM_{2.5}$ concentrations and mortality. It did not identify thresholds for effects, even below 15 $\mu g/m^3$. Effects of changes in exposure on mortality were seen within two years (Schwartz, J. et al. 2008, “The effect of dose and timing of dose in the association between airborne particles and survival”, *Environmental Health Perspectives* 116: 64–69).

12. The Task Force noted that these recent studies confirmed the significant public health benefits due to PM exposure reduction. Policy changes to reduce air pollution could be expected

to produce almost immediate improvements in health. There was little delay between expenditures, which produced improvements in air quality, and expected reductions in mortality. This would have a major impact on cost-benefit analyses of pollution reduction scenarios.

13. Recent analysis of the American Cancer Society cohort of 448,000 subjects, followed up to 18 years, indicated that exposures to $PM_{2.5}$ and O_3 affected mortality independently. In a two-pollutant model, including O_3 and $PM_{2.5}$, O_3 was significantly associated only with death from respiratory causes (Jerrett, M. et al. 2009, “Long-term ozone exposure and mortality”, *New England Journal of Medicine* 360: 1085–1095). For every 10 parts per billion (ppb) increase in O_3 exposure, an estimated increase in the risk of death from respiratory causes was 2.9 per cent in single-pollutant models and 4 per cent in two-pollutant models. Although this increase might appear moderate, the risk of dying from a respiratory cause was more than three times greater in metropolitan than in low-concentration areas. The respective levels were 104 ppb and 33 ppb, measured as an average of daily maximum one-hour means in the warm season (April–September). Although the slope of the concentration-effect function was somewhat steeper above 60 ppb, the evidence for a threshold was limited. The effects were mainly seen in areas with higher mean of maximum daily external temperature in the summer (above 25.4° C). The results of earlier, smaller long-term studies were not conclusive but, in general, indicative of a possibility of O_3 effects on mortality. The association of respiratory mortality with long-term O_3 levels might be a combination of effects of short-term peaks of exposure on susceptible subjects, who have influenza or pneumonia, and of long-term effects on the respiratory system, caused by airway inflammation with subsequent loss of lung function.

14. The Task Force discussed the need for an alternative, health-relevant PM indicator, proposed by a delegate from the Netherlands. It might help in judging the effectiveness of air quality management plans, especially traffic measures. Although PM was a complex heterogeneous aerosol mixture, varying in particle size and chemical and physical composition, probably not every component was equally relevant for causing adverse health effects. In particular, several studies indicated combustion processes as source of health-relevant PM. The combustion-related PM could be a possible candidate for such health-relevant indicator. It would also reflect health-relevant traffic combustion emissions in urban areas, for which coarse PM (PM_{10}) and $PM_{2.5}$ might be less suitable. It would further enable to assess the risk of people living close to roads.

15. The Task Force noted that there was not much additional evidence had emerged since conclusions summarized in its tenth report. Developing an alternative health-relevant combustion PM indicator might distract attention from size-based indicators, such as PM_{10}, $PM_{2.5}$, and coarse PM fraction (PM_{10}–$PM_{2.5}$), for which the link with health effects was well established. The Task Force reiterated its view on the importance of this PM fraction and encouraged Parties to judge the effectiveness of air quality management plans and control measures through evaluation of health-relevant PM components. It also welcomed Parties to provide more research evidence on this issue for further evaluation.

IV. MONITORING AND MODELLING OF AIR POLLUTION EFFECTS

16. The Task Force noted that the Guidelines for reporting on the monitoring and modelling of air pollution effects (hereinafter, the Guidelines) had been adopted by the Executive Body decision 2008/1 (ECE/EB.AIR/96/Add.1 and ECE/EB.AIR/2008/11). They specified key parameters to be monitored included annual average concentration of $PM_{2.5}$ and daily maximum eight-hour mean O_3 concentrations. The Guidelines also recommended health effects be assessed by epidemiological studies.

17. Currently, only limited data on $PM_{2.5}$ were available in Europe. The exposure to PM_{10} remained the main health-relevant PM indicator. Air quality monitoring data on PM_{10} and O_3 concentrations had been collected by the European Environment Agency (EEA) through its Airbase system. For 2006, PM_{10} data from regular monitoring were available for 566 cities from 27 countries. These data covered 22 per cent of urban population of the region. For 2004, data were available for 416 cities from 26 countries.

18. Country average PM_{10} exposure levels varied from 16 $\mu g/m^3$ (Finland, Ireland) to 50–52 $\mu g/m^3$ (Bulgaria, Romania). A wide (three-fold) variation in the PM_{10} exposure level was observed in some countries. The country average PM_{10} exposure level had not changed substantially in the last few years in most of the European countries. However, in some countries the exposure levels had increased by at least 5 $\mu g/m^3$ for the period 2004–2006. In some other countries, a similar decline had been observed.

19. Most (90 per cent) people in European cities where PM_{10} was monitored were exposed to PM_{10} levels exceeding the *WHO Air Quality Guidelines* level of 20 $\mu g/m^3$, indicating a substantial risk to health. For 13 per cent, the European Union (EU) limit value of 40 $\mu g/m^3$ was exceeded. Recent estimates of impact of PM on mortality completed by EEA indicated that 492,000 deaths per year and 4892,000 years of life lost could be attributed to PM exposure in 27 EU Member States. Further efforts to reduce population exposure and its health effects were needed, in particular in several highly polluted areas, which included transnational areas such as Ostrava region of Czech Republic and Silesia in Poland.

20. An approximate assessment indicated that pollution levels and corresponding health risks might be even higher in many of the countries which are Parties to the Convention, but for which data were not available in Airbase. The delegates from Belarus and Turkey indicated that PM_{10} data were collected in several cities in their countries and should be available to the Task Force. In some other countries (e.g. Albania and Republic of Moldova), efforts were under way to establish PM_{10} monitoring.

21. Approaches to analysing and communicating information on air pollution and its health effects were discussed based on experiences from European projects APHEKOM and CITEAIR and from the Environmental Public Health Tracking Project of the United States Center for Disease Control. The Task Force confirmed that the accessibility of the relevant air quality and

health data was crucial for local analyses. Further development of methods and availability of concentration-response functions, in particular from long-term studies, were deemed necessary.

V. HEALTH-RELATED ASPECTS OF THE REVISION OF THE GOTHENBURG PROTOCOL [2]

22. The Task Force welcomed the possible inclusion of PM_{10} and $PM_{2.5}$ in the proposal to amend the Gothenburg Protocol. It emphasized the health relevance of primary combustion particles both in reducing emissions and exposures. In particular, emissions from dispersed sources, such as residential combustion of biomass, should be covered by the Protocol. The Task Force reconfirmed the significant contribution of agricultural burning of biomass and of wildfires to the $PM_{2.5}$ concentrations and to the population exposure.

23. The Task Force expressed concern how to most effectively reduce ambient levels of the health-relevant fractions of PM (PM_{10} and $PM_{2.5}$) through reductions of total suspended particles. Technical measures should assure that emission controls were effective in the reduction of primary PM_{10} and $PM_{2.5}$ in ambient air. They should also address precursor gases, which might contribute to the formation of hazardous particles and gases.

24. The Task Force discussed aspirational targets in 2050 for the levels of PM_{10}, $PM_{2.5}$, sulphur and nitrogen dioxides, and lead. It agreed that targets should reflect the current *WHO Air Quality Guidelines*. In the future, studies might reveal health effects at levels lower than the currently suggested levels. The Task Force therefore considered it likely that aspirational targets would become low in the future.

VI. HEALTH RELEVANCE OF AIR POLLUTION ALERT SYSTEMS

25. The Task Force considered how pollution alert systems in several countries have been beneficial to population health. It noted that some alert systems might even be counterproductive. There were only few studies providing evaluation of health effects or benefits of such systems. Estimates of the air pollution reduction due to the alert systems had been calculated only in few cases. The few existing surveys of patients using alert systems were not reliable enough to formulate general conclusions. Several further studies were under way, inter alia in Canada, Sweden and the United States of America.

26. The Task Force recommended that well-designed studies should be undertaken that focused on the use of information, exposure reductions and the decrease of health impact.

27. The Task Force considered the relevance of the impacts of high exposure days in comparison with the health impact of days with average level of pollution, the former occurring

[2] The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.

occasionally and the latter frequently. The public health impact of the alerts was limited, taking into account the known exposure-response links of pollutants considered by these systems (e.g. PM, O_3) and the relatively high alert levels. However, such alerts might provide an opportunity to raise the awareness of the public and decision makers with regard to the health effects of air pollution.

VII. 2009 AND 2010 WORKPLANS

28. The Chair presented the main results of the Convention's 2009 workplan items for the Task Force on Health.

29. **Annual progress report on health impacts of PM**. The Task Force took note of the results, which strengthened previous evidence on the health damage caused by PM. The Task Force confirmed the need for further action to effectively reduce population exposure to PM and related effects on health.

30. **Final report on health impacts of O_3**. The Task Force took note of the publication of the report "Health risks of ozone from long-range transboundary air pollution" as well as recent results indicating association of respiratory mortality with long-term exposure to O_3. It concluded that O_3 was one of the most important air pollutants associated with health in Europe. Available data indicated that currently implemented policies were not sufficient to reduce the impacts significantly in the next decade.

31. **Preliminary report on health risks of biomass combustion**. The Task Force noted that there was substantial evidence confirming the hazardousness of pollutants emitted from biomass combustion. These emissions, in particular from residential wood-burning, contributed similar amounts of PM as that of fossil-fuel combustion. Health risk prevention required reducing the population's exposure related to domestic wood combustion. Improved data, in particular on PM emissions and on population exposure, were needed to quantify the risks from biomass combustion.

32. **Review of health relevance of pollution alert systems**. The review revealed the scarcity of information on the effects of existing alert systems on population exposure to air pollution and on its health-related effects. While well-designed evaluation studies might be needed, there were limitations of this approach to the management of risk related to air pollution.

33. **Development of guidelines for reporting on monitoring and modelling of health effects of air pollution**. The Task Force noted that significant health effects were caused by PM in Europe, in particular in its more polluted parts, and that PM_{10} levels were had not declined in 10 years in most countries. Monitoring data on essential parameters were currently missing for half of the Parties to the Convention, mostly due to the lack of relevant air quality monitoring systems.

34. Some delegates proposed that the Task Force review the evidence on impacts of various air pollution management options on health. The review of various approaches to air quality management and their health effectiveness would be beneficial to the Parties. The Task Force noted that it needed to collaborate with the Working Group on Strategies and Review in the preparation of such a review.

35. The Task Force agreed on its draft 2010 workplan:

(a) Annual progress report on health impacts of PM and O_3;

(b) Review of evidence on impacts of various air pollution management options on health;

(c) Reporting on monitoring and modelling of health effects of air pollution;

(d) Hold the thirteenth meeting of the Task Force, tentatively scheduled for 26 and 27 April 2010 in Bonn, Germany.

Annex

HEALTH RISKS OF AIR POLLUTION FROM BIOMASS COMBUSTION

I. BACKGROUND

1. Biomass combustion causes pollutant emissions and exposure of people in many ways. The most intensive way is cooking with unvented stoves, which is still common in developing countries. In developed countries, the cooking and heating devices burning biomass indoors are mostly well vented and combustion is usually effective in these installations. Vegetation fires lit on purpose in agriculture and forestry, or natural or accidental fires due to excessive dryness of the soil and vegetation, lead to exposures of large populations in both developed and developing countries. The human exposure and health effects of smoke originating from these fires have been generally overlooked. The largest attention has been paid on victims directly killed or injured by the fires.

2. Many factors, such as the type of biomass or biofuel and most importantly the completeness of combustion process, affect the type and amount of the pollutants formed. Smoke from incomplete biomass combustion is rich in CO and VOCs such as acrolein, formaldehyde and benzene, gaseous and particulate polycyclic aromatic hydrocarbons (PAHs), and other organic substances. A more complete combustion produces less organics, but emissions of elemental carbon remain almost constant. Inorganic salts, such as potassium sulphates, chlorides and carbonates, increase depending on the biomass type.

3. Levoglucosan is an abundant and specific tracer of incomplete biomass combustion both in $PM_{2.5}$ emissions and atmospheric $PM_{2.5}$. Water-soluble potassium and oxalate have also been used as tracers of biomass combustion in the atmosphere, but they are not specific due to other significant sources.

II. WILDFIRES AND AGRICULTURAL BURNING

4. The type of burning biomass and the prevailing meteorological conditions are likely to affect the amount and quality of gaseous and PM emissions in vegetation fires. Fire maps are produced with modern satellite techniques, but the intensity of burning and the emissions cannot be reliably assessed with current techniques. Better assessment would improve the modelling of air mass transport and particulate concentrations in air quality forecasts. Satellite technique-based modelling techniques and early warning systems for susceptible populations should be developed in the future.

5. In the vicinity to local fires, daily $PM_{2.5}$ and PM_{10} concentrations can increase manifold and hourly values 10–20-fold. The concentrations of CO, VOCs and particulate PAHs can increase significantly. The smoke cloud does not usually change gaseous pollutants after some

hours or days of transport. The exception is O_3, which can increase in a warm and sunny weather. However, the daily and hourly $PM_{2.5}$ and PM_{10} concentrations can still increase significantly hundreds of kilometres away from the wildfires. The particulate PAHs are mostly transformed to less reactive derivatives during the transport of some days. They can be reflected as lower inflammatory and cytotoxic potency of $PM_{2.5}$, which are sampled during wildfire smoke episodes, in comparison with sampling of seasonal air quality, which is dominated by various local sources. The overall harmfulness of breathable air increases during a regional wildfire episode due to increased ambient PM concentration. The studies conducted during local and regional transport of wildfire smoke use detailed online air quality measurements, including size-segregated chemical composition by time-of-flight aerosol mass spectrometry. Further toxicological data on $PM_{2.5}$ collected during wildfire smoke episodes in different climates would be useful.

6. The limited available information suggests that particles penetrate readily into indoor environments during air pollution episodes caused by wildfires. Wildfires are most likely the main outdoor PM source to cause the highest daily exposures in many countries, based on the extremely high hourly and daily outdoor PM concentrations during such episodes. However, there are no published studies on local personal exposures to PM from wildfires.

7. Air pollution alert systems are common in major cities around the world. It is not clear whether the advisories have any effect on the exposure during wildfire episodes.

8. Epidemiological studies have established an association between wildfire smoke and respiratory health. High ambient PM concentrations during forest fire episodes are associated with increased respiratory hospital admissions and emergency room visits. There was some evidence on increased respiratory symptoms and medication use during such episodes. Smoke from agricultural burning seems to exhibit similar harmful effects on health as smoke from forest fires. In particular, asthmatics and persons with COPD are susceptible to respiratory effects.

9. Information on the effects of exposure to wildfire smoke on mortality and cardiovascular health is not sufficient to conduct a full-scale risk assessment.

III. DOMESTIC WOOD BURNING IN DEVELOPED COUNTRIES

10. The emissions from biomass burning, mostly wood, constitutes a substantial part of total national $PM_{2.5}$ emissions in many developed countries (20–40 per cent). The combustion emissions depend on factors such as type and model of wood combustion appliance, tree species and the operation of the appliance (e.g. loading of the firebox, air supply, kindling). Operational practices causing incomplete wood combustion could increase the emissions CO, VOCs, $PM_{2.5}$, and particulate PAHs manifold, even in the same appliance. The difference of the $PM_{2.5}$ emission factor between the worst and best small-scale heating appliance could be 100-fold.

11. The development and introduction to practical use of more effective domestic combustion appliances was hampered, as only few countries had emission limits for wood combustion. The development of such limits for $PM_{2.5}$ in Europe suffers from a lack of harmonized emission measurement tests.

12. The toxicity of PM from different small-scale wood combustion appliances or different operational practices has been little investigated. The present limited evidence suggests a large impact on toxic properties by the chemical composition of emitted particles. Abundant genotoxic PAHs in $PM_{2.5}$ samples seem to associate with increased cytotoxicity and immusuppression. In human volunteers, acute exposure to wood smoke aerosols caused mild systemic inflammation and increased blood coagulation.

13. Residential wood combustion is associated with the exacerbation of respiratory diseases, especially asthma and COPD. Recent studies suggest that exposure to particles from wood combustion is also associated with cardiovascular health. In general, particles from wood combustion seem to be at least as harmful to health as particles from fossil fuel combustion.

14. There is very little information on the effect of residential wood combustion on indoor concentrations of and personal exposures to PM. In particular, there are no studies assessing short-term peak exposures or long-term exposures to fine particles or exposure to ultrafine particles.

15. Residential wood combustion could be responsible for a significant fraction of long-term exposure to PAHs, in particular among persons heating with wood. Many PAHs are known carcinogens. Consequently, possible effects of long-term exposure to wood smoke on the incidence of cancer should be evaluated.

16. Studies evaluating the chronic and sub-chronic health effects of wood smoke are needed. For example, effects of exposure during pregnancy on birth outcomes have not been evaluated in developed countries, despite emerging evidence in developing countries. The association of long-term exposure to wood smoke with incident respiratory or cardiovascular diseases is not known.

IV. DOMESTIC BIOMASS BURNING IN DEVELOPING COUNTRIES

17. Open unvented cookers used in developing countries are likely to have incomplete combustion of wood and other biomass at much lower temperatures than in closed appliances. They produce large amounts of carbonaceous PM, CO and VOCs. Biomass fuels other than wood include dry animal feces, the burning of which always produces large emissions. The use of inexpensive cookers heated by solar energy or other clean fuels should be strongly promoted.

18. In developing countries, indoor air pollution due to combustion of biomass for cooking and heating is one of the major environmental health problems. There is strong evidence linking biomass combustion with ALRI in children and COPD in women. New information was needed on cardiovascular and carcinogenic effects of biomass smoke.

19. Recent intervention studies conducted in developing countries demonstrate that considerable decreases in particle exposures could be achieved by relatively simple means. The effects of intervention programmes on population health should be evaluated.
