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EXPERT GROUP ON BEST AVAILABLE
TECHNIQUES AND BEST ENVIRONMENTAL
PRACTICES

Second session

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Item 3 of the provisional agenda¹

Development of guidelines on best available techniques and provisional guidance on best environmental practices relevant to the provisions of Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants

INFORMATION AND COMMENTS RECEIVED ON OPEN BURNING

Note by the Secretariat

The attached was submitted by Mr. Francis Njuguna Kihumba (Kenya) who coordinated its development. This note and the attached have not been formally edited.

¹ UNEP/POPS/EGB.2/1.

INFORMATION AND COMENTS RECEIVED ON OPEN BURNING

22nd October 2003

Introduction

As a result of the circulation of the coordinators discussion paper on open burning a number of responses were received on the draft paper prepared mainly to help recap discussions in the 1st BEP/BAT meeting and to initiate a discussion on what should or should not be in the draft guidelines on BAT and guidance on BEP as required by the Stockholm Convention

Comments were received from the following people who also participated in the 1st meeting:

- ◆ Heldelore Fiedler of UNEP
- ◆ Vandana – Fiji
- ◆ Pat Costner – Green Peace
- ◆ Marat Ishankulou – Kazaksban
- ◆ Steffi Richter - Germany
- ◆ Zoltan – UNIDO
- ◆ Limkew leong – Singapore
- ◆ Bill carrol – ICCA
- ◆ Patrick Finlay of Canada

The paper was also circulated at the Africa Dioxin/Furan workshop held in Kampala on 15th – 18th August, 2003. No comments have been received so far from this group. In Africa, it was noted in the past that waste burning is possibly the least known factor in the production of dioxins and furans. However, considering the normal practice of burning rubber tyres, stuppung of copper and cable wires. This comments will form a background document for the 2nd meeting of BAT and BET. The comments form Annex 1 to this summary. The Draft discussion paper is Annex 2.

(a) Critical Issues that were highlighted

Many comments received highlighted the following:

Waste burning could potentially be the largest source of dioxins and furans. The burning of sugar cane to mature it and to reduce the volume seems like an accepted practice. The EGB may wish to decide that it is a “Bad” Environmental practice not a BEP. There is shortage of data in the African region for this aspect but yet this could be the biggest source of UPOPs.

- ◆ The need to rely to the Toolkit as much as possible emphasis
- ◆ Generation of energy is not part of open burning but rather as a bad technology and practice.
- ◆ In door burning as they are outside building should not be considered as open burning.
- ◆ Indoor burning to go into the category of energy/power/steam
- ◆ Flaring at industrial sites should be not in general measures to burn releasing chemicals for the cases of emergency only and the practice of continuous flaring be discouraged.

(b) Preferred BAT/BEP Emphasis

Apparently the most desired guidelines and guidance will be on:

- ◆ Biomass burning where part of development/social activities i.e forestry, farming, including accidental fires.
- ◆ Burning bagasse, maize cobs, shells for energy when considered as is to proceed as energy generation.
- ◆ Waste burning e.g. landfill fires accidentally or incidentally
- ◆ Burning of waste pyres and piles
- ◆ Inclusion of barrel burning in category of open burning.
- ◆ Recommendations that incidentals/prescribe land fill fires to be strongly discouraged and guidance on exemption be made.
- ◆ Guidelines on flaring oil wells and also gas production to be included
- ◆ Burning land for clearing to plan
- ◆ Introduce open fire for cooking purposes as open burn category
- ◆ Introduce components of technology guidance in open burning.
- ◆ Introduction of zero burning policy in the ASEAN Region guideline could be considered
- ◆ Flare gas burning especially from lower quality oilfields
- ◆ Uncontrolled flaring at industrial sites in chemical plants and refineries.

(c) Typical guidance BEPS

1. Examples of BEPs emphasized include: *Signs “Do not permit smoking during Dry Season”*
2. Prescribed burning in land management or for development activities e.g. construction
3. agricultural practices e.g. sugar can harvesting
4. Recycle of phosphorous into soils
5. disposal of harvest residues
6. systems to track through satellite monitoring for oils/gas wells
7. remote analysis of thermal sources in oil fields.
8. the ASEAN Region has already developed a guideline on open burning for plantation the EGB may wish to discuss it. This report could not be attached to this document because it is in acrobat while this document is in MS word. It will be availed at the 2nd meeting.

ANNEX I: COORDINATOR DISCUSSION PAPER ON OPEN BURNING

Background

The 6th session of the Intergovernmental Negotiating Committee of the Stockholm Convention on Persistent Organic Pollutants, held from 17th – 21st June, 2002 in Geneva, Switzerland established the Expert Group (EGB) on Best Available Techniques (BAT) and Best Environment Practices (BEP) to develop guidelines on BAT and provisional guidance on BEP relevant to the provisions of article 5 and annex C of the convention.

The 1st session of the EGB was held in Triangle Park North Carolina, United States of America from 10th - 14th March, 2003. The group considered sources of Unintentional Persistent Organic Pollutants ((UPOPs) and identified open burning as a priority source of emissions for which guidelines on BAT and guidance on BEP would be useful.

The EGB noted the desirability of intercessional work on open burning source among other (6) thematic areas and nominated volunteers to coordinate assembly and synthesis of information relating to this source category

1. Reference Documents

The EGB has before many useful reference materials in which a few are highlighted below for this specifically PCDD/PCDF from uncontrolled combustion

- Open burning of domestic waste. A source of dioxins by perspective International Council of Chemical Associations (ICCA).
- BAT and BEPs of Municipal solid waste by Ms Pat Costner of Green peace international.
- 3 UNEP Reports on Dioxin/Furan workshops in Brazil and Bangkok.

The EGB also formed a breakaway group that synthesized the information available on the subject and came up with a summary of contributions from other sources.

1.0 Intercessional Work

The EG discussed the approaches to the work of BAT/BEP on open burning as called for in its Terms of reference TOR. This work may involve: -

- Identification of alternatives to open burning with a view to its eventual prohibition.
- Possible sources of dioxins arising from burning unclean fuels (e.g. oil from refineries)
- Collecting information of BEP projects that could prevent or minimize forest fires; and
- Collection of relevant reference documents especially on technology and regulatory measures;

2.0 Source Categories

The BAT Expert identified group identified the following as sources of UPOPs from open burning.

- Land fires;

- Barrel Burning/Backyard burning;
- Prescribed agricultural burning;
- Construction/demolition debris;
- Land clearing for construction; and
- Open burning of waste oil and gas fields

It noted that there might be policy options in some countries but which may not be uniform or representative of developed or developing countries technologies. It was not possible to compare the “Best” in BAT and BET in such technologies. It was also recognized that open burning to be the mode for disposal of waste in many countries. The only effective way to address pollution from open trash burning is to ultimately eliminate it. It will require the efforts of all stakeholders and close cooperation between the developed and developing countries.

There was intense debate on whether it is a major source of dioxins and furans. Some felt that it is the BEP so far for disposal of wastes though there was no consensus. The ICCA recognized however that this is a most highly polluting source. Some developed countries have accepted “barrel burning” as a means of disposal. Whether it is a BEP was nevertheless debatable. The general consensus was however that open burning is not an environmentally sound waste disposal method. The goal is its elimination all open burning of agricultural practices. The EGB could not arrive at specific recommendations.

3.0 Generation Of UPOPs From Uncontrolled Combustion

The main combustion categories generating dioxins and furans from both controlled and uncontrolled sources categories are:

- ❖ Formal Waste Incineration
- ❖ Heating, lighting, and
- ❖ Electric Power generation from biomass and fossil fuel burning.

In order to develop BATs and BEPs for these sources of UPOPs, it is important to identify key processes and main human activities, collect and assess information on their quantitative contribution to processes and qualities of the emissions.

The 2nd edition of UNEP Toolkit adopted by the 7th session of the *intergovernmental negotiating committee* assists in the process somewhat in providing a roadmap to what might be guidelines to BATs and guidance to BEPs.

This paper addresses only the uncontrolled combustion.

3.1 Uncontrolled Combustion Activities:

Uncontrolled combustion will mainly occur from the following sources.

- Energy generation;
- Accidental fires;
- Waste disposal.

By uncontrolled combustion, it means the fuels are not pre-pared no air supply enhanced to assist in combustion.

3.1.1 Energy Generation in General

According to the International Energy agency report of 1998/2000 for 1997 Energy sources were as follows:

Oil	35.9%
Coal	23.8%
Gas	20.1%
Nuclear	6.6%
Solar Hydro	2.3%
Combustible renewable energy and waste	11.2%

This totals 9521 metric tons oil equivalent of the global energy consumption.

3.1.2 Biomass Sources

Biomass fuels form the major part of combustible renewable sources.

In uncontrolled burning for biomass constitute the following fuels:

- (i) Food crops: Sugarcane, maize stalks and cob, cassava, palm oil kernels, rapeseed,
- (ii) Fiber crops: mainly from forests: Firewood, charcoal.

Therefore if we can assume uncontrolled combustion of oil, coal and renewable would represent 49.90% of the energy uses. Of course a large amount of oil and coal may be under controlled regime such as vehicle gasoline, diesel, central heating etc that are not the subject of this guideline and guide. However much of combustible, renewable and waste is uncontrolled.

According to World Resources Institute, in Sub-Saharan Africa this source represents 75-80% of, 40-60% for South Asia, 20-40% for East Asia, 20-30% for North Africa and Middle East and 20% for Latin American and the Caribbean for energy respectively.

The application of BAT/BEP in the Sector should consider that for most developing countries the continued reliance of biomass energy to the year 2010 and beyond and focus on improving technology which minimizes generation of POPs where this is possible. Where possible application of renewable energy technologies such as fuel cells and exploitation of solar wind and geothermal sources which have the potential to produce energy with considerable lower impact, notably on air quality should be given the highest priority as this may have benefits to environment far beyond the mandate of the convention.

3.1.3 Wastes/Residues

In this categories are these types of fuels: -

- Crop residues
- Food processing residues
- Forest industry residues
- Manures
- Municipal wastes

Depending on a country, these sources of energy/or disposal problem are either at primary stage on in various stages of commercialization. Agricultural and forest wastes are often used as alternative sources of fuel. Technologies have been developed to briquette waste to ease distribution and harness of calorific value. In Kenya for example, about 2,500 tonnes of briquettes channel are produced annually from coffee husks.

3.2 Air Pollutants from Uncontrolled Combustion Sources.

Energy related air pollution is caused by the combustion of fossil fuels in vehicles, industrial boilers and furnaces. Burning of biomass fuels for charcoal production (and directly for household use) results in local and indoor air pollution. Air pollution is the primary cause of energy related effects on human health. The major air pollutants created by the burning of fossil fuels are as follows:

Carbon dioxide (CO ₂)	82%
Methane (CH ₄)	12%
Nitrous oxides (N ₂ O)	4%
Others	2%

Source: UNFCCC. Second compilation and synthesis of national community UN FCC c/cp/1998/1/add1 September 1998

The others (represented by 2%) may be the dioxins and furans plus in intermediary chemicals and precursors of POPs. All of them are unintentional emissions and can increased or decreased by application of BATs and BEPs that aim to minimize them. These are the emissions covered under Annex c of the convention.

By far the greatest source of indoor pollution is the use of traditional cooking and heating fuels in developing countries. Some 3.5 billion people mainly in rural areas but also in many slum areas in cities rely on biomass for fuel for cooking and lighting. Sometimes they are also used for agricultural activities such as tobacco curing.

As such it is an important aspect of uncontrolled combustion. This source produces large amounts of particulate laden smoke, which may be carrier of dioxins and furans among other POPs in the confined space of home, creating conditions of high exposures as such conditions; exposure of pollutants is frequently much higher indoors than outdoors. This makes this category important and intervention a possible case a national implementation plan under the Stockholm Convention.

3.3. BAT/BEP in the Energy Sector

Article 5 requires parties to take measures to reduce or eliminate releases from unintentional production. This include policy issues such as those identified by the UN Economic and Social Council (ECOSOC) which has identified the following energy issues by promoting: -

- Accessibility, availability, reliability and affordability of appropriate energy sources.
- Rural energy services that meet the basic developmental needs of rural and dispersed populations;
- Financing of sector improvements needed for ecological sustainability;
- Energy efficiency in production, conversion, distribution and use;
- For renewable energy, accelerated development, and wider scale use; and
- Improved energy efficiency and mitigation of the environmental and health impacts.

The above policy issues may serve as a guide to developing options that will promote the objectives of the convention in minimizing PCDDs/F

3.4 Application of BATs

The simplest cases of BATs in the energy sector that ones biomass has been the improved stoves. The improved stoves fulfill several complementary objectives such as: -

- Reduction of indoor pollution;
- Reduction of time spent gathering wood;
- Improvement of daily life;
- Creating of jobs and therefore increased income;

- Securing of energy supply and environmental protection.

In Kenya application of this relative BAT, 150,000 improved stoves are in operation and it has set a growth industry for wood stoves to improve efficiency and minimize pollution.

3.5 Guidance to BAT & BEP

In any combustion process, emissions of dioxins and furans will depend upon material, technology type and pollution control policies. These will be drivers of any BAT or BEP. Emission will also vary with the size and vintage of the combustion technology, its maintenance and its operation.

Coal can be discounted as insignificant sources of dioxins and furans. The following elements must be present in any combustion process to form any PCDD/F.

- Carbon
- Chlorine
- Oxygen
- Temperature
- Catalysts
- Surfaces

3.6 Guidance to selecting BEP

PCDD/PCDF can form due to incomplete combustion of carbon in the presence of chlorine. Open or uncontrolled burns represent poor fuel/oxidant mixtures, leading to uncombusted carbon. If chlorine is present, reactions with the carbon structures may lead to PCDD/PCDF formation. The practice of open combustion must ensure that the conditions for generating PCDD/F are minimized and eliminated.

3.7 Guideline for Selecting BAT

- (i) PCDD/F reduction
 - Only use pure wood, avoid pine;
 - Avoid wet fuels;
 - Avoid mixed fuels with contaminants of chlorine or products made with chlorine such as textiles and PVC
- (ii) To ensure complete combustion,
 - Choose technologies that avoid exposure to hot gases of combustion by exhausting gases from the environment of humans by using smoke stacks or exhaust vents that promote wider dispersion
 - Use improved stoves that promote higher oxygen mix with fuel and that vent the stacks away from the breathing environment
- (iii) Economic/Social Considerations
 - Continuous search for cost effectiveness, average and marginal costs of technologies that minimize or eliminate generation of PCDD/Fs
 - Provide external assistance to least cost Capital and operating costs, opportunity costs, incremental costs etc for technologies that promote combustion.
- (iv) Equity

To reduce burdens tend exposure to vulnerable groups especially women and children, income groups or future generations promote human shelter that complement the aims of the convention;

- (v) Replicability

Adaptability to different geographical and social economic-cultural settings.

Consequently, paper plastics, textiles represent the highest possibilities of generating dioxins. In terms of quantity, wood and organic matters represent small but in terms of quality, significant sources of PCDDF

4.0 Minimizing UPOPs

In summary, the EGB concluded that as open uncontrolled burning is concerned, emission of dioxins are as a result of, Poor or marginal combustion and Presence of chlorine (organic or inorganic).

In compliance with the Stockholm Convention and in order to minimize UPOPs, the minimization of dioxins emissions from uncontrolled burns might be achieved by:

- Promotion of good combustion and
- Limiting the presence of chlorine and catalytic metals.

4.0 Receiving Information

In order to understand and appreciate regulations and technologies on open burning for all countries, the attached draft questionnaire has been developed for consideration by members of EGB. They are invited to comment on it. Some information has been downloaded from organizations, which have addressed the issue of open burning from the USA, Green peace, and Canada. There is little comparative data and information from developing countries. The TOR for the EGB was quite clear on identifying the special circumstances of developing countries when developing BATs and BEPs. Some of these are annex to this paper

1. Open burning should be the last resort in the waste management hierarchy. It is an environmentally unacceptable process to be minimized and eliminated. If any other responsible alternative is available it should be used in preference to open burning. Countries should diligently work to establish and implement such a hierarchy including, but not necessarily in this order, source reduction, recycling, modern sanitary land filling, and BAT incineration.
2. In cases where open burning is the only alternative, such burning should be done in a manner consistent with what science we have. Recognizing that the reproducibility of open burning experiments conducted by a single laboratory not to mention between laboratories is poor, some reasonable advice can be given. Specifically, improving combustion conditions will likely have the most significant effect upon reducing PCDD and PCDF emissions. Other suggestions include:
Remove non combustibles, including glass and bulk metals, including glass and bulk metals
Supply sufficient air
Dry, not wet, waste fuels
“Homogeneous or well-blended fuels
Steady burn (steady rate of mass loss)
Minimize smoldering period
3. On a practical basis, this means that it is difficult to imagine how burning a dump—by its nature somewhat moist and poorly aerated – for volume reduction could ever be carried out with difference to these suggestions. Small scale open burning may, under some circumstances, be improved by burning open piles rather than closed containers; removing wet organic waste; assuring a hot, short fire, burning materials with a high surface to mass ratio (smaller rather than larger items); overtly extinguishing that fire with water rather than allowing it to smolder.

4. Minor influences in the PCDD/F emissions might under some circumstances be obtained by avoiding high concentrations of chloride-containing materials, metals such as copper or other non-combustible "surfaces" such as silica. Detailed waste composition studies should be conducted to discover the prevalence of any of these materials in waste in a particular country before basing open burning policy on managing those materials.
5. However, taking all that into consideration, it should be noted that open combustion of dry straw—seemingly near an ideal fuel—still generates significant dioxins and furans, and points up the fundamentally polluting nature of the method.

Expert Group on BAT and BEP

Questionnaire for information on open burning

Country _____

Email/Fax of Respondent/Organization _____

Sources of UPOPs	Details (please answer yes or no)	Reference Document/comment
1. Are there general air emission standards in relation to POPs or POP like emissions from the following sources? Yes/No		
2. Any regulations /emission regulation targets even if not purely made for UPOPs?	Prescribed agriculture burning.	
	Preventing landfill fires.	
	Backyard burning practices.	
	Open burning of used/ waste engine and machine oils;	
5. Are dioxins/furans from open burning monitored for UPOPs or in general?	How?	
	Existence guidelines on BAT	
	Existence Guidance Documents available on?	
	Internet	
6. Have you identified or recommended alternatives to these practices such as:	Municipal/domestic waste disposal by burning	
	Solid waste disposal in rural areas	
	To agricultural burning and for what crops	
7. What are the priority category sources of dioxins and furans you would like to see? Arrange them in order of your priority: <ul style="list-style-type: none"> • Land fill fires • Barrel burning • Pit burning • Construction /Demolitions burning; • Vegetation Burning for Construction; • Solid waste disposal • Textiles disposal • Condemned Material burning • Tiles • PVC 	Priorities	

ANNEX 2 : RESPONSES RECEIVED ON OPEN BURNING

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Subject: EGB2 - some thoughts on open burning paper

Dear all,

I would like to thank Francis Kihumba for his initial thoughts on the open burning issue. I also acknowledge Bill Carroll's first comments on this paper; it contains a lot of useful thoughts and may help to structure the next draft.

Concerning the introduction and context, I refer to my earlier e-mail that the group may wish to develop a "master" for the introduction", which will be used in all of the individual guidance documents.

Coverage:

The present draft refers to the revised Toolkit and the methodological approach taken therein (which by INC7 was noted as the guidance to undertake release reporting under the Convention). In the sense of the Toolkit - and as I understand - "open burning" refers to combustion of different materials/combustible where no equipment to facilitate the combustion/burning is present (see Category 6 of the Toolkit). In the sense of the Toolkit and in my understanding, poorly controlled or uncontrolled combustion processes in poor facilities are NOT included. In this sense, generation of energy cannot be included in the "open burning" chapter of the guidance. Thus, I have difficulties with sections 3.1.1 and 3.2.2

Section 3.1.3: I would like to divide - following the Toolkit approach - into

(1) biomass burning where crop residues and wood residues, which are left in the forests and bushes, are burned on-site with the main purpose to get rid of them. This section will also include accidental fires when during the dry season forests, bushes, grassland, etc. catch fire - there may be some simple BEP possible such as "don't permit smoking during the dry season", "no glass permitted", etc. - Another dimension are prescribed burns in

(a) land management for clearing ways for, e.g., construction activities, reforestation, etc., and
(b) agricultural practices to (i) facilitate harvest, e.g., sugarcane, (ii) recycle phosphorous into the soils, (iii) get rid of the harvest residues - these are "permitted" uses and very often common practice.

(c) other?

when coconut shells are being used to produce energy or steam at a small facility/plant, then this would go under Category 3 - production of energy, power, steam, heating, cooking.

(2) waste burning: here landfill fires (accidentally and incidentally) will be included as well as the burning of different types of wastes in pyres, piles are considered. Since the barrel burns are

typically included under open burning, I suggest to keep this practice in the "open burning" section and not move to the incinerator part (although a container, which may be considered as a very primitive equipment, is being used). With respect to incidental/prescribed landfill fires, the group may consider that this should not happen at all and recommend this as BAT/BEP.

and

(3) accidental fires: when houses, vehicles, etc., burn down. Prevention strategies will apply.

For Section 3.3: in the above sense, I would prefer not to talk about "technologies"; for me these are practices.

Also, the indoor air pollution aspect will not apply since the sources are outside buildings (except for the house fires but these are case by case evaluations and recommendations to reduce exposures are given elsewhere). The examples listed here would go into the Category of energy/power/steam production/heating/cooking and the group of diffuse sources (see document UNEP/POPS/EGB1/3).

That's all for now.

Kind regards,
Heidi

The International Council of Chemical Associations (ICCA)

The International Council of Chemical Associations (ICCA) is grateful to Mr. Francis Njuguna Kihumba of Kenya for taking on the task of assembling Best Available Techniques for Open Burning. These comments are offered in the hope of catalyzing discussion on an extremely complex technical and policy topic. We believe that discussion will eventually result in a paper of the form of the other BAT-BEP papers that are being developed; we hope such a paper will be available for discussion at the BAT-BEP meeting in December.

Open Burning of Household, Municipal, Commercial, Construction, Demolition Waste and Landfill Fires.

Perhaps the most problematic of the types of open burning considered in the paper is the open burning of personal, municipal or commercial refuse. The presence of the questionnaire asking for information on local practices is valuable. I would strongly suggest, in the interest of gaining more information on this topic in individual countries, that questions be developed for this questionnaire regarding:

- 1) Typical waste collection practices: Individual responsibility; municipal collection; individual drop-off at remote site or a combination of practices
- 2) Typical waste disposal practices: Municipal Incinerator; modern compartmentalized landfill; dumpsites; scavenging, recycling or container reuse, and the types of materials typically recovered.
 - a. Are food growing activities (animal or vegetable) conducted on these disposal sites

This information will eventually aid in the development of a waste disposal hierarchy of processes, and potentially integrated waste disposal practices. We should remember that open burning is a symptom of a problem in an overall system; a functioning, practical, environmentally defensible system is the ultimate goal, not a fix-up of open burning.

- 3) Typical classes of refuse burned: Personal; Municipal; Commercial; Construction and Demolition; Animal (dung or offal); Other
- 4) Typical modes in which waste is burned: Inside the house; In piles or barrels by individual households; In piles or barrels in neighborhood localities; On a community basis at a site inside a city; On a community basis at a site remote from the city; As a means of volume reduction at a landfill
- 5) Typical composition of municipal/household waste: Paper and paper products; wood; plastics, by type if known; metals; glass; compostables; textiles; leather;

I envision that the information could be assembled in two two-axis grids combining 1 & 2 and 3 & 4 together, with comments at the intersections on the presence and execution of waste disposal under those conditions.

An example of these tables follows:

Types of Collection methods vs. Types of Disposal Methods

	Individual Responsibility	Municipal Collection	Individual Drop-off Remote site	Combination	Other
Reuse					
Scavenger Recycling (note materials recovered)					
Modern Landfill					
Dumpsite					
Municipal Incinerator					
Open Burning					

Types of waste vs. types of open burning

	Personal	Municipal	Commercial	Const./Demo	Animal	Other
Inside house						
Individual Piles or Barrels						
Neighborhood Piles or Barrels						
Community In-city						
Community, outside city						

Landfill burning						
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This information could be helpful in assembling a national inventory of dioxins and furans. It will also be important in development, and particularly implementation, of “Best Techniques” for what is admittedly an inherently poor practice. From this knowledge, it may be possible to decrease some of the inherent variability of PCDD/F generation in open burning based on technical parameters disclosed to the BAT-BEP group. Improvements will be highly dependent upon understanding current techniques and practices on a local basis.

General Discussion of Best Available Techniques and Environmental Practices. ICCA believes, and the convention states clearly, that open burning is an environmentally unacceptable practice that should be minimized and eliminated where feasible. In cases where open burning is the only alternative eventually a set of processes for improvement of open burning practices should follow the recommendations heard by the Expert Group in Research Triangle Park. With respect to the generation of PCDD/F in open burning, the group was told that improving combustion conditions will likely have the most significant effect upon reducing PCDD and PCDF emissions.

Practical process suggestions for improvement include:

- Reduction in the amount of material discarded via uncontrolled burning
 - Consistent with the recommendation of the Convention, this is the first line of improvement
- Removal of non-combustibles, including glass and bulk metals
- Supply of sufficient air
- Steady burning or rate of mass loss
- Minimization of smoldering period, possibly with direct extinguishment

And with respect to the materials burned:

- Dry, not wet, waste fuels of high fuel value
- “Homogeneous” or well-blended fuels
- Low density; e.g. non-compacted waste

Lower-probability techniques that may provide some reduction of PCDD/F include:

- Burning in piles rather than confined in burners
- Avoiding burning waste that is exceptionally high in chloride content—many times that of normal household waste
- Recognize that there is no apparent difference between inorganic chloride (salt) and organic chloride (PVC)
- Avoiding burning waste that contains metals such as copper

ICCA would like also to acknowledge that it is literally true that in order to make chlorinated dioxins and furans—or chlorinated anything, for that matter—the chemical element chlorine is required. However, we also re-emphasize that with or without any PVC there is a more than a million times as much chloride already present in normal waste from, for example, paper, wood and food as is needed to make the dioxin emitted. In fact, it would be impossible to “starve” the chloride out of the feed under any circumstance, since even ambient air feeding combustion—especially salt air close to the ocean—can contain many times as much chloride as is necessary to make the dioxin emitted. Given these facts, it is difficult to imagine how micromanaging PVC—assuming it exists to any extent in normal waste in the country of interest—could have a major effect on PCDD/F generation, particularly given the other more easily accomplished means of improving combustion.

It will be most important in the final paper to develop a hierarchy of process improvement techniques that take into account the probability of success, the ease of obtaining compliance and to separate those that are totally the discretion of the person conducting the burning from those that they have socioeconomic impacts beyond simple disposal of waste.

Disconnection of Sources of PCDD/F from Receptors

In developing BAT and BEP we should consider more than simply the technical practices of burning. A fundamentally environmentally inferior practice such as open burning will be, in some situations, the most practical waste disposal option. The question should be: can this process be partially disconnected from human exposure to the products of combustion

Exposure via food. Recognizing that the process of human exposure to PCDD/F is generally through the food supply, authorities will need to consider whether PCDD/F from this process can be disconnected from local food generation.

Anecdotally, it is known that food animals and birds can be allowed to scavenge feed in landfill or open burning areas. Such animals have been found to contain higher levels of PCDD/F than counterparts whose feed has been otherwise managed. Additionally, open burning in areas where food crops are grown can significantly increase the concentration of PCDD/F in those foodstuffs.

Ash from uncontrolled open burning may contain significant amounts of pollutants including metals as well as PCDD/F and other organics. Use of ash from sites where open burning is common as a soil amendment should be discouraged.

To the greatest extent possible, collection of waste and location of open burning at sites remote from food production will reduce human exposure.

Exposure via direct contact. It is now well-known that the quality of indoor air in residences dependent upon direct combustion for heating can be extremely poor. This situation is exacerbated by poor combustion of inappropriate fuels.

To the greatest extent possible, combustion of undifferentiated waste should be discouraged in residential heating and cooking.

Dear Mr. Kihumba,

I'm sending you my comments to the file previously sent by you, these comments are relevant to articles 4.1 e. and 4.2 c. The stated system of observation is actual for the countries with vast territories like Kazakhstan. Since the activities I am proposing are already being conducted in Kazakhstan, I expect to report on the first results during the meeting in December.

I do apologize for late reply as I was on vacations.
Regards,

Marat Ishankulov

Proposal to articles 4.1 and 4.2 c.

Thermal emissions pose a threat as source of environmental pollution since during the process of oil and gas production waste combustion the solid and gaseous substances are being discharged into the air. Among them there are not just sulfur, carbon and nitrogen dioxides and hydrocarbons but also persistent organic pollutants. One part of thermal emissions of the regions is result of oil and gas production operating peculiarities (burning of jets used during combustion of oil-well gas, etc.), the second part is caused by - emergency situations (storages burning caused by electricity cutoff, oil spills combustion, etc.).

Compared to burning jets used for oil-well gas combustion and not accompanied by POP emissions, with regards to POP problem of spontaneous and emergency fires resulting in oil and gas production wastes combustion: oil and gas production wastes are the source of persistent organic pollutants emission.

In order to track spontaneous and emergency fires it is suggested to introduce system of satellite monitoring of oil and gas field. Monitoring enables controlling unit to detect spontaneous thermal sources of landscape pollution and also period of operation and capacity.

Experience of Institute of space explorations of the Ministry of Education and Science, RK – Academy of Sciences of the Republic of Kazakhstan related to remote sensing data interpretation facilitates solving of a wide range of relevant problems. System of low-resolution synoptic satellites NOAA/AVHRR provides information on earth surface in five spectral channels: two visible and three infra-red (ch1 0,58-0,68 *mcm* (*micrometre*); ch2 0,725-1,1 *mcm*; ch3 3,55-3,93 *mcm*; ch4 10,3-11,3 *mcm*; ch5 11,5-12,5 *mcm*) with width of 2700 *km* and resolution of 1,1 *km* in nadir. AVHRR scanner sensibility in thermal channels enables differentiating 0.1°C temperature differences and defining absolute temperature to within 0.2°C. Currently there are three operable satellites NOAA 10,12,16 with orbital period 90 *min* in orbit. AVHRR scanner sensibility enables fixing thermal source with area of 50 *m*² and spectral-bright temperature over 2000°C (gas flame). In this case average temperature on area of one *km*² (minimum estimated area) will increase for 0.1°C. In case of large oil fire the snapshot records not only zones of high temperature but also accompanying zones of low temperature caused by cold upper level of smoke clouds.

Currently there is available a new satellite system equipped by hyperspectrum scanner MODIS (36 spectrum channels) with resolution 250 *m* , 500 *m* and 1000 *m*. The first satellite of this system (TERRA) is in orbit. Scanning range is 2200 *km*, spectrum

resolution is four times better than AVHRR scanner. Presumably, sensitivity of thermal channels (channels # 20-36) enables fixing thermal sources with total area of gas flame of 25 m^2 . Exactness of identification could be essentially improved by use of additional ground cartographical information on location of oil and gas deposits production sites.

Within the frameworks of “Initial assistance to the Republic of Kazakhstan to meet its obligations under the Stockholm Convention on Persistent Organic Pollutants” project” there were started activities on remote analysis of thermal sources capacity in oil and gas zones that generate persistent organic pollutants. The above analysis is to be carried out with the use of remote sensing data (RSD) during day and nighttime. The date of activities completion is December of this year. During research there will be revealed permanent sources of oil and gas production wastes combustion, brightness temperature of the above mentioned as well as temporal (emergency and volley) sources of burning, operation period and also area and temperature characteristics according to historical space information of year of 2002. At the same time there will be developed the scientific and methodological principles of detecting oil and gas production industry wastes combustion sources and estimation of their capacity on the territory of the Caspian oil and gas bearing region.

The implementation of activities will result in analyzing a number of test sources in a form of daily monitoring according to data of night and day shooting of HOAA satellite system for collecting of information on RSD capabilities in fixation (sample is attached), duration and capacity of thermal emissions’ dynamics estimate. Area characteristics of territories subjected to fire could be specified with the aid of space information MODIS.

In future project implementation will facilitate the development of geoinformation system (GIS). This system unites cartographical information on oil and gas fields with the data of satellite monitoring. The abovementioned system will track normal and emergency thermal modes of these objects’ operation and will provide on-line and objective information on modes of their operation.

Dear Colleagues,

There is a further source that seems to be missing from the very excellent outline prepared by Francis and modified by Heidi.

It is the flare gas burning. In several countries with significant oil (petroleum) extraction/production, the collection of associate gas is not economically feasible, therefore it is openly burnt. In some other countries it is collected and processed as LPG or used in other different ways as a source of energy.

Flare gas burning, particularly from lower quality oilfields, could be regarded as a significant source in the open burning category.

With best regards.

Zoltan

Dear Mr. Kihumba ,

first of all, thank you very much for this draft Guideline on open burning. This is a very complicated issue. Also very sorry for being very late with our comments from the EU, hoping that will not be too late for including them. We would like to raise some aspects having in mind, that we are faced with living proposals and draft documents, which are not closed for further work and commenting later on, especially at our second meeting.

From our point of view, the proposed measures outlined in this draft guideline are more or less adequate. UNIDO added, that an important source of UPOP emissions from open burning also in industrialized countries is also uncontrolled flaring at industrial sites, for instances in chemical plants and refineries. Flaring at industrial sites should be not general measure to burn releasing chemicals, but for cases of emergency only.

Some more specific comments are to be added:

Chapter 2 refers to the list of sources identified by the expert group. Therefore, I we also do not see the energy section as a part of these categories.

Section 3.2: Table on emissions from fuel combustion. The Tables was taken from a UNFCCC report which refers to greenhouse gases. I suppose that the "others" category covers GHG only. The link which is made between 2% "others" and POPs will be misleading with regard to the order of magnitude of POPs emissions. In terms of mass released, POPs cannot be compared to CO₂.

The open burning of agricultural waste is an important source in many countries. This issue should be addressed in more detail (see also the input from Singapore).

In general we would like to propose, that we should leave the drafts of any guidance open for further comments also after the second meeting. Currently is obviously, that the deep of information in the different drafts is different from each other. This implies, that this deep of information should be assessed after further discussion and the second meeting, If further is needed, it could be added.

Best regards from

Steffi.

Hello Mr Kihumba,

I have gone through the document you prepared on open burning in great detail and must say that it was well done and had considered all the issues. However I have the following comments for section 4.1 Guidance to Selecting BEP.

1) I have noticed that there is nothing for burning land for farming or construction purposes. Do you think this should be included or was this omitted on purpose?

2) No consideration has been given to open fire for cooking purposes. This can be incorporated in education and awareness whereby people are told on how to improve on biomass cooking methods.

Besides these two minor comments the document is well written. I know there can be concerns on in the inclusion of technology aspects in open buring but I feel it all fits in well.

Attached please find the survey form.

regard
Vandana

Expert Group on BAT and BEP
 Questionnaire for information on open burning
 Country Fiji Islands

Email/Fax of Respondent/Organization _____

Sources of UPOPs	Details (please answer yes or no)	Reference Document/comment
3. Are there general air emission standards in relation to POPs or POP like emissions from the following sources? Yes/No	No	
4. Any regulations /emission regulation targets even if not purely made for UPOPS?	Prescribed agriculture burning. Still in draft legislation	
	Preventing landfill fires. No	
	Backyard burning practices. Is restricted in urban centres	
	Open burning of used/ waste engine and machine oils; Is not permitted under the Public Health Act	
8. Are dioxins/furans from open burning monitored for UPOPS or in general?	How? No	
	Existence guidelines on BAT None	
	Existence Guidance Documents available on?	
	Internet	
9. Have you identified or recommended alternatives to these practices such as:	Municipal/domestic waste disposal by burning Encouraging composting through our education an awareness programmes	
	Solid waste disposal in rural areas This is still a major problem	
	To agricultural burning and for what crops This is not regulated	
10. What are the priority category sources of dioxins and furans you would like to see? Arrange them in order of your priority: <ul style="list-style-type: none"> • Land fill fires • Barrel burning • Pit burning 	Priorities <ul style="list-style-type: none"> • Solid waste disposal • Land fill fires • Condemned Material burning • Barrel burning, Pit burning • Construction /Demolitions 	

Sources of UPOPs	Details (please answer yes or no)	Reference Document/comment
<ul style="list-style-type: none"> • Construction /Demolitions burning; • Vegetation Burning for Construction; • Solid waste disposal • Textiles disposal • Condemned Material burning • Tiles • PVC 	burning; <ul style="list-style-type: none"> • Vegetation Burning for Construction; • Textiles disposal • Tiles, PVC 	

Please forward information to: Kihumba F.Njuguna. Tel/fax 254-2-3760461
 Email :kihumbafn@yahoo.com.

Dear All

As discussed at our first session in Mar 03, I would like to share some salient developments in the Southeast Asian region (ASEAN) relating to open burning.

In response to the land and forest fires that affected the ASEAN region, the region had adopted a policy on zero burning and strived to promote its application by large plantation owners and timber concessionaires. To-date, research and commercial experience had focus on palm oil as well as Acacia tree (pulp and paper) plantations as substantial areas come under these crops. A set of guidelines had been developed and adopted by ASEAN to help the plantations owners and managers apply zero burning technique for the development of their plantations. A copy of the guideline is attached for reference

(See attached file: zeroburning_guidelines.PDF)

Owners or occupiers of small areas of agricultural land may have difficulties in implementing the guideline as implementation of zero burning technique would require resources and economies of scale that might not be available to these owners/occupiers. For this group of owners/occupiers, ASEAN is also developing guidelines on "controlled burning" which is expected to be ready before end 2004

Best regards

Lim Kew Leong
Chief Engineer (Pollution Control Dept)
National Environment Agency
Singapore

Note: Document on ASEAN Region Zero Burning guidelines not attached here. Distributed to EGB members by Email and will be made available at the 2nd EGB Meeting

Dear Francis,

Thank you so much for all of your hard work on the draft paper on open burning. I particularly appreciated the information you included on biomass contribution to energy production in various parts of the world and air pollutants from uncontrolled combustion sources.

I hope you find my comments to be useful. If there are any of the papers or reports that I have cited that you need, just let me know and I will email them to you.

Best regards,

Pat

**Comments on
Draft Intersessional Work on Open Burning for the Expert Group on BAT and BEP**

General Comments: This paper reflects the major points of the Expert Group discussion of open burning and serves as a very useful basis for moving forward. Each of the source categories listed at 2.0 Source Categories requires careful consideration in the Expert Group's ongoing deliberations.

page	
1-2	<p>2.0 Source Categories <i>The EGB identified the following as sources of UPOPs from open burning.</i></p> <ul style="list-style-type: none"> ▪ <i>Land fires;</i> ▪ <i>Barrel Burning/Backyard burning;</i> ▪ <i>Prescribed agricultural burning;</i> ▪ <i>Construction/demolition debris;</i> ▪ <i>Land clearing for construction; and</i> ▪ <i>Open burning of waste oil and gas fields</i> <p>Comment: In addition to the sources listed above, the Expert Group also identified accidental fires involving vehicles, buildings and warehoused materials.</p> <p>Suggestion: Modify the list as follows;</p> <ul style="list-style-type: none"> ▪ Land fires; ▪ Barrel Burning/Backyard burning; ▪ Prescribed agricultural burning; ▪ Construction/demolition debris; ▪ Land clearing for construction; ▪ Open burning of waste oil and gas fields ▪ Accidental fires (vehicles, buildings and warehoused materials)
2-3	<p>3.0 Generation Of UPOPs From Uncontrolled Combustion <i>...[through]</i></p>

	<p>3.2 Air Pollutants from Uncontrolled Combustion Sources</p> <p>Comment: This entire section contains some very useful information. However, some information is relevant to sources that are more appropriately considered as energy production sources rather than as open burning of waste.</p> <p>Suggestion: Remove information specific to combustion or burning for purposes other than waste disposal. Include this information in more appropriate sectors, such as energy sources.</p>
5	<p>4.0 Guidance to BAT & BEP</p> <p>...</p> <p><i>Coal can be discounted as insignificant sources of dioxins and furans.</i></p> <p>Comment: This statement is not supported by various national dioxin inventories as well as published scientific studies. Dioxin releases from the combustion of coal can be substantial. Dioxin formation is known to vary with the chlorine content of the coal. For example, in their study of coal combustion in domestic stoves, Thuss and Popp (1995) found the dioxin formation increased with increasing chlorine levels in the coal.ⁱ On the other hand, Gullett and Wikstrom (2000) reported reduced dioxin formation when high-sulfur coal is co-fired with refuse derived fuel.ⁱⁱ</p> <p>Suggestion: Omit this sentence</p>
5	<p>Therefore guidelines and guidance will aim at controlling the parameters that promote complete combustion and minimization of air pollutants in general.</p> <p>Comment: It is also important to include materials substitution and/or segregation, in the guidelines and guidance.</p> <p>Suggestion: Therefore guidelines and guidance for reducing/eliminating dioxin formation during open burning of waste will address primary measures including alternative waste management practices that are not dioxin sources and, when open burning is the only or preferred option, substituting high-chlorine materials in the waste or otherwise segregating such materials from the waste to be burned. For example, replace PVC in packaging and other products possibly destined for open burning with chlorine-free materials. Secondary measures such as optimizing combustion conditions will also be addressed.</p>
5	<p>4.1 Guidance to selecting BEP</p> <p>Comment: The Expert Group has discussed the difficulties of distinguishing between BAT and BEP. However, no strategy has yet been agreed.</p> <p>Suggestion: Delete this heading.</p>

5	<p><i>For situations that may need use of waste, the waste or biomass can be sorted out to ensure that no metals such as copper, iron and aluminum are in the fuel.</i></p> <p>Comment: Formation of dioxins and furans can also be reduced by sorting out chlorine-containing materials. For example, in their study of burning waste in barrels, Lemieux et al. (2000) reported increased dioxins in air emissions with a higher PVC content in the waste as well as higher copper content.ⁱⁱⁱ Based on the same series of experiments, Gullett et al (2000) concluded that dioxin air emissions “increased with higher amounts of Cl, whether organic or inorganic, and higher amounts of Cu catalyst.^{iv}</p> <p>Suggestion: For situations where waste burning cannot be avoided, measures should be taken to prevent to the greatest extent possible the inclusion of chlorine-containing materials and metal-containing materials in the waste or, in the event this has not been accomplished. Such measures include substituting chlorine-containing materials with chlorine-free materials, for example, using chlorine-free plastics rather than PVC. In the event such steps have not yet been taken, the wastes should be sorted to remove from the waste, as much as possible, materials containing chlorine in any form and materials containing metals.</p>
6	<ul style="list-style-type: none"> • <i>There should be education/awareness raising on the adverse effects of open burning on bad combustion conditions and the role of chlorine containing materials such as textiles in the waste to be burnt.</i> <p>Comment: PVC has been identified in many studies as the primary source of chlorine in municipal solid waste and/or household waste. Consequently, it is very important that it is mentioned here in the context of chlorine containing materials. Polyvinylidene dichloride (PVDC) is also a less well-recognized but common source of chlorine in municipal and household waste that is a dioxin source when burned.^{v,vi}</p> <p>It is also important to note that, in some cases, authorities encourage backyard burning in order to reduce the amount of waste they must collect.^{vii}</p> <p>Suggestion:</p> <ul style="list-style-type: none"> • There should be education/awareness raising on the adverse effects of open burning, on bad combustion conditions and the role of chlorine containing materials such as PVC, polyvinylidene (PVDC, also known as Saran), textiles, etc in the waste to be burnt. • There should be capacity building to ensure that both urban and rural authorities have adequate resources for collecting and managing household waste.

6

b) For Landfill fires the primary measures required are:

- **Waste management practice to minimize the amount of waste such as recycling, sorting, minimization etc to modify its contents.**
- **Landfill fire should not occur as they are unacceptable**
- **Landfills should be managed in such a way as to avoid spontaneous fires through better landfill management;**
- **Capacity building at the local government level for personnel licensing landfills so that they can recognize the above landfill BEPS;**
- **Separation of hazardous/non hazardous waste before land filling.**

Comment: It is important to be explicit in guidance and guidelines for reducing dioxin formation in landfill fires. Based on a study of PVC in landfills by Mersiowsky et al (1999), it can be estimated that PVC may contribute as much as 97 percent of chlorine available for dioxin formation in landfill fires.^{viii} As with open burning, this suggests that the most effective primary measure for reducing dioxin formation in landfill fires is replacement of PVC, PVDC and other chlorine-containing packaging and other products with chlorine-free materials. As an interim measure, a strategy similar to the Danish PVC Strategy for diverting PVC from waste incinerators would be effective: separate PVC from the wastes and send the non-recyclable fraction to special landfill cells so that it can be recovered for further treatment.^{ix} Special fire prevention measures could be taken for the landfill cells designated for PVC.

It is also important to note that landfill fires are, in some cases, used by local authorities to reduce waste volume and thereby lengthen the life of landfills. For example, UNEP notes that this is common where authorities cannot afford bulldozers for compacting the waste.^x Landfill contents are also burned by waste pickers for metals recovery.^{xi}

Suggestion:

b) For Landfill fires the primary measures required are:

- Substitution of PVC, PVDC and other chlorine-containing packaging and other products with chlorine-free materials.
- Separation of PVC, PVDC and other chlorine-containing materials at source or post-collection.
- Place PVC and PVDC in special cells in the landfill and focus fire prevention efforts particularly on these special cells.
- Waste management practice to minimize the amount of waste such as recycling, sorting, minimization etc to modify its contents.
- Landfill fire should not occur as they are unacceptable
- Landfills should be managed in such a way as to avoid spontaneous fires through better landfill management;
- Capacity building at the local government level for personnel licensing landfills so that they are adequate equipment and can recognize the above landfill measures;
- Separation of hazardous/non hazardous waste before land filling.

6	<p><u>c) For Demolition and construction waste; the group recommended that:</u></p> <ul style="list-style-type: none"> • Except in emergency situations like accidental fires, construction and demolition waste should never be allowed to burn in the open; • No intentional open burning for this type of waste <p>Comment: The primary measures for reducing/eliminating dioxin formation during the open burning of demolition and construction waste are essentially the same as primary dioxin reduction measures for open burning of household waste and landfill fires.</p> <p>Suggestion: <u>c) For Demolition and construction waste</u></p> <ul style="list-style-type: none"> • Substitution of chlorine-free materials and products for use in construction; • Except in emergency situations like accidental fires, construction and demolition waste should never be allowed to burn in the open; • No intentional open burning for this type of waste
6	<p><u>e) Waste Oil.</u></p> <p><i>It was recognized that the limited data available from uncontrolled burning of waste with salt UPOPS emissions is high.</i></p> <p>Comment: It may be useful to review the Basel ESM Guidelines for Used Oil and related documents. In his presentation, Giovanna (2002) provides a good overview of the occurrence and fate of used oil in Europe as well as technologies for re-use, etc. He noted, for example, that 40 percent of lubricant oils sold in Europe are, after use, dumped or otherwise unaccounted for.^{xii} Another potentially useful document is the “Toxicological profile for used mineral-based crankcase oil,” by the Agency for Toxic Substances and Disease Registry.^{xiii}</p>
6	<p><u>4.2 Guideline for Selecting BAT</u></p> <p>Comment: This section addresses energy generation which should be placed in another category.</p> <p>Suggestion: Delete this section from the open burning guidelines and incorporate in the guidelines for energy production.</p>

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- ⁱ Thuss, U., Popp, P., 1995. Domestic lignite combustion as source of polychlorodibenzodioxins and -furans (PCDD/F). *Chemosphere* 31: 2591- 2604.
- ⁱⁱ Gullett, B., Wikstrom, E., 2000. Mono- to tri-chlorinated dibenzodioxin (CDD) and dibenzofuran (CDF) congeners/homologues as indicators of CDD and CDF emissions from municipal waste and waste/coal combustion.
- ⁱⁱⁱ Lemieux, P., Lutes, C., Abbott, J., Aldous, K., 2000. Emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans from the open burning of household waste in barrels. *Environ. Sci. Technol.* 34:377-384.
- ^{iv} Gullett, B., Lemieux, P., Winterrowd, C., Winter, D., 2000. PCDD/F emissions from uncontrolled, domestic waste burning. *Organohalogen Cpd.* 46:193-196.
- ^v Ohta, M., Oshima, S., Iwasa, T., Osawa, N., Kumatoriya, K., Yamazaki, A., Takasuga, T., Matsushita, M., Umedzu, N., 2001. Formation of PCDDs and PCDFs during the combustion of polyvinylidene chloride. *Chemosphere* 44: 1389-1394..
- ^{vi} Katsura, T., Sasaki, H., 2001. On-going solutions to environmental issues in plastic packaging. *Packag. Technol. Sci.* 14: 87-95
- ^{vii} UNEP, undated. International Source Book on Environmentally Sound Technologies. <http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/index.asp>
- ^{viii} Mersiowsky, I., Stegmann, R., Ejlertsson, J., Svensson, B., 1999. Long-term behaviour of PVC products under soil-buried and landfill conditions: Final report of the research project. Hamburg: Technische Universität.
- ^{ix} Danish Ministry of Environment, 1999. PVC Strategy: Status Report and Future Initiatives. Copenhagen, Denmark.
- ^x UNEP, undated. International Source Book on Environmentally Sound Technologies. <http://www.unep.or.jp/ietc/ESTdir/Pub/MSW/index.asp>
- ^{xi} Johannessen, L., Boyer, G., 1999. Observations of Solid Waste Landfills in Developing Countries: Africa, Asia, and Latin America. Washington, D.C.: The World Bank.
- ^{xii} Giovanna, F., 2002. Used Oil Technologies: Perspectives and Problems. Presented at Perspectives on Cleaner Technologies for Sustainable Chemistry, Expert Group Meeting, Trieste, Italy, 29-30 April 2002.
- ^{xiii} Agency for Toxic Substances and Disease Registry (ATSDR). 1997. Toxicological profile for used mineral-based crankcase oil. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. <http://www.atsdr.cdc.gov/>