

# **Update of Dioxin Emission Factors for Forest Fires, Grassland and Moor Fires, Open Burning of Agricultural Residues, Open Burning of Domestic Waste, Landfills and Dump Fires**

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## **Introduction**

This briefing paper presents dioxin emission factors that have appeared in the scientific literature since the release in 2005 of the IPEN report, "Estimating Releases and Prioritizing Sources in the Context of the Stockholm Convention: Dioxin Emission Factors for Forest Fires, Grassland and Moor Fires, Open Burning of Agricultural Residues, Open Burning of Domestic Waste, Landfills and Dump Fires." <sup>1</sup>

These new studies are briefly described below and, where appropriate, their emission factors are shown alongside those previously presented in the 2005 IPEN report, including emission factors proffered in the UNEP Dioxin Toolkit.

## **1.0 Forest Fires, Grassland and Moor Fires**

### **1.1 French Study**

In France, Collet and Fiani (2006) collected four sets of samples of litter, moss, heather, brackens, conifer needles, pine cones, shrubs, bark, and small diameter pine and oak branches from forest sites in the southwest, 10 and 50 kilometers from the coast, and in the southeast, near to and 50 kilometers from the coast. These four samples were burned in a large, circular metal bowl inside a combustion chamber. A fifth test burn was carried out on samples from the southeast, 50 kilometers from the coast, after they had been sprayed with salt water and then dried.

For the five test burns, concentrations of dioxins in air ranged from 2.76 to 68.2 pg I-TEQ/m<sup>3</sup>, with an average of 29.4 pg I-TEQ/m<sup>3</sup>. Four field blanks showed dioxin concentrations ranging from 4.79 to 147.9 pg I-TEQ/m<sup>3</sup>, with an average of 45.7 pg I-TEQ/m<sup>3</sup>. The authors of this study derived emission factors ranging from 1.02 to 25.9 ng I-TEQ/kg, with an average of 10.5 ng I-TEQ/kg. <sup>2</sup> However, since the average dioxin concentration of the field blanks was higher than that for the test burns, it is necessary to extend and/or repeat this work in order to derive useful emission factors.

### **1.2**

## **Open Burning of Domestic Waste**

Domestic waste is burned in open piles, barrels, fireplaces, household stoves, and primitive incinerators, even in the wealthiest, most technologically-advanced countries.

### **1.1 Belgian Study**

Wevers et al. (2004) burned household waste and yard waste (trimmings and fallen leaves) in a galvanized steel drum, an oil barrel and open piles. The household waste consisted of the “combustible fraction, a mixture of plastics, beverage cartons, paper and cardboard” sorted from the waste collected by 15 families during one month. The composition of this waste was “considered to be representative for backyard waste burning but lower in water, organic and inert material than municipal waste.” Based on their experiments, Wevers et al. (2004) reported the following air emission factors: <sup>3</sup>

- 4.7 – 20 ng TEQ/kg for garden waste in galvanized drums;
- 4.4 ng TEQ/kg for garden waste in an open pile; and
- 35 ng TEQ/kg for household waste in a steel oil barrel.

The higher air emission factor, 20 ng TEQ/kg, for garden waste burned in a galvanized drum was attributed to poorer combustion due to restricted air flow into the drum. The dioxin content of the ashes was not determined for any of the experiments.

Using wood stoves for household heating, Wevers et al. (2003) reported mean air emission factors of 24.4 ng TEQ/kg and 350 ng TEQ/kg when burning the combustible portion of household waste with untreated and treated wood, respectively. <sup>4</sup>

## **1.2 Japanese Studies**

Ikeguchi and Tanaka (2000) burned various household waste components in small metal “home incinerators” that appear to be no more complex than barrels with air vents and a large chimney. Among the air emission factors that were derived are the following: <sup>5</sup>

- 5-140 ng TEQ/kg for garden waste;
- 400-420 ng TEQ/kg for newspaper;
- 6-420 ng TEQ/kg for corrugated paper;
- 1,670-11,500 ng TEQ/kg for corrugated paper plus 5 percent PVC;
- 4,000-17,000 ng TEQ/kg for corrugated paper plus 10 percent PVC;
- 6,100-28,000 ng TEQ/kg for corrugated paper plus 20 percent PVC;
- 40 ng TEQ/kg for corrugated paper plus 5 percent polystyrene;
- 3-30 ng TEQ/kg for corrugated paper plus 10 percent polystyrene;
- 10 ng TEQ/kg for corrugated paper plus 10 percent polyethylene; and
- 3-40 ng TEQ/kg for corrugated paper plus 20 percent polyethylene.

In this study, chlorine was added to the materials burned in the form of PVC and as sodium chloride. Air emissions of dioxins were found to increase with higher chlorine levels in the materials combusted.

Nakao et al. (2005) burned a variety of materials – paper, leaves, natural wood, building materials, fiber, non-chlorine-containing plastics, chlorine-containing plastics, and copper electric wire – in a small, uncontrolled metal incinerator. No emission factors were derived. However, they found that including non-chlorine-containing plastics had no impact on dioxin releases but the addition of chlorine-containing plastics increased dioxin concentrations in flue gas and residual ash by some 60-fold, expressed as TEQ. With the further inclusion of copper wire, dioxin flue gas concentrations increased 570-fold and residual ash concentrations, more than 2,000-fold. <sup>6</sup>

### 1.3 Korean Study

In an open-burning simulation facility, Moon et al. (2006) burned household waste in a steel barrel. The waste was comprised of 85 percent paper, 10 percent plastics and 5 percent other materials (wood, rubber, garbage, etc.). Emission factors for releases to air of dioxins ranged from 5.89 to 8.56 ng W-TEQ/kg, with an average of 7.34 ng W-TEQ/kg, for the three experimental test burns. Emission factors for releases in residues were not reported.<sup>7</sup>

### 1.4 Swedish Study

Hedman et al. (2005) burned garden waste and refuse derived fuel in open steel barrels and on a steel plate. The refuse derived fuel was described as “*municipal waste where the combustible fractions (e.g. paper, textile and soft plastics) had been mechanically sorted out from noncombustible waste and decomposable material at a waste sorting plant.*” Their findings suggest that “*general [air] emission factors for PCDF and PCB may be in the range ... of 4-72 ng/kg, with a median value of 20 ng/kg (WHO-TEQ).*”

They also found that dioxin levels in ash “*were usually less than 5% of the total*” dioxin releases. More specifically, these researchers reported dioxin emission factors of 16-18 ng W-TEQ/kg for releases to air and 0.3 ng W-TEQ/kg for releases to residues when burning a mixture of refuse derived fuel and garden waste.<sup>8</sup> The refuse derived fuel had a chlorine content ranging from 0.13 to 0.52 percent, with almost 75 percent of the chlorine attributed to the plastic fraction of the waste, which was known to contain PVC.<sup>9</sup>

### 1.5 U.S. Studies

In the first of a series of experiments, Lemieux (1997) burned simulated household waste<sup>a</sup> in steel barrels in an enclosed testing facility. The average air emission factors derived for waste with PVC content of 0.2 and 4.5 percent were 140 ng TEQ/kg and 2,654 ng TEQ/kg, respectively.<sup>10</sup> Based on the data from this study, the U.S. Environmental Protection Agency used an air emission factor of 140 ng TEQ/kg in the U.S. dioxin inventory in 1998.<sup>11</sup>

In a follow-on study at the same facility, Gullett et al. (1999; 2001) derived the following air emission factors when burning simulated household waste in a steel barrel:<sup>12, 13</sup>

- 14 ng TEQ/kg with no PVC;
- 79 ng TEQ/kg with 0.2 percent PVC;
- 201 ng TEQ/kg with 1 percent PVC;
- 4,916 ng TEQ/kg with 7.5 percent PVC; and
- 734 ng TEQ/kg with no PVC but with the addition of chlorine, as calcium chloride, in a quantity equivalent to that present with 7.5 percent PVC.

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<sup>a</sup> The wastes are described as “*a reasonable representation of a waste stream ... according to the typical percentages of various materials characterized and quantified for New York State residents.*” It consisted of various kinds of paper products, plastic resins, food waste, textile/leather, wood, glass/ceramics, iron and aluminum cans, as well as wire, copper pipe and batteries (see Lemieux, 1997). This same general composition was used in all of the U.S. studies described here.

Drawing on the results of earlier experiments at this facility and with additional variables including copper content, moisture levels and further combustion conditions, Gullett et al. (2000) reported air emission factors ranging from 1.7 to 6,433 ng TEQ/kg. They also found lower dioxin releases in one experiment in which wastes were burned in an open pile rather than a steel barrel.<sup>14</sup>

In a related study, Lemieux et al. (2000) burned simulated household waste containing 0.2 percent PVC and 4.5 percent PVC in a steel barrel in the enclosed testing facility and reported air emission factors of, respectively, 759 to 903 ng TEQ/kg and 1,230 to 5,400 ng TEQ/kg.<sup>15</sup> However, these values were apparently erroneously reported, given the wide disparities between these and air emission factors presented in closely related studies, including a later review paper by the same author.

In the most recent description of these and additional results from this series of experiments, Lemieux et al. (2003) reported an average air emission factor of 76.8 ng W-TEQ/kg for household waste containing 0.2 percent PVC.<sup>23</sup> This air emission factor is used in the most recent U.S. dioxin inventory.<sup>16</sup> Lemieux et al. (2003) also reported a somewhat lower air emission factor, 61 ng TEQ/kg, when household waste was burned in an open pile on a steel grate rather than in a steel barrel. In addition, they concluded, *“At moderate levels of [chlorine], a statistically significant effect of waste [chlorine] concentration is not observed, because other more important variables have a much greater influence on the emissions of [dioxins].”*<sup>23</sup> However, in a detailed reanalysis of these same data, Neurath (2004) found that chlorine content and, especially PVC content, are the most important predictors of dioxin emissions from the open burning of domestic waste.<sup>17</sup>

### **1.6 UNEP Dioxin Toolkit**

All three versions of the Toolkit give an air emission factor of 300 ng TEQ/kg for uncontrolled burning of domestic waste – burning such wastes in open piles, in barrels, and in home fires – *“where a wide range of wastes including items such as household hazardous wastes and chemicals may be burned.”*<sup>18, 19, 20</sup> The studies cited as the basis for this emission factor are described in Section 1.5 above: two studies by scientists with the U.S. Environmental Protection Agency -- Lemieux (1997)<sup>21</sup> and Gullett et al. (1999)<sup>22</sup> – as well as a review by Lemieux et al. (2003).<sup>23</sup>

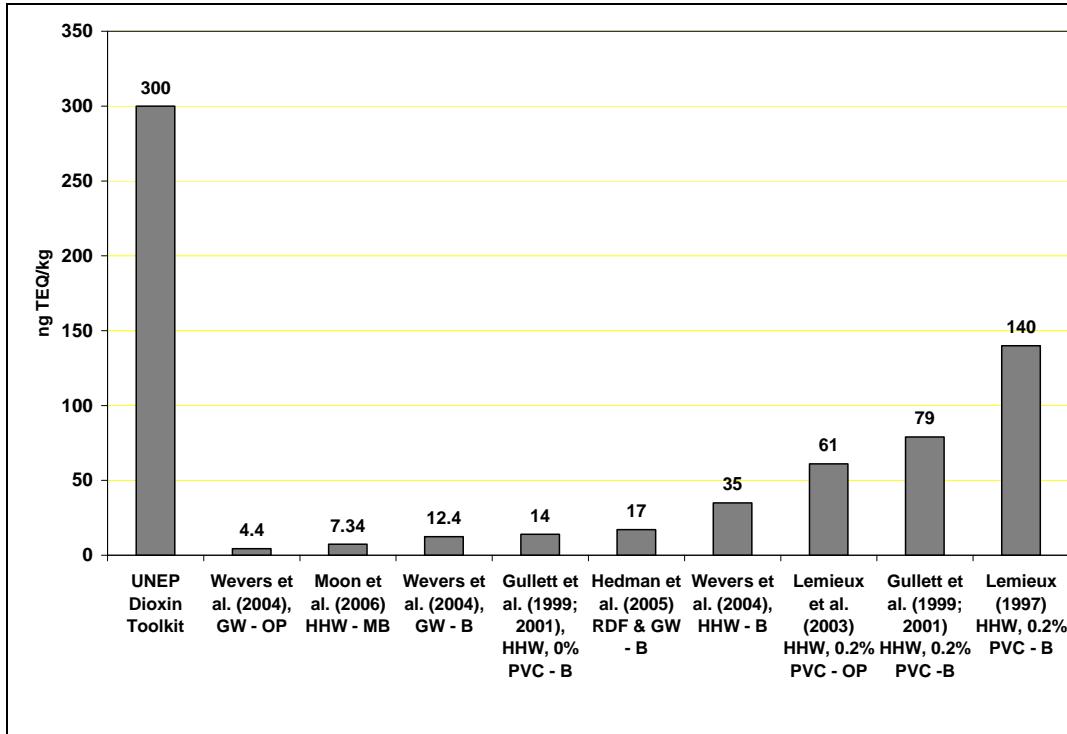
The Toolkit’s emission factor for releases to residues, 600 ng TEQ/kg, is attributed to the study by Lemieux et al. (1997).

### **1.7 Summary -- Burning Domestic Waste in Steel Barrels, Metal Bowls and Open Piles**

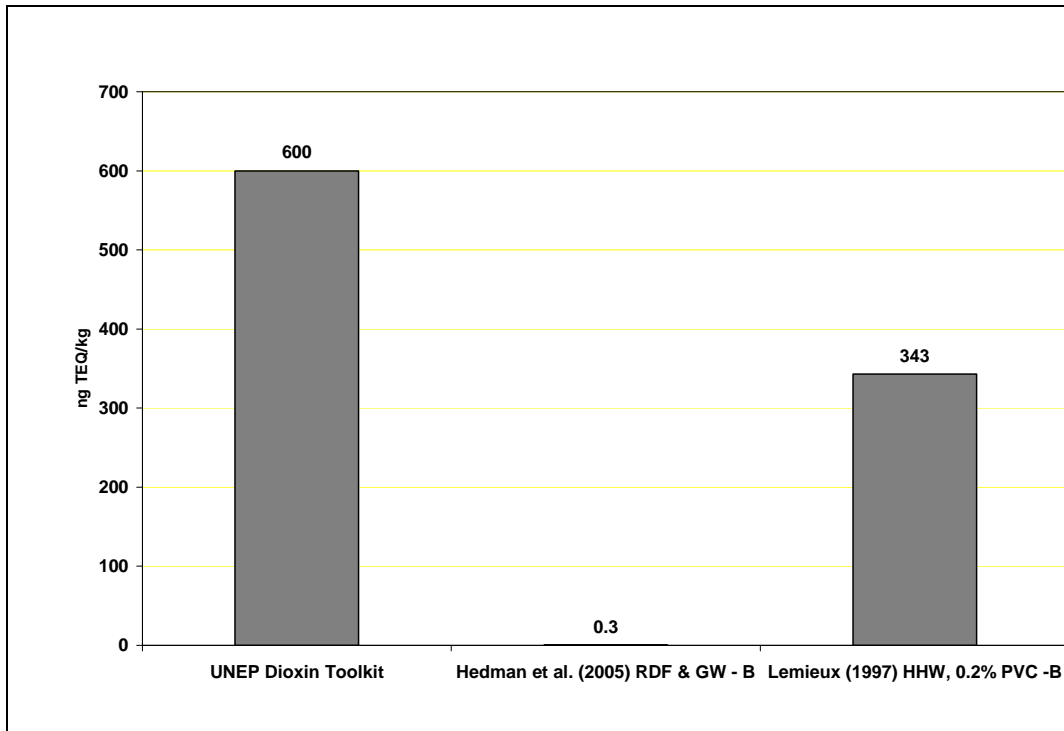
As shown below in Figure 1, the Toolkit’s emission factor for dioxin releases to air during open burning of domestic waste is markedly higher than the emission factors reported for ordinary domestic waste in other published studies, including those cited as its basis.

As shown in Figure 2, the Toolkit emission factor for releases to residues during open burning of ordinary domestic waste is also higher than that reported in the study to which it is attributed, Lemieux et al. (1997). Further it is far higher than the emission factor

reported by Hedman et al. (2005) when the combustible portion of Swedish domestic waste was burned.<sup>24</sup>



**Figure 1: Burning Domestic Waste in Steel Barrels and Open Piles – Emission Factors for Releases to Air (GW = garden waste; HHW = household waste; RDF = refused derived fuel; OP = open pile; B = barrel; MB = metal bowl)**



**Figure 2: Burning Domestic Waste in Steel Barrels and Open Piles – Emission Factors for Releases to Residues (GW = garden waste; HHW = household waste; RDF = refuse derived fuel; OP = open pile; B = barrel)**

The composition of domestic waste and combustion conditions determine the extent of dioxin formation. Because these determinants vary over broad ranges, there are no universally applicable emission factors for dioxin releases to air, land or residues for open burning of domestic waste.

To estimate dioxin releases from open burning of domestic waste, Parties must be familiar with the waste compositions and combustion conditions that prevail in their individual countries and choose emission factors that were derived with wastes and conditions most similar to their own.

**Table 1: Open Burning of Domestic Waste -- Dioxin emission factors for releases to air according to combustion conditions, general waste composition, and PVC content**

General waste composition	Combustion conditions	PVC content					
		0 %	0.2 % or less	1 %	4.5%	7.5%	Not given
Unsorted domestic waste, including glass, cans, food, etc.	Open pile		61 <sup>25</sup>				
	Metal container (steel barrel, etc.)	14 <sup>26,27</sup>	79-140 <sup>28,29,30</sup>	201 <sup>31,32,33</sup>	2,654 <sup>34</sup>	4,916 <sup>35,36</sup>	
Combustible portion of	Open pile						

<b>domestic waste</b>	<b>Metal container (steel barrel, etc.)</b>						<b>35</b> <sup>37 b</sup>
							<b>7.3</b> <sup>38</sup>
<b>Combustible portion of domestic waste and garden waste</b>	<b>Open pile</b>						
	<b>Metal container (steel barrel, etc.)</b>						<b>17</b> <sup>39 c</sup>
<b>Garden waste</b>	<b>Open pile</b>	<b>4.4</b> <sup>40</sup>					
	<b>Metal container (steel barrel, etc.)</b>	<b>12.4</b> <sup>41</sup>					

As made apparent by the scarcity of data in Table 1, there is great need for more study of open burning of domestic waste. Nonetheless, Table 1 provides insight into the selection of the most appropriate emission factors for a given circumstance. For example, is domestic waste most commonly burned in barrels or in open piles? Is the waste sorted or unsorted? Is it burned together with yard or garden waste?

- Open pile or metal container (steel barrel, etc.): In two studies, emission factors were higher when waste was burned in barrels rather than open piles. This is not surprising since iron, the primary constituent in steel barrels and most other metal containers that might be used for waste burning, was found to be “a strong promoter for PCDD/F [dioxin] formation” by Halonen et al. (1997).<sup>42</sup> Iron in the metal grates and plates used as combustion platforms in open burning experiments may be promoting dioxin formation.
- Domestic waste – sorted or unsorted: Unsorted waste burned in the U.S. studies included not only combustibles but also glass/ceramic materials, food wastes, steel and aluminum cans. As noted in the Belgian and Swedish studies, burning such waste is not a common practice in those countries, or, in all likelihood, in most countries. Consequently, the emission factors from the U.S. studies may be more useful as indicators of the effects of variables, such as PVC content, than as factors for general use in estimating releases.
- Domestic waste or a mixture of domestic and yard waste: The combustible portion of domestic waste is commonly burned together with garden and yard waste. Reduced dioxin formation through such “co-firing” is supported by the findings of 1) relatively low emission factors in the Belgian and Swedish studies in which domestic and yard wastes were burned together and 2) considerably higher emission factors in the U.S. studies in which only unsorted domestic waste was burned.

<sup>b</sup> “The household waste was collected by 15 families during one month. Mainly the combustible fraction, a mixture of plastics, beverage cartons, paper and cardboard was used. This composition is considered to be representative for backyard waste burning but lower in water, organic and inert material than municipal waste.”

<sup>c</sup> “The refuse-derived fuel (RDF) consisted of municipal waste where the combustible fractions (e.g. paper, textile and soft plastics) had been mechanically sorted out from noncombustible waste and decomposable material at a waste sorting plant.”

At present, the emission factors from the Korean study – 7.3 ng TEQ/kg for air releases – and the Swedish study – 17 ng TEQ/kg for air releases and 0.3 ng TEQ/kg for releases to residues -- appear to be the most appropriate when, as is the common practice, the combustible portion of domestic waste is burned.

## **2.0 Landfill and Dump Fires**

Fires at landfills and dumps are common occurrences, even in the wealthiest regions of the world. For example, the most recent European Dioxin Inventory notes as follows: <sup>43</sup>

*“It is well known that in some European countries still illegal and uncontrolled dump sites for municipal solid waste exist. Such dumping sites frequently are set to fire either by autoignition or intentionally in order to increase their capacity.”*

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## **2.2 Asian Studies**

Minh et al. (2003) examined soils from open dumps in the Philippines, Cambodia, India, and Vietnam, where open burning was observed, and found dioxin levels in soils that were, in some cases, hundreds of times higher than soils from control sites. <sup>44</sup> In a related study at some of these sites, Hirai et al. (2003) determined that the emission factor for total releases (air and land) must be greater than 400 ng TEQ/kg to explain dioxin levels in soil samples at the Indian dump and greater than 4,000 ng TEQ/kg at the Cambodian dump. <sup>45</sup>

## **2.3 French Study**

Collet and Fiani (2006) burned two samples taken from landfills in a metal bowl filled with soil or sand and placed within an enclosed chamber. They derived an emission factor for release to air of 242 ng I-TEQ/kg with the sample composed of 70.5 percent non-hazardous industrial waste and 29.5 percent municipal solid waste and an air emission factor of 233 ng I-TEQ/kg with the other sample which consisted of 33.5 percent non-hazardous industrial waste and 66.5 percent municipal solid waste. <sup>46</sup>

## **2.4 Japanese Study**

In a landfill fire simulation, Hirai et al. (2005) burned refuse derived fuel (RDF) in a steel bowl filled with soil. The RDF was comprised of paper and textiles, 51.8 percent; plastics and leather, 32 percent; wood and grass, 5.3 percent; garbage, 9.5 percent; non-combustibles, 0.4 percent; and others, 1 percent. They reported emission factors for releases to air of 23-46 ng TEQ/kg and for releases to residues, 120-170 ng TEQ/kg, with 70-90 percent of the dioxins partitioned to the residues. <sup>47</sup>

## **2.5 Swiss Study**

In the discussion of landfill fires in the European Dioxin Inventory, Quass et al. (2000) described a study in Switzerland that reported an air emission factor of 450 ng TEQ/kg for landfill fires based on a dioxin concentration of 15 µg TEQ/kg in the filter dust of a municipal solid waste incinerator and a dust release rate of 30 kg dust/t waste. <sup>48</sup>



## **2.6 UNEP Dioxin Toolkit**

All versions of the Toolkit present an air emission factor of 1,000 ng TEQ/kg for landfill and dump fires. This value is said to be based on Swedish work as reported by the U.S. Environmental Protection Agency.<sup>49, 50, 51</sup> Although the original Swedish study by Persson and Bergstrom (1991)<sup>52</sup> was not readily available, the results of this study have been described as follows:

- According to the U.S. Environmental Protection Agency, the study reported an average emission rate of 1,000 ng Nordic TEQ/kg of waste burned.<sup>53</sup>
- According to the European Dioxin Inventory, the Swedish researchers carried out simulation experiments in which dioxin concentrations in the combustion gas ranged from 66 to 518 ng N-TEQ/m<sup>3</sup>. At a specific flue gas volume of 1700 m<sup>3</sup>/t, an air emission factor of about 100 – 900 ng TEQ/kg can be derived.<sup>54</sup>
- According to the landfill review by Bates (2004), the Swedish study estimated dioxin releases of 0.07 g TEQ per surface fire and 0.35 g TEQ per deep fire.<sup>55</sup>

## **2.7 Summary -- Landfill and Dump Fires**

Emission factors for fires at landfills and open dumps cover very broad ranges which depend on many, highly variable factors. As with open burning of domestic wastes, there are no universally applicable emission factors. However, the recent study by Hirai et al. (2005) presents what appears to be the most rigorous derivation of emission factors: 23-46 ng TEQ/kg for releases to air and 120-170 ng TEQ/kg for releases to residues.<sup>56</sup>

## **3.0 Findings and Recommendations**

Based on the studies considered in this report, the emission factors shown below in Table 2 appear currently to have the strongest scientific support and, as such, are most appropriate for preparing release estimates in dioxin inventories.

Emission factors for forest fires, grassland and moor fires and for open burning of agricultural residues have relatively low values and narrow ranges. For forest fires, grassland and moor fires, the most appropriate emission factors are those based on measurements taken during actual fires, 0.5 ng TEQ/kg for releases to air and 0.05 ng TEQ/kg for releases to land. Similarly, the appropriate factors for open burning of agricultural residues are 0.8 ng TEQ/kg for releases to air and 0.05 ng TEQ/kg for releases to land.

Emission factors for open burning of domestic waste vary by more than a thousand-fold, as shown in Table 2. For this source category, 17 ng TEQ/kg for releases to air and 0.3 ng TEQ/kg for releases to land are, at present, the most appropriate emission factors for open burning of domestic waste when the common practice is to burn the combustible portion of domestic waste with an ordinary PVC content (~0.2 percent) together with yard and garden waste.

Studies that have derived emission factors for landfill/open dump fires are very limited. However, where the composition of the waste burned is similar to that studied by Hirai et

al. (2005),<sup>57</sup> the means of the emission factors derived in their study can be regarded as appropriate – 34.5 ng TEQ/kg for releases to air and 145 ng TEQ/kg for releases to land.

**Table 2: Dioxin Emission Factors with Strongest Scientific Support to Date**

	<b>Emission factor for releases to air</b>	<b>Emission factor for releases to land</b>	<b>Emission factor for releases to residues</b>
ng TEQ/kg			
<b>Forest fires, grassland and moor fires</b>	0.125-0.5	0.02-0.05	
<b>Agricultural residues, open burning</b>	0.5-0.8	0.02-0.05	
<b>Domestic waste, open burning</b>			
No PVC content, 0%	4.4-14		0.3
Moderate PVC content, 0.2% or less	17-79		0.3-343
High PVC content, 1.0 - 7.5%	200-5,000		343-892
<b>Landfill/open dump fires</b>	23-46		120-170

<sup>1</sup> Costner, P., 2005. Estimating Releases and Prioritizing Sources in the Context of the Stockholm Convention: Dioxin Emission Factors for Forest Fires, Grassland and Moor Fires, Open Burning of Agricultural Residues, Open Burning of Domestic Waste, Landfills and Dump Fires. International POPs Elimination Network, Mexico, December 2005.

<sup>2</sup> Collet, S., Fiani, E., 2006. PAH, PCB and PCDD/F emissions from simulated forest and landfill fires. Presented at Dioxin 2006, 21-25 August 2006, Oslo, Norway.

<sup>3</sup> Wevers, M., De Fre, R., Desmedt, M., 2004. Effect of backyard burning on dioxin deposition and air concentrations. Chemosphere 54: 1351-1356.

<sup>4</sup> Wevers, M., De Fre, R., Vanermen, G., 2003. PCDD/F and PAH emissions from domestic heating appliances with solid fuel. Organohalogen Cpds. 63: 21-24.

<sup>5</sup> Ikeguchi, T., Tanaka, M., 2000. Dioxins emission from an open-burning-like waste incineration: Small incinerators for household use. Organohalogen Cpds. 46: 298-301.

<sup>6</sup> Nakao, T., Aozasa, O., Ohta, S., Miyata, H., 2005. Formation of toxic chemicals including dioxin-related compounds by combustion from a small home waste incinerator. Chemosphere. In Press.

<sup>7</sup> Moon, D., Hwang, T., Park, K., Jung, E., Jang, T., Oh, J., Yoon, S., Joo, C., Kim, Y., 2006. Estimation of emission factors for PCDD/Fs and co-PCBs emitted from uncontrolled incineration of waste wood (construction/demolition) and domestic waste. Presented at Dioxin 2006, 21-25 August 2006, Oslo, Norway.

<sup>8</sup> Hedman, B., Naslund, M., Nilsson, C., Marklund, S., 2005. Emissions of polychlorinated dibenzodioxins and dibenzofurans and polychlorinated biphenyls from uncontrolled burning of garden and domestic waste (backyard burning). Environ. Sci. Technol. 39:790-8796..

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- <sup>9</sup> Hedman, B., 2005. Dioxin Emissions from Small-Scale Combustion of Bio-Fuel and Household Waste. Department of Chemistry, Environmental Chemistry, Umea University, Umea Sweden.
- <sup>10</sup> Lemieux, P., 1997. Evaluation of emissions from the open burning of household waste in barrels. ResearchTriangle Park, NC: U.S. Environmental Protection Agency, National Risk Management Research Laboratory. EPA-600/R-97-134a.
- <sup>11</sup> U.S. Environmental Protection Agency, 1998. The Inventory of Sources of Dioxin in the United States. Review Draft. EPA/600/P-98/002Aa. Washington, D.C.
- <sup>12</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 1999. PCDD/F emissions from uncontrolled, domestic waste burning. *Organohalogen Compounds* 41:27-30.
- <sup>13</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 2001. Emissions of PCDD/F from uncontrolled, domestic waste burning. *Chemosphere* 43: 721-725.
- <sup>14</sup> Gullett, B., Lemieux, P., Winterrowd, C., Winters, D., 2000. PCDD/F emissions from uncontrolled, domestic waste burning. Presented at Dioxin '00, 20th International Symposium on Halogenated and Environmental Organic Pollutants & POPs, held Aug 13-17 at Monterey, CA. Corrected revision of short paper in *Organohalogen Compounds* 46:193-196.
- <sup>15</sup> Lemieux, P., Lutes, C., Abbot, J., Aldous, K., 2000. Emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans from the open burning of household wastes in barrels. *Environ.Sci. Technol.* 34: 377-384.
- <sup>16</sup> U.S. Environmental Protection Agency, 2005. The Inventory of Sources and Environmental Releases of Dioxin-Like Compounds in the United States. The Year 2000 Update. EPA/600/P-03/002A. External Review Draft, Washington, D.C.
- <sup>17</sup> Neurath, C., 2004. PVC's role in dioxin emissions from open burning: New analysis of US EPA data. *Organohalogen Cpds.* 66: 1146-1152.
- <sup>18</sup> UNEP Chemicals, 2001. Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases. Draft. January 2001, Geneva.
- <sup>19</sup> UNEP Chemicals, 2003. Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases. First Edition. May 2003, Geneva.
- <sup>20</sup> UNEP Chemicals, 2005. Standardized Toolkit for Identification and Quantification of Dioxin and Furan Releases. Second Edition. February 2005, Geneva.
- <sup>21</sup> Lemieux, P., 1997. Evaluation of emissions from the open burning of household waste in barrels. ResearchTriangle Park, NC: U.S. Environmental Protection Agency, National Risk Management Research Laboratory. EPA-600/R-97-134a.
- <sup>22</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 1999. PCDD/F emissions from uncontrolled, domestic waste burning. *Organohalogen Compounds* 41:27-30.
- <sup>23</sup> Lemieux, P., Gullett, B., Lutes, C., Winterrowd, C., Winters, D., 2003. Variables affecting emissions of PCDD/Fs from uncontrolled combustion of household waste in barrels. *J. Air & Waste Manage. Assoc.* 53: 523-531.
- <sup>24</sup> Hedman, B., Naslund, M., Nilsson, C., Marklund, S., 2005. Emissions of polychlorinated dibenzodioxins and dibenzofurans and polychlorinated biphenyls from uncontrolled burning of garden and domestic waste (backyard burning). *Environ. Sci. Technol.* 39:790-8796..
- <sup>25</sup> Lemieux, P., Gullett, B., Lutes, C., Winterrowd, C., Winters, D., 2003. Variables affecting emissions of PCDD/Fs from uncontrolled combustion of household waste in barrels. *J. Air & Waste Manage. Assoc.* 53: 523-531.
- <sup>26</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 1999. PCDD/F emissions from uncontrolled, domestic waste burning. *Organohalogen Compounds* 41:27-30.
- <sup>27</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 2001. Emissions of PCDD/F from uncontrolled, domestic waste burning. *Chemosphere* 43: 721-725.
- <sup>28</sup> Lemieux, P., 1997. Evaluation of emissions from the open burning of household waste in barrels. ResearchTriangle Park, NC: U.S. Environmental Protection Agency, National Risk Management Research Laboratory. EPA-600/R-97-134a.
- <sup>29</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 1999. PCDD/F emissions from uncontrolled, domestic waste burning. *Organohalogen Compounds* 41:27-30.
- <sup>30</sup> Gullett, B., Lemieux, P., Lutes, C., Winterrowd, C., Winters, D., 2001. Emissions of PCDD/F from uncontrolled, domestic waste burning. *Chemosphere* 43: 721-725.

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