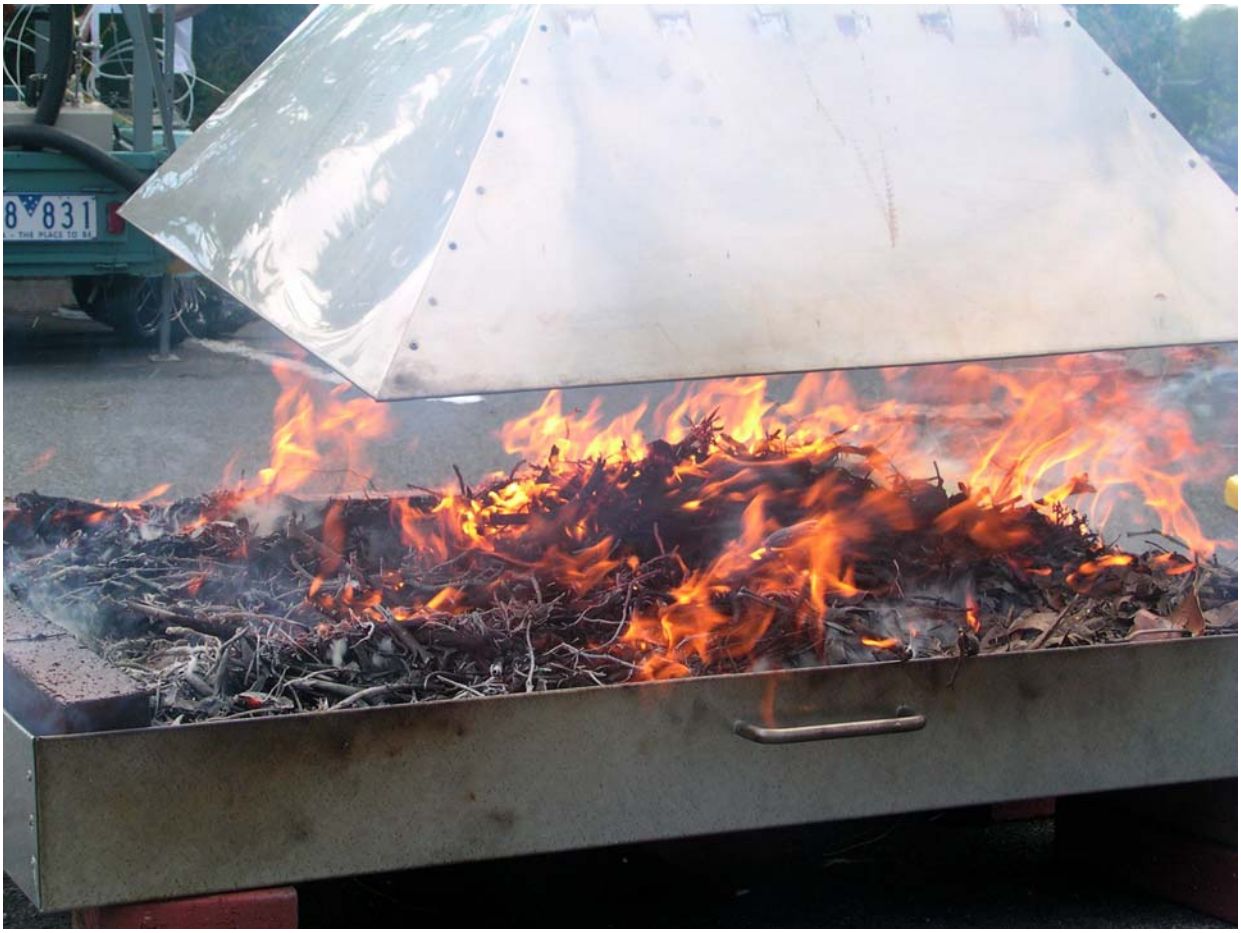
United Nations Environment Programme

UNEP Chemicals / Australian Government Department of the Environment and Heritage

Expert Workshop on Dioxin and Furan Releases from Uncontrolled Combustion

Melbourne, Australia, 7-9 December 2005



UNEP Chemicals
December 2005

IOMC

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United Nations Environment Programme

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Title page: Photo: Biomass burning experiment at CSIRO Aspendale, Australia
Photo courtesy of Dr. Heidelore Fiedler, UNEP Chemicals

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Copies of this report are available from:

UNEP Chemicals
International Environment House
11-13 chemin des Anémones
CH-1219 Châtelaine (Geneva), Switzerland
Tel.: +41 (22) 917 8170
Fax: +41 (22) 797 3460
e-mail: chemicals@unep.ch

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PROCEEDINGS

UNEP Chemicals / Australian Government Department of the Environment and Heritage

Expert Workshop on Dioxin and Furan Releases from Uncontrolled Combustion
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1 INTRODUCTION

Dioxin and furan release inventories have shown that uncontrolled combustion processes such as open burning of domestic waste (*e.g.,* barrel burns and landfill fires), agricultural burns (*e.g.,* pre-harvest in sugar-cane or post-harvest of rice straw), as well as forest and bushfires, are responsible for a high percentage in the overall national dioxin inventories. Results of studies from Europe, United States, Japan, and Australia formed the basis for dioxin/furan emission factors that are presently used by countries that establish their inventories within the National Implementation Plans for the Stockholm Convention on Persistent Organic Pollutants.

However, the results from these studies are scarce and sometimes contradictory. Furthermore, the emission factors for the burning of domestic waste in developed countries may not be appropriate for developing countries because of differences in the composition of waste. This workshop bought together researchers with experiences in combustion studies and formation of PCDD/PCDF in open burning processes. In addition, governmental experts from developing countries contributed to the discussions and provided insight into the contribution from these sources to the national release inventories and provided input to the discussions with respect to conditions under which such processes occur in their countries.

The workshop addressed the following issues:

- Burning practices and PCDD/PCDF emission factors in open burning processes;
- Contributions from uncontrolled combustion in the areas of domestic waste management, agricultural fires, and forest/bush fires to the global loading of PCDD/PCDF;
- Sound and scientifically based ways of understanding the contribution of uncontrolled combustion to releases of unintentionally produced POPs and how to effectively reduce releases from this source;
- Identification of areas for experimental studies using laboratory, medium scale or field experiments to determine emission factors from the three areas mentioned above.

The Workshop, attended by 26 experts and decision-makers from 16 countries and organizations (see Appendix 2), was jointly organized by UNEP Chemicals and the Australian Government Department of the Environment and Heritage. The workshop, which took place in Melbourne, Australia, from 7 to 9 December 2005, was financed through the Canada POPs Fund and by the Australian Government.

These proceedings contain the conclusions and recommendations from the workshop working groups, the country presentations, and other expert contributions. The proceedings are also available through the Internet at the UNEP Chemicals' website http://www.chem.unep.ch/pops.

2 DEVELOPMENT OF THE WORKSHOP

The workshop took place in the Quay West Suites Melbourne according to the expected agenda (see Appendix 1), as follows:

2.1 Opening

Wednesday, 7 December 2005

The Expert Workshop was opened on behalf of the Australian Government, Department of the Environment and Heritage, by Mr. Lee Eeles, Director Chemicals Policy Section and by Mr. John Whitelaw, Deputy, on behalf of UNEP Chemicals.

2.2 Presentation of Participants

Participants briefly introduced themselves by stating their affiliation, experience and interest in uncontrolled combustion processes.

2.3 Objectives, Program, and Organizations of the Workshop

John Whitelaw and Heidi Fiedler, of UNEP Chemicals, presented the objectives of this Expert Workshop, detailed the program, and briefed participants on organizational matters.

2.4 Burning Processes in the Context of the Stockholm Convention

By John Whitelaw, UNEP Chemicals.

John Whitelaw briefed the participants on the context of uncontrolled combustion processes in the Stockholm Convention and informed about recent developments under the Convention such as progress in the Expert Group on BAT/BEP and the preparations of the 2nd meeting of the Conference of the Parties, scheduled from 1 to 5 May 2006 in Geneva, Switzerland. The slides of the presentation are shown in Annex I.

2.5 Significance of Open Burning Processes in Dioxin Inventories from Developing Countries

The following country delegates gave brief overviews on their country's findings as to the importance of open burning processes as addressed in Category 6 of the Toolkit. The full presentations are found in Annex II:

1. China – G. Yu
2. Fiji – R. Muhammed
3. Kenya – F. Kihumba
4. Mexico - G. Solórzano
5. Philippines – G. Peralta
6. Papua New Guinea – K. Solien
7. Thailand – N. Chersuwan

2.6 Emission Factors for Open Burning Processes in the Toolkit and Its Implications for National PCDD/PCDF Release Inventories

By Heidelore Fiedler, UNEP Chemicals

Heidi Fiedler gave a brief summary on the basis for the emission factors as included in the Category 6 of the Toolkit, 2nd edition, 2005. She also summarized the results from national PCDD/PCDF release inventories for the two subcategories of open burning processes. The presentation is included as Annex III.

2.7 Principles of Formation of PCDD/PCDF and Characteristics of Bush and Forest Fires

Stellan Marklund of Umeå University, Sweden, and Mick Meyer of CSIRO, Australia, summarized the principles and main findings how PCDD/PCDF are formed in incineration processes and on characteristics of biomass burns such as forest and bush fires. These two presentations are included as Annexes IV and V.

2.8 Experimental Set-up and Results from Laboratory and Field Studies

The experimental designs and findings from laboratory and field studies on open burning processes were grouped into three main topical areas and presented by the authors of these studies.

2.8.1 Experiments for Measurement of PCDD/PCDF in Barrel Burns, Landfill Fires

Presentations were given by:

1. Study design and results from the USA by Brian Gullett, US-EPA (Annex VI/1)
2. Study design and results from Sweden by Stellan Marklund, Univ. Umeå (Annex VI/2)
3. Study design and results from Japan by Yosuhiro Hirai, NIES (Annex VI/3)

2.8.2 Experiments for Measurement of PCDD/PCDF in Agricultural Residue Burns

Presentations were given by:

1. U.S. experience by Brian Gullett, US-EPA (Annex VII/1)
2. Australian experience by Mick Meyer, CSIRO (Annex VII/2)

2.8.3 Experiments for Measurement of PCDD/PCDF in Forest, Bush Fires

Presentations were given by:

1. Results and conclusions from a regional project on biomass burning in South America by Roberto Fernández, Univ. de Buenos Aires (Annex VIII/1)

2. Forest fires in USA by Brian Gullett, US-EPA (Annex VIII/2)
3. Forest and bush fires in Australia by Jochen Müller, Univ. of Queensland (Annex VIII/3).

2.9 Working Groups on Open Biomass and Open Waste Burns

From Thursday morning until Friday noon, participants met in two working groups. Charge questions were given as an introduction and as a stimulus for the working group discussions. The objectives of the working groups were to develop a common position as follows:

WG 1: Experiments and characteristics that influence PCDD/PCDF formation and releases in open biomass fires
Chair: Ken Froese, Canada; Rapporteur: Jochen Müller, Australia

WG 2: Experiments and characteristics that influence PCDD/PCDF formation and releases in open incineration of waste
Chair: Chris Mobbs, Canada; Rapporteur: Roland Weber, Germany

The two papers were developed and the text adopted as shown in Chapter 3 - Results.

2.10 Field-trip to CSIRO

On Thursday afternoon, 8 December 2005, a field trip was undertaken to the CSIRO Experimental Site in Aspendale where a test burn of litter was conducted.

2.11 Closure

The organizers, the Australian Government and UNEP Chemicals, thanked all participants for their participation and good spirit of work during the workshop and wished them a safe trip home. The workshop was concluded at 4:00 p.m. on 9 December 2005.

3 RESULTS

3.1 WG1: Determining Emission Factors from Forest, Bush, Savannah and Agricultural Fires

The working group discussed what are the key issues related to the emission of PCDD/PCDF from agricultural and other biomass fires. The group undertook a critical evaluation of the combined data sets (published and unpublished) of results obtained in the laboratory and the field.

The group also attempted to identify parameters or characteristics either in the combustion process or in the biomass that is burned that would be drivers towards higher and lower emission factors (EFs). Identify such key parameters would allow to propose BAT and BEP to lower the emissions from biomass fires.

The following important issues were identified and include:

- To get the methodology right, using only validated methodology;
- Recognize the impossibility to measure all factors together;
- Use laboratory simulation in the first place and then get the field data for validation (in addition, ambient air measurements may be undertaken to study the environmental impact);
- Importance to obtain the correct activity data. At least for South America, the uncertainty or the variance in the activity is larger than the uncertainty in the emission factors.

Conclusion from the Biomass Group:

- It was recognized that there exists a large variability in the datasets. This is a concern and should be reflected in the description of how emission factors (EFs) are presented;
- A meta-analysis of existing results from biomass burns found the following results:
  - Highest confidence with results from grass/savannah fires with data that supports an EF <0.3-0.5 μg TEQ/t (the present factor is 0.5 μg TEQ/t for clean biomass and 5 μg TEQ/t in the case of savannah fires);
  - The best estimate from all data in forest fires suggest an EF of 1-2 μg TEQ/t (the present EF to air in the Toolkit is 5 μg TEQ/t. Note: The emission factor to land of 4 μg TEQ/t was not discussed);
  - Globally, sugarcane crops are the most important source of agricultural residues that are routinely burned. It is suggested that countries with high activity try different emission factors. The present emission factors would have a median of 1.8 μg TEQ/t burned (field and laboratory data combined) or 1.0 μg TEQ/t (only field data) from the Australian studies and of 10 μg TEQ/t of sugarcane burned from the US studies. (Presently, the Toolkit suggests using the bushfire EF, which is 5 μg TEQ/t). Present assumption that pesticide treatment in sugarcane, if occurring at all, does not impact the formation of PCDD/PCDF in open burning;
- Presently, there is not sufficient information to give recommendations on crop management to reduce PCDD/PCDF generation and releases (no data)

- Similarily, no recommendation can be given as to the key drivers, which would cause high or low emissions of PCDD/PCDF. This means that no good practices can be recommended to reduce the releases from open biomass fires. The only parameter that influences the scale of the dioxin formation is the retention of particles in the fire zone, a parameter that seems hard to modify within each vegetation type and agricultural crop.

Recommendations

- Collaborate on sampling and experimental methods (between USEPA/CSIRO/ENTOX) to enable/identify potential artifacts and obtain harmonized datasets. Ideally, the experiments would be done in a sugarcane-producing country comparing the two most contrasting methods.
- The experimental approach should be executed as an iteration between lab and field trials;
- Scientifically, validation studies using the receptor approach is recommended (seasonal/ conditional air sampling in region of high activity – to validate EFs);
- Other crops/vegetation types may be of interest, *e.g.,* corn in China, pesticide-intensive cotton that is burned for insect control, and conifers in North America, Russia, *etc.*;
- Any future laboratory or field experiments should attempt to clarify if treatment of biomass with pesticides prior to being burned in the open has any influence on the scale of the emission factor. Pesticides of interest are those that contain chlorine or metals acting as catalyst. Reason: Presently, the Toolkit assigns a higher emission factor to pesticide-treated agricultural crops.

3.2 WG2: Summary of Expert Meeting on Dioxin and Furan Release from Uncontrolled Combustion – Toolkit Category 6b "Open Combustion of Waste

Status/Findings

- Wide range of different uncontrolled waste combustion practice including dump fires, pit burning, fires on plain soil, barrel burning, and accidental fires in houses/cars. Note: Sub-category 6b of the Toolkit only addresses waste burning practices that take place in the open and does not include "uncontrolled combustion" in poorly designed and operated incinerators, stoves, *etc.* This sub-category also does not include "private waste disposal" in households, *e.g.,* in small boilers, chimneys, *etc.* Without no doubt, these may be important sources of PCDD/PCDF but these types of sources are covered in Category 1 (waste incinerators) or Category 3 (Generation of power and domestic heating/cooking);
- There are likely to be a wide range of waste types in domestic versus industrial waste. Domestic waste would have lots of organic material whereas industrial waste would have other materials. A large share of PCDD/PCDF in waste in Europe can come from textile and leather materials, which contain flame retardants, chlorine from tanning, metals, and colouring (reference S. Marklund);
- There is lack of dioxin data from uncontrolled waste combustion. Limited or no data from most uncontrolled combustion sources (dump fires, open burning in pit, waste burning on soil). However, there is sufficient data for barrel burning, at least for waste as found in OECD countries such as United States, Sweden, and Japan;

- In order to estimate releases from open burning of waste, accurate activity data as to the mass of waste that is combusted in the open is required as well as adequate emission factors are needed (if these have to be regionally needs to be seen). The UNFCC data on the amount of waste burnt in countries may provide useful data for the determination of the activity;
- Despite many studies of waste incinerators, there is a lack of understanding of the formation (mechanism) and emissions of PCDD/PCDF from uncontrolled waste combustion;
- Important information on PCDD/PCDF formation in processes of open burning of waste can be derived from investigations in the first combustion zone of an incinerator where similar conditions are present (Hunsinger (2002), Chemosphere **46**, 1263-1272). There are two PCDD/PCDF emission peaks when sampling in the first combustion zone of an incinerator:
  - The first peak starts during the ignition phase of the fire, where PCDD/PCDF are formed and emitted, and is found;
  - In the fully developed fire where hardly any PCDD/PCDF are emitted (low O_2);
  - The second PCDD/PCDF peak is generated in the burn out of the fuel bed (high O_2).
- Halogens (chlorine, bromine), metals, and unburned carbon have a significant impact on PCDD/PCDF emission factors from uncontrolled combustion (data from barrel burn studies in Sweden, Germany, Japan, and Switzerland). However, the data are not sufficient for other uncontrolled/open combustion processes such as pit or dump fires and there are no data from developing countries:
  - Laboratory and pilot scale combustion experiments (measurements after first combustion zone simulating open, uncontrolled combustion processes) with waste containing brominated flame retardants show high emissions of PCDD/PCDF resulting in emission factors of more than 100,000 µg TEQ/t (data from National Institute of Environmental Research Studies (NIES), Japan and Forschungszentrum Karlsruhe (FZK), Germany);
  - High chlorine/BFR impacted waste (Japan, Germany, Sweden)
  - Possible impact of contamination of heating/cooking biomass material by chlorine containing waste (Results from S. Marklund and Swiss BUWAL report 2003)).
- Role of bromine:
  - It is expected that high levels of bromine in waste containing equipment with brominated flame retardants (*e.g.,* computers, foam insulation, carpets) would result in higher emissions of PCDD/PCDF as bromine acts as a catalyst for dioxin formation. The oxidation potential of bromine is comparable to oxygen therefore when combusting Br containing materials, elemental bromine and bromine radicals are formed facilitating the halogenation (bromination and subsequent bromine-chlorine exchange) of aromatic and other organic materials;
  - In addition, bromine (like chlorine) has a flame retarding effect and thus, is interfering in the chain reactions of combustion processes; subsequently, the combustion quality decreases with increased bromine content resulting in higher overall emissions of products of incomplete combustion;

- Role of chlorine:
  - Carbon is the limiting factor for PCDD/PCDF formation in state-of-the-art municipal solid waste incinerators. This is the main reason that typically no correlation is found between the chlorine content and PCDD/PCDF emissions;
  - In open or uncontrolled combustion processes, the combustion quality is low resulting in the generation of high concentrations of products of incomplete combustion (PICs). Therefore, not carbon but chlorine is the limiting factor for PCDD/PCDF formation in uncontrolled combustion processes. This is underlined by results from Japan where PCDD/PCDF emissions correlate with chlorine content (Ikeguchi and Tanaka (2000), Organohalogen Compd. **46**, 298-301);
  - Domestic waste typically would have less chlorine. The chlorine load in domestic waste may increase with inclusion of PVC or other chlorinated materials. Then, the chlorine content would be >1%;
  - When PVC or other chlorinated organics are combusted, the chlorine is converted to hydrochloric acid (HCl) and the chlorine is released in the gas phase;
  - For inorganic chlorine, the release strongly depends on the temperature and only part of the chlorine is released;
  - It is anticipated that waste collected/generated near the coast would have higher content of chlorine due to influence of salt spray;
  - For wood combustion, the limiting factor is chorine;
  - $CuCl_2$ is the most important catalytic compound. $CuCl_2$ is used as a fungicide in coffee plantations in Africa; the coffee husks are used as a biomass fuel (as charcoal briquettes). Since $CuCl_2$ is an effective catalyst for *de novo* synthesis of PCDD/PCDF, a considerable impact on dioxin formation can be expected;
- Role of metals:
  - If chlorine is present, it can convert to HCl but HCl does hardly form PCDD/PCDF without metal catalysts. The catalytic effect of metals converting HCl in active forms of chlorine to create PCDD/PCDF (elemental/molecular chlorine, metal chlorides);
  - The role of containment in the formation of PCDD/PCDF, especially when made of metals, *e.g.,* barrels, fume hoods, *etc.*, may need special attention when designing studies on open burning of waste;
- Animal waste as a fuel needs to be considered, *e.g.,* liquid manure, dung, *etc.*, but also dead animals being combusted for quarantine reasons;
- Waste composition differences between countries. There is often less control of what goes into waste dumps in many developing countries. Change of waste composition over time (*e.g.,* increasing fraction of electronic waste). There is a need to characterize waste in (developing) countries (this could be obtained from the waste management system in a respective country).
- The physical parameters in fuel would influence the way material burns including:
  - Size of burned material - smaller material compacted would burn less efficiently;
  - Open dumps would have more combustion than compacted material due to greater amount of O_2;
  - Higher humidity and water content in waste increases the formation of PCDD/PCDF.

Recommendation with Respect to Toolkit Emission Factors

- At the present stage, the data for open waste burning of waste is too limited to recommend changes in the given emission factors of the UNEP Toolkit and the incineration categories. Therefore it is recommended to continue with these emission factors and categories until more results are generated by studies in the field of uncontrolled waste combustion;
- However the data from laboratory and pilot studies in Japan and Germany indicate that high emissions up to 150,000 µg TEQ/t to air and 15,000 µg TEQ/t to residues can be generated from uncontrolled combustion of waste containing brominated flame retarded material (BFR) and/or high PVC, and metals. This could be reflected in the Toolkit by addition of a waste category with higher emission factors for waste containing these materials;
- Further, the class "landfill fires" should be replaced by "dump fires" because this expression better reflects the fact that at these sites, there is uncontrolled dumping of wastes. These sites are not managed or controlled, neither for incoming waste nor for prevention of accidental or incidental fires.

Table 1: Proposed future emission factors for waste burning and accidental fires (µg TEQ/t)

	Air	Water	Land	Residue
Waste **dump fires**	1,000	ND	600	
Uncontrolled domestic waste burning	300	ND	600	
Uncontrolled burning of waste containing BFR, PVC, and metals (*e.g.*, waste containing WEEE[1], car shredder residues, *etc.*)	**6,000**	**ND**	**4,000**	
Accidental fires in houses, factories	400	ND	400	
Accidental fires in vehicles (*per vehicle)	94*	ND	18*	
Open burning of waste wood	60	ND	10	

[1] WEEE (Waste Electrical and Electronic Equipment): Large household appliances (television, refrigerator, washing machine, micro-wave, *etc.*), small household appliances (coffee machine, iron, electric tooth brush, shaver, *etc.*) IT and telecommunications equipment (computers, fax machines, phones, mobile phones, printer, *etc.*), consumer goods, lighting equipment, electrical and electronic tools, toys with battery, *etc*

Recommendations on Future Activities – Research Priorities

- Important to identify a time frame for undertaking a research program to improve emission factors. Ideally this would be over a 3-5 year period;
- Several countries (Sweden) have indicated they are willing to fund research for this work. The Clean Air Initiative through World Bank and Asia Development Bank has also indicated an interest in funding research into waste burning;
- Collaborative field study of developing countries with support of developed countries (research groups/institutes in Sweden, Japan, Germany) in the area of uncontrolled combustion with sampling in the respective countries and analysis in the institutes/laboratories abroad;
- Countries have some funds under their NIPs to fund sampling but it is important that this work is done in a strategic manner in coordination with other countries. Combine countries for collaborative studies (*e.g.,* African countries; South America; Asia, Pacific Islands) in a strategic, coordinated manner and compare the results;
- Need to have a consistent methodology for collecting samples which could cover:
  - Selection of combustion practices/sites (landfill fires, combustors, stoves in house, pit burning, barrel burning, stoves in house)
  - Combustion experiments
  - Sampling
  - Interpretation of results
- Developing countries don't need their own laboratory to undertake analysis – samples could be sent to laboratories in other countries. However, developing countries may need assistance to cover costs for transporting samples. Developing countries would also require assistance in training people on how to collect samples and interpret results;
- Laboratory experiments on uncontrolled combustion (Japan, Sweden, others?);
  - Normal waste and different combustion practice (baseline);
  - Chlorine content and metal content and emission of unintentional POPs from uncontrolled combustion;
  - BFR and chlorine-containing waste (textile - S. Marklund, electronic waste - Y. Hirai).

Other Supporting Actions

- Future International Dioxin Symposiums should have a special session on emission factors/UNEP Toolkit;
- UNEP Chemicals should:
  - Review inventories to determine use of the Toolkit and the results obtained
  - Compile a summary/database/forum or blog of existing emissions data;
  - Prepare Frequently Asked Questions (FAQ) for POPs – while this is applicable for the whole Convention having one for the emission factors/Toolkit could be a good start;
- Need waste characterization for each country/region. This would be obtained from a countries solid waste management strategy;
- Use the UNFCC data on the amount of waste burnt to validate the activity.

3.3 Overall Conclusions and Next Steps

- Overall, the data are scarce and some significant data gaps were identified;
- Whereas, there are thousands of data from waste incinerators, there are only few data from open burning. However, it has to be noted that the process in an incinerator is totally different from an open burning process. Also barrel burns are different from totally open burns due ot the presence of metal or other surfaces;
- There was strong perception that there is greater uncertainty in the activity level than in the emission factors;
- In order to better determine the activity level in each country, tools already available through climate change work under the UNFCC, such as satellite data, should be applied. Training to countries may be needed to apply these tools on a routine basis (for dioxin release inventory development);
- Although the datasets are limited, none of the experiments on open burning of either wastes or biomass revealed that PCB (expressed in TEQ) were a major contributor to the overall TEQ;
- There was consensus that only validated methods should be used for any experiments to be undertaken in order to apply the same methodology world-wide and to obtain comparable results;
- There was consensus that the baseline burns or that repetition of the same burning experiments results in a quite large range of emissions; *e.g.,* in the U.S. barrel burn experiments the results from the combustion of the baseline waste gave a variation of a factor of 20. This means for example, that experiments on open combustion of waste would only make sense if the composition of wastes (in developing countries) would be different from OECD wastes by a factor of 20;
- If tests on open burning of municipal solid waste are planned, the inherent variability in burning the same waste compositions under the same conditions several times should be considered. However, the effects of most variables still remain unknown;
- Similarly, there is no recommendation for crop management because the key drivers towards low or high emission factors could not be identified from the present experiments;
- In the biomass burn experiments, laboratory tests resulted in higher emission factors than field tests;
- Proposed research projects should consist of an iteration between laboratory and field experiments using the same samples;
- When planning experiments, most funding would be needed to build the facility, calibrating the equipment, QA/QC, data evaluation, staff time; the actual costs for analysis of the samples would be minor;
- Stellan Marklund (Sweden) together with Heidi Fiedler (UNEP) will prepare a methodology for sampling wastes from different countries and prepare a project proposal to determine emission factors for open burning of waste;
- Jochen Müller (Australia) and Brian Gullett (USA) will develop a proposal to determine emission factors for biomass burning with emphasis on sugar-cane.

4 APPENDIX 1: PROGRAM OF THE EXPERT WORKSHOP

Australian Government
Department of the Environment and Heritage

UNEP

Expert Meeting on Dioxin and Furan Releases from Uncontrolled Combustion

7-9 December 2005
Quay West Suites Melbourne, Australia

Draft Program

6 Dec 2005	**Arrival of participants**	
17:00-18:30	Registration of participants (at Quay West Suites)	
19:00-21:00	*Reception at Aquarium*	
7 Dec 2005	**Opening and Introduction**	
8:30-9:00	Registration of participants	
9:00-10:00	Welcome – Opening remarks	Australian Government UNEP Chemicals
	Presentation of the participants	
	Objectives of the workshop, program and structure	UNEP
	Open burning processes in the context of the Stockholm Convention	J. Whitelaw, UNEP
10:00-10:30	*Coffee break*	
10:30-11:15	Significance of open burning processes in dioxin inventories from developing countries (5-7 min each)	China, Fiji, Kenya, Mexico, Mongolia, Philippines, PNG, Thailand
11:15-12:45	Emission factors for open burning processes in the Toolkit and its implications for national PCDD/PCDF release inventories	H. Fiedler, UNEP Chemicals
	Principles of PCDD/PCDF formation in combustion processes	S. Marklund, Univ. Umeå
	Principles of forest/bush fires	C. Meyer, CSIRO
12:45-14:00	*Lunch*	
14:00-15:00	**Experiments for Measurement of PCDD/PCDF in Barrel Burns, Landfill Fires**	
	• Study design and results from the USA	B. Gullett, US-EPA
	• Study design and results from Sweden	S. Marklund, Univ. Umeå
	• Study design and results from Japan	Y. Hirai, NIES
15:00-16:00	**Experiments for Measurement of PCDD/PCDF in Agricultural Residue Burns**	
	• U.S. experience	B. Gullett, US-EPA
	• Australian experience	Australia
16:00-16:30	*Coffee break*	

16:30-17:30	**Experiments for Measurement of PCDD/PCDF in Forest, Bush Fires**	
	• Results and conclusions from a regional project on biomass burning in South America	R. Fernandez, Univ. de Buenos Aires
	• Forest fires in USA	B. Gullett, US-EPA
	• Forest and bush fires in Australia	J. Müller, Univ. of Qld.
8 Dec 2005	**Working Groups (in parallel)**	
9:00-12:30	WG1: Experiments and characteristics that influence PCDD/PCDF formation and releases in open incineration of waste	
	WG2: Experiments and characteristics that influence PCDD/PCDF formation and releases in open biomass fires	
11:00-11:30	*Coffee break*	
12:45-14:00	*Lunch*	
14:00-18:00	Field visit to CSIRO laboratory in Aspendale	
9 Dec 2005	**Working Groups (cont'd.)**	
8:30-10:00	• WG1 (cont'd.) • WG2 (cont'd.)	
10:00-10:30	*Coffee break*	
10:30-12:15	• Report from WG1 • Report from WG2 • Discussion	
12:15-13:30	*Lunch*	
13:30-15:30	**Proposal for Study Designs for the Determination of Emission Factors from**	
	(a) Open burning of domestic waste (b) Agricultural burns (c) Forest, bush, savannah fires	
15:30-15:45	*Coffee break*	
15:40-16:30	**Conclusions and Recommendations**	
	Adoption of report Closure of the workshop	

5 APPENDIX 2: LIST OF PARTICIPANTS

Mr. Lee Bell
NECF
47 Seventh Avenue, Bassendean
Perth 6054
Australia
Tel.: +61 (8) 62781447
Fax: +61 (8) 62781447
E-mail: l.bell@murdoch.edu.au

Dr. Nares Chersuwan
Suranaree University of Technology
School of Environmental Health, Institute of Medicine
111 University Avenue, Muang District,
Nakhon Ratchasima 3000
Thailand
Tel.: +66 (44) 224-242
Fax: +66 (44) 224240
E-mail: nares@sut.ac.th

Dr. Roberto J. Fernandez
Universidad de Buenos Aires - IFEVA/CONICET
Facultad de Agronomía, Ecología-IFEVA
Av. San Martín 4453
Buenos Aires C1417DSQ
Argentina
Tel.: +54 (11) 4524-8070 , ext. 8135
Fax: +54 (11) 45148730
E-mail: fernandez@agro.uba.ar

Dr. Heidelore Fiedler
UNEP Chemicals
International Environment House
11-13, chemin des Anémones
CH-1219 Châtelaine (GE)
Switzerland
Tel.: +41 (22) 917-8187
Fax: +41 (22) 7973460
E-mail: hfiedler@unep.ch

Dr. Kenneth L. Froese
Golder Associates Ltd.
Risk Assessment and Environmental Management
1000, 940 - 6th Ave SW
Calgary, AB T2P 3T1
Canada
Tel.: +1 (403) 299-5617
Fax: +1 (403) 299-5606
E-mail: kfroese@golder.com

Dr. John Gras
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Air Pollutants: Sources and Exposure Team
107-121 Station Street
Aspendale, Vic 3195
Australia
Tel.: +61 (3) 9239-4614
Fax: +61 (3) 92394444
E-mail: john.gras@csiro.au

Dr. Brian K. Gullett
U.S. Environmental Protection Agency
Nat'l Risk Management Res. Lab.
Office of Research and Development
Research Triangle Park, NC 27711
United States of America
Tel.: +1 (919) 541-1534
Fax: +1 (919) 5410554
E-mail: gullett.brian@epa.gov

Dr. Yasuhiro Hirai
National Institute for Environmental Studies
Research Center for Material Cycles and Waste Management, Hazardous Waste Management Section
16-2 Onogawa
305-8506 Tsukuba, Ibaraki
Japan
Tel.: +81 (29) 850-2747
Fax:
E-mail: hirai.yasuhiro@nies.go.jp

Mr. Francis N. Kihumba
National Environment Management Authority (NEMA)
Kenya POPs Project
Kapiti Road
P.O. Box 67839
00100 Nairobi
Kenya
Tel.: +254 (20) 376-0461
Fax: +254 (20) 3760461
E-mail: kihumbafn@yahoo.com

Dr. Stellan Marklund
Umeå University
Department of Environmental Chemistry
S-901 87 Umeå
Sweden
Tel.: +46 (90) 7865-715
Fax: +46 (90) 128133
E-mail: smd@chem.umu.se

Dr. Mick Meyer
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Atmospheric Research
107-121 Station Street
Aspendale, Vic 3195
Australia
Tel.: +61 (3) 9239-4686
Fax: +61 (3) 92394444
E-mail: Mick.Meyer@csiro.au

Ms. Razia Zahina Zariff Muhammed
Ministry of Local Government and Environment
Department of Environment
P.O. Box 2131
Government Building
Suva
Fiji
Tel.: +679 (331) 1699
Fax: +679 (331) 2879
E-mail: popsfiji@connect.com.fj

Dr. Jochen Müller
The University of Queensland
National Research Center for Environmental Toxicology (EnTox)
39 Kessels Rd
Coopers Plains,Qld. 4108, Brisbane
Australia
Tel.: +61 (7) 30009197
Fax: +61 (7) 32749003
E-mail: j.mueller@uq.edu.au

Dr. Genandrialine L. Peralta
University of the Philippines
Department of Chemical Engineering
Melchor Hall, Room 205, Diliman,
Quezon City 1101
Philippines
Tel.: +63 (2) 929-6640
Fax: +66 (2) 4269860
E-mail: glperalta@up.edu.ph

Mr. Khangal Purevdorj
Ministry of Nature and Environment
Water Authority Agency
Government Building-3, Baga-Toiruu-44
Ulaanbaatar-11
Mongolia
Tel.: +976 (11) 263-341
Fax: +976 (11) 321401
E-mail: mne@mongol.net

Dr. Ian D. Rae
The University of Melbourne
History and Philosophy of Science
16 Bates Drive
Williamstown, Vic 3016
Australia
Tel.: +61 (3) 9397-3794
Fax: +61 (3) 93973794
E-mail: idrae@unimelb.edu.au

Ms. Katrina Monalisa Theresa Solien
Department of Environment and Conservation
Environment Division
P.O. Box 1212
Waigani
National Capital District (NCD)
Papua New Guinea
Tel.: +675 (323) 3910
Fax: +675 (323) 6037
E-mail: popspom@datec.net.pg

Mr. Gustavo Solórzano Ochoa
Ministry of Environment and Natural Resources, National Institute of Ecology
National Center for Environmental Research and Training (CENICA)
Edificio de Ciencia y Tecnología Ambiental "W"
Universidad Autónoma Metropolitana-Iztapalapa
Av. San Rafael Atlixco 186, Col. Vicentina,
México, D.F. 09340
Tel.: +52 (55) 5613-3821
Fax: +52 (55) 56133787
E-mail: gsolorza@ine.gob.mx

Dr. Robert K. Symons
National Measurement Institute
Chemical & Biological Metrology Branch
1 Suakin Street
Pymble, NSW 2073
Australia
Tel.: +61 (2) 9449-0150
Fax: +61 (2) 94491653
E-mail: robert.symons@measurement.gov.au

Dr. Roland Weber
Ulmenstrasse 3
D-73035 Goeppingen
Germany
Tel.: +49 (7161) 506-669
Fax: +49 (7161) 506669
E-mail: Roland.Weber10@web.de

Dr. Gang Yu
Tsinghua University
Department of Environmental Science and Engineering
Beijing, 100084
People's Republic of China
Tel.: +86 (10) 62785685 (Off)
Fax: +86 (10) 62794006
E-mail: yg-den@tsinghua.edu.cn

Australian Government

Mr. Chris Mobbs
Department of the Environment and Heritage
Chemical Policy
GPO Box 787
Canberra, ACT 2601
Australia
Tel.: +61 (2) 6274-2385
Fax: +61 (2) 62742060
E-mail: chris.mobbs@deh.gov.au

Mr. Lee Eeles
Department of the Environment and Heritage
Chemicals Policy Section
GPO Box 787
Canberra, ACT 2601
Australia
Tel.: +61 (2) 6274-1427
Fax: +61 (2) 62742428
E-mail: lee.eeles@deh.gov.au

Ms. Karen Hayhurst
Department of the Environment and Heritage
Chemical Policy Section, Environment Protection Branch
GPO Box 787
Canberra, ACT 2601
Australia
Tel.: +61 (2) 6274-2385
Fax: +61 (2) 62742060
E-mail: Karen.Hayhurst@deh.gov.au

Dr. Amala Jayasekara
Department of the Environment and Heritage
Chemical Policy Section
GPO Box 787
Canberra ACT 2601
Australia
Tel.:
Fax: +62 (2) 62741164
E-mail: Amala.Jayasekara@deh.gov.au

UNEP Chemicals

Mr. John A. Whitelaw
UNEP Chemicals
11-13, chemin des Anémones
CH-1219 Châtelaine (GE)
Switzerland
Tel.: +41 (22) 917-8360
Fax: +41 (22) 7973640
E-mail: jwhitelaw@unep.ch