# Using HAP Emissions Data to Evaluate Maximum Achievable Control Technology Standards

Regi Oommen and Darcy Wilson
Eastern Research Group, Inc. (ERG, Inc.), 1600 Perimeter Park Drive, Morrisville, NC 27560
regi.oommen@erg.com

Anne Pope
U.S. Environmental Protection Agency, USEPA Mailroom, Mail Code: C304-06, Research Triangle Park, NC 27711
pope.anne@epa.gov

## ABSTRACT

Acute and chronic exposure to specific hazardous air pollutants (HAPs) can lead to cancer and/or noncancer effects. Since the passage of the 1990 Clean Air Act Amendments (CAAA), the U.S. Environmental Protection Agency (EPA) has spent considerable time and resources establishing federal regulations, primarily through maximum achievable control technology (MACT) standards, to reduce emissions for hazardous air pollutants (HAPs) from stationary sources. Identification of the most important individual emission sources and source categories significantly contributing to potential health risks is challenging for many air quality managers. Large reductions in HAP emissions may not necessarily translate into significant reductions in health risk because toxicity varies by pollutant. For example, acetaldehyde mass emissions are more than double acrolein emissions on a national basis, according to EPA's 2002 National Emissions Inventory (NEI). However, according to the Integrated Risk Information System (IRIS), acrolein is 450 times more toxic in terms of respiratory noncancer risk than acetaldehyde. Thus, it is important to account for the toxicity as well as the mass of the targeted emissions when designing reduction strategies to maximize health benefits.

This paper uses the 2002 and 2005 NEI point source data to explore a toxicity-weighting approach for identifying pollutants that pose the greatest potential health risk. In addition, the results of this toxicity weighted emissions approach are summarized by MACT standard.

## INTRODUCTION

Acute and chronic exposure to specific hazardous air pollutants (HAPs) can lead to cancer and/or noncancer effects. Since the passage of the 1990 Clean Air Act Amendments (CAAA),[1] EPA has spent considerable time and resources establishing federal regulations, primarily through maximum achievable control technology (MACT) standards, to reduce emissions for HAPs. Atmospheric models, such as those executed for the National Air Toxics Assessment (NATA), are often used to characterize the nation's air toxics problem both in absolute as well as relative senses by geographic area and pollutant. In addition, ambient monitoring data can help identify pollutants and specific emission sources impacting an area's air quality, and track changes or identify trends in ambient concentrations.

HAP modeling may not be feasible for many state, local, and tribal agencies to perform due to time, resource, and expertise constraints. Additionally, due to the complexity and time required to develop national emissions inventories and subsequently model the entire U.S., NATA results are often available years after the actual time of the emissions (e.g., NATA 1999 was not publicly available until 2006). An alternative approach may help air quality managers screen for pollutants that may contribute most significantly to health risks in their area by toxicity-weighting their emissions inventory using an analytic method developed by EPA.[2] This paper demonstrates the approach for the toxicity-weighting process, as well as preliminarily evaluating the effectiveness of MACT standards implemented between the 2002 and 2005 NEIs.

## DATA SOURCES

### National Emissions Inventory (NEI)

EPA compiles the NEI, consisting of stationary (point and nonpoint area), mobile (onroad and nonroad), and biogenic source emissions for the entire United States.[3] These emission inventories are typically compiled for three years. Primary data sources for the point sources NEI include:

1) State, local, and tribal agency emission inventories;
2) EPA's SPPD and Risk Technology and Review (RTR) Programs;
3) Department of Energy's (DOE) Energy Information Agency (EIA) and EPA's Clean Air Markets Division (CAMD) Emission Tracking System/Continuous Emissions Monitoring (ETS/CEM) data for electric generating utilities (EGUs);
4) EPA's Toxic Release Inventory (TRI); and
5) data from other studies (e.g., trade associations, Minerals Management Services oil and natural gas platform data).

Pollutants in the NEI consist of HAPs and criteria air pollutants (CAPs) and their precursors (CO, $NH_3$, $NO_x$, PM, $SO_2$, and VOCs). Base year inventories are typically compiled every three years; Version 3 of the 2002 point sources NEI is publicly available.[4] At this time, Version 3 of the 2005 point sources NEI is currently being evaluated internally by EPA.[5] It is important to note that although most of the data in the NEI is submitted by state/local/tribal air agencies, it is by no means complete and may contain under- and over-reported emissions data.

### Maximum Achievable Control Technology (MACT) Data

Since the passage of the 1990 CAAA, EPA's Sector Policies and Programs Division (SPPD) has promulgated and implemented dozens of industry-specific MACT emission standards to reduce HAP emissions.[6] MACT standards are typically implemented 3 years after they are promulgated. During 2003 and 2004, nine MACT standards were implemented by SPPD, and they are presented in Table 1 with their MACT codes. One source category, Secondary Aluminum Production, was recently split into three MACT subcategory groups. Additionally, four source categories are also being evaluated under EPA's RTR Program, and they are also denoted in Table 1.

## METHODOLOGY

### Extracting NEI Data

The MACT codes of interest in Table 1 were applied to the 2005 NEI, and a total of 787 facilities were identified as being subject to the regulations of interest. Using this list, all of the HAP emissions data were extracted from both the 2005 and 2002 point sources NEI. From the original list of 787 facilities in the 2005 NEI, 682 were also in the 2002 NEI. Thus, all HAP emissions data were retrieved from the 2002 and 2005 NEIs for these 682 facilities.

Of the nine categories, Flexible Polyurethane Foam, Pesticides and Active Ingredients, Polymers and Resins III, Pulp and Paper, and Secondary Aluminum are part of the Risk and Technology Review (RTR) Phase II, Group 3. These categories have undergone extensive review by EPA industry experts and the assignment of MACT codes to emissions units and processes is likely more accurate in the NEI. Version 3 of the 2005 NEI uses RTR data for these categories.[7] Additionally the pulp and paper data has undergone public review as part of SPPD sector work. Some of the facilities in Polymers and

Resins III category contain emissions units subject other Polymer and Resins categories (I, II, and IV). In some facilities, it is difficult to assign emissions units to the correct Polymer and Resins category. Phase III RTR includes Boat Manufacturing, Nutritional Yeast Manufacturing, Primary Magnesium refining, and Solvent Extraction of Vegetable Oil categories will be initiated later this year.

**Toxicity-Weighted Emissions Approach**

The more toxic the pollutant, the more risk associated with its emissions in ambient air. However, a pollutant emitted in high quantities does not necessarily present a higher risk to human health than a pollutant emitted in very low quantities. The toxicity-weighted emissions approach for this study consisted of four basic steps:

1. Obtain HAP emissions data for point sources of interest.
2. Apply the mass extraction speciation profiles to extract metal and cyanide mass. This mass extraction step ensures that only the toxic portion of metal or cyanide compound group is considered for toxicity-weightings. Non-metals were multiplied by 1. The only exception is for two chromium species in which the trivalent and hexavalent species are not defined: chromium and chromium compounds.
3. Speciate chromium and chromium and compounds into hexavalent and trivalent chromium. For chromium and chromium compounds, it was important to separate trivalent chromium (non-toxic) vs. hexavalent chromium (toxic). To do this, apply the chromium speciation profile to extract the hexavalent chromium mass by industry group using MACT codes, standard industrial classification (SIC) codes, and/or source classification codes (SCCs).
4. Weight the emissions derived in Step 2 and 3 above by their toxicity.
    a. To weight by cancer toxicity, multiply the emissions of each pollutant by its cancer unit risk estimate (URE).[8] A URE is an upper bound estimate of an individual's probability of contracting cancer over a lifetime of exposure to a concentration of one microgram of the pollutant per cubic meter of air. Cancer toxicity can be summed together to calculate a cumulative cancer toxicity.
    b. To weight by noncancer toxicity, divide the emissions of each pollutant by its noncancer reference concentration (RfC).[8] A RfC is an estimate of a continuous inhalation exposure concentration to people (including sensitive subgroups) that is likely to be without risk of deleterious effects during a lifetime. Noncancer pollutants affect specific Target Systems (e.g., Respiratory, Neurological, and Respiratory) and pollutant noncancer toxicity can be summed together by Target System.

While the absolute magnitude of the pollutant-specific toxicity-weighted emissions is not meaningful, the relevant magnitude of toxicity-weighted emissions is useful in identifying the order of potential priority or pollutants of interest. For example, higher values suggest greater priority; however, even the highest values may not reflect potential cancer effects greater than a level of concern (1 in 1 million) or potential noncancer effects above levels of concern (e.g., HQ = 1).

Additionally, the comparison of the toxicity-weighted emissions between the two base years can preliminarily indicate the effectiveness of the implemented MACT standards. However, the real effectiveness of the MACT standards is best measured through NATA modeling and ambient monitoring data.

**RESULTS**

It is important to note that this study only examines emissions data for facilities and pollutants that were in both the 2002 and 2005 NEIs, and not total emissions from each of those facilities.

**Cancer-Causing Pollutants**

Table 2 presents the results of the cumulative cancer toxicity-weighted emissions by MACT source category. While emissions for four MACT Standards increased (range: 0.02% to 1,049%), emissions for three MACT Standards decreased (range: -8.6% to -44.1%). Emissions for two MACT standards did not change. The large increase in MACT emissions was for Solvent Extraction for Vegetable Oil (+1,049%), where one facility increased comparative emissions from 14.5 tpy to 166.8 tpy. Decreases in comparative emissions were realized for Pesticide Active Ingredient (-8.6%), Polymers and Resins III (-34.4%), and Secondary Aluminum Production (-44.1%).

Cumulative cancer toxicity increased for four MACT standards (range: <0.01% to 129.6%), while cumulative cancer toxicity decreased for three MACT standards (range: -5.8% to -18.5%). The MACT standards which decreased were: Pesticide Active Ingredient (-5.8%); Pulp and Paper Production (-16.5%); and Secondary Aluminum Production (-18.4%).

Some observations include:

- Polymers and Resins III emissions decreased by 34%, while cancer toxicity-weighted emissions increased by over 58%;
- Pulp and Paper emissions increased by 2%, while cancer toxicity-weighted emissions decreased by over 18%;
- Overall emissions of the cancer-causing pollutants increased by less than 2%; and
- Overall toxicity-weighted emissions of the cancer-causing pollutants decreased by over 16%.

**Noncancer-Causing Pollutants**

Table 3 presents the results of the cumulative noncancer toxicity-weighted emissions by MACT source category. Overall, emissions for five Target Systems increased (range: 9.9% to 33.1%), while emissions for nine Target Systems decreased (range: -3.6% to -46.9%). The following emissions observations were made for facilities subjected to the study MACTs:

- Secondary Aluminum Production: emissions decreased for 10 of 12 Target Systems;
- Pesticide Active Ingredient Production: emissions decreased for 9 of 14 Target Systems;
- Solvent Extraction for Vegetable Oil Production: emissions increased for 10 of 12 Target Systems;
- Boat Manufacturing: emissions increased for 10 of 11 Target Systems;
- Flexible Polyurethane Foam Fabrication: emissions increased for 7 of 8 Target Systems;
- Polymers and Resins III: emissions decreased for 7 of 11 Target Systems; and
- Pulp and Paper Production: emissions decreased for 8 of 14 Target Systems.

Overall, noncancer toxicity-weighted emissions for five Target Systems increased (range: 1.7% to 146.9%), while noncancer toxicity-weighted emissions decreased for nine Target Systems (range: -7.6% to -42.3%). The following toxicity-weighted noncancer observations were made for facilities subjected to the study MACTs:

- Secondary Aluminum Production: toxicity-weighted emissions decreased for 7 of 12 Target Systems;
- Pesticide Active Ingredient Production: toxicity-weighted emissions decreased for 6 of 14 Target Systems;
- Solvent Extraction for Vegetable Oil Production: toxicity-weighted emissions increased for 9 of 12 Target Systems;
- Boat Manufacturing: toxicity-weighted emissions increased for 10 of 11 Target Systems;
- Flexible Polyurethane Foam Fabrication: toxicity-weighted emissions increased for 7 of 8 Target Systems;

- Polymers and Resins III: toxicity-weighted emissions decreased for 6 of 11 Target Systems; and
- Pulp and Paper Production: toxicity-weighted emissions decreased for 9 of 14 Target Systems.

**CONCLUSIONS**

Mass and toxicity-weighted emissions (cancer and noncancer) were calculated for facilities subject to MACT standards implemented during 2003 and 2004. Using the emissions data from the 2002 and 2005 point source NEI, a toxicity-weighted approach was applied to compare the mass and toxicity-weighted emissions pre- and post-implementation of the MACT standards. It is important to note that this study only examines emissions data for facilities and pollutants that were in both the 2002 and 2005 NEIs, and not total emissions from each of those facilities.

The following observations were made:

- Toxicity-weighting data from an emissions inventory can be useful for preliminarily evaluating MACT effectiveness and identifying facilities for closer scrutiny. Air quality managers can also use this approach to evaluate NATA results, as well as help target audits.
- Overall emissions of the cancer-causing pollutants for nine MACT Standards increased by less than 2%, yet there was a 16% reduction in cancer toxicity-weighted emissions.
- Overall emissions of the noncancer-causing pollutants for nine MACT Standards increased by nearly 12%, yet there was a reduction in noncancer toxicity-weighted emissions for 9 of 12 target systems.

NEI data for the Phase II, Group 3 RTR categories included in this paper have been improved as a result of public comment, EPA engineering reviews and preliminary exposure modeling. Data for the other categories will be evaluated in the future as part of Phase III RTR to improve emission estimates and assignment to MACT categories. Better inventory data are needed to support regulatory activities and analyses such as the one presented in this paper. State and local agencies, tribes, industry and the public are strongly encouraged to participate in the review of inventory data to improve NEI data and resulting risk analyses and assessments.

**REFERENCES**

1. U.S. EPA. Clean Air Act Amendments. OAQPS. Internet address: http://www.epa.gov/air/oaq_caa.html/
2. U.S. EPA. 1990 – 2002 NEI HAP Trends: Success of CAA Air Toxic Programs in Reducing HAP Emissions and Risk. Proceedings at the 16th Annual International Emissions Inventory Conference. Raleigh, NC. May 2007. Internet address: http://www.epa.gov/ttn/chief/conference/ei16/session6/a.pope.pdf
3. U.S. EPA. Emissions Inventories. Internet address: http://www.epa.gov/ttn/chief/eiinformation.html
4. U.S. EPA. 2002 National Emissions Inventory (NEI) Data and Documentation, Version 3. Data retrieved from ftp://ftp.epa.gov/EmisInventory/2002finalnei/
5. U.S. EPA. 2005 National Emissions Inventory (NEI), Version 3. Data provided by A. Pope. OAQPS. March 2009.
6. U.S. EPA. National Emission Standards for Hazardous Air Pollutants (NESHAP). Internet address: http://www.epa.gov/ttn/atw/mactfnlalph.html
7. Schaffner, K., et. al. Using and Improving National Emissions Inventory Data for Residual Risk and Technology Review Projects. Paper presented at the 17th Annual International Emission Inventory Conference. Portland, OR. June 2008. Internet address: http://www.epa.gov/ttn/chief/conference/ei17/session7/schaffner.pdf

8. U.S. EPA. Health Effects Information Used in Cancer and Noncancer Risk Characterization for the 1999 National-Scale Assessment. OAQPS. November 2007. Internet address: http://www.epa.gov/ttn/atw/nata/

**KEYWORDS**

Hazardous Air Pollutants (HAPs)
National Emissions Inventory (NEI)
Toxicity-Weighting
MACT Standards
National Air Toxics Assessment (NATA)

**Table 1.** Implemented MACT standards, 2003-2004.

| MACT Standard | Applicable MACT Codes | Implementation Date | Website |
|---|---|---|---|
| Secondary Aluminum Production | 0202, 0202-1, 0202-2 | 3/24/2003 | http://www.epa.gov/ttn/atw/alum/alumpg.html |
| Primary Magnesium Production | 0207 | 10/4/2004 | http://www.epa.gov/ttn/atw/pmag/pmagpg.html |
| Pesticide Active Ingredient | 0911 | 12/23/2003 | http://www.epa.gov/ttn/atw/pest/pestpg.html |
| Manufacture of Nutritional Yeast | 1101 | 5/21/2004 | http://www.epa.gov/ttn/atw/yeast/yeastpg.html |
| Solvent Extraction for Vegetable Oil Production | 1103 | 4/12/2004 | http://www.epa.gov/ttn/atw/vegoil/vegoilpg.html |
| Boat Manufacturing | 1305 | 8/22/2004 | http://www.epa.gov/ttn/atw/boat/boatpg.html |
| Flexible Polyurethane Foam Fabrication | 1341 | 4/14/2004 | http://www.epa.gov/ttn/atw/foam2/foam2pg.html |
| Polymers and Resins III | 1347 | 1/20/2003 | http://www.epa.gov/ttn/atw/amino/aminopg.html |
| Pulp & Paper Production | 1626-2 | 1/12/2004 | http://www.epa.gov/ttn/atw/pulp/pulppg.html |

**Table 2.** Cancer toxicity comparison by MACT standard.

| MACT Standard | # Sites | Mass Emissions (tpy) | | Cancer Toxicity-Weighted Emissions | | % Emissions Change | % Toxicity Change |
|---|---|---|---|---|---|---|---|
| | | 2002 | 2005 | 2002 | 2005 | | |
| Secondary Aluminum Production[1] | 99 | 177.04 | 98.95 | 0.01534 | 0.01251 | -44.11% | -18.43% |
| Primary Magnesium Production | 1 | 0.05 | 0.05 | 0.00001 | 0.00001 | -- | -- |
| Pesticide Active Ingredient | 19 | 247.68 | 226.47 | 0.01017 | 0.00958 | -8.56% | -5.78% |
| Manufacture of Nutritional Yeast | 2 | 48.79 | 48.79 | 0.00011 | 0.00011 | -- | -- |
| Solvent Extraction for Vegetable Oil Production | 40 | 14.50 | 166.76 | 0.00076 | 0.00174 | 1049.80% | 129.62% |
| Boat Manufacturing | 48 | 3.44 | 4.53 | 0.00149 | 0.00254 | 31.74% | 70.52% |
| Flexible Polyurethane Foam Fabrication | 3 | 16.846 | 16.849 | 0.00007 | 0.00007 | 0.02% | <0.01% |
| Polymers and Resins III | 22 | 172.36 | 113.07 | 0.00012 | 0.00018 | -34.40% | 58.29% |
| Pulp & Paper Production[2] | 140 | 5,480.07 | 5,590.55 | 0.16399 | 0.13372 | 2.02% | -18.46% |
| OVERALL | 374 | 6,160.79 | 6,266.01 | 0.19204 | 0.16046 | 1.71% | -16.45% |

-- = no change

[1] Includes 1 facility also subject to the Boat Manufacturing MACT.

[2] Chemical Recovery Combustion Sources at Kraft, Soda, Sulfite, and Stand-alone Semichemical Pulping Mills.

**Table 3.** Noncancer toxicity comparison by MACT standard.

| MACT Standard | Target System | # Sites | Mass Emissions (tpy) | | Cancer Toxicity- Weighted Emissions | | % Emissions Change | % Toxicity Change |
|---|---|---|---|---|---|---|---|---|
| | | | 2002 | 2005 | 2002 | 2005 | | |
| Secondary Aluminum[1] | Developmental | 136 | 109.30 | 79.21 | 30,673.54 | 29,419.70 | -27.53% | -4.09% |
| | Endocrine | 5 | 11.29 | 5.93 | 28.23 | 14.83 | -47.47% | -47.47% |
| | Hematological | 22 | 5.17 | 5.56 | 258.56 | 277.86 | 7.46% | 7.46% |
| | Immunological | 77 | 16.51 | 14.43 | 70,624.10 | 91,321.39 | -12.59% | 29.31% |
| | Kidney | 36 | 12.06 | 7.85 | 38,637.06 | 87,921.79 | -34.94% | 127.56% |
| | Liver | 26 | 6.39 | 6.76 | 262.12 | 281.35 | 5.84% | 7.34% |
| | Neurological | 92 | 799.73 | 471.87 | 328,801.19 | 209,348.16 | -41.00% | -36.33% |
| | Ocular | 1 | 6.07 | 6.07 | 10.12 | 10.12 | -- | -- |
| | Reproductive | 28 | 366.75 | 217.48 | 18,337.27 | 10,873.78 | -40.70% | -40.70% |
| | Respiratory | 123 | 1,703.96 | 1,178.47 | 424,642.88 | 495,679.23 | -30.84% | 16.73% |
| | Skeletal | 36 | 630.42 | 517.26 | 21,013.87 | 17,242.03 | -17.95% | -17.95% |
| | Thyroid | 5 | 0.69 | 0.69 | 230.05 | 229.72 | -0.14% | -0.14% |
| Primary Magnesium | Developmental | 1 | <0.01 | <0.01 | 2.09 | 2.09 | -- | -- |
| | Hematological | 1 | <0.01 | <0.01 | <0.01 | <0.01 | -- | -- |
| | Immunological | 1 | 0.01 | 0.01 | 165.99 | 165.99 | -- | -- |
| | Kidney | 1 | <0.01 | <0.01 | 16.39 | 16.39 | -- | -- |
| | Liver | 1 | <0.01 | <0.01 | 0.01 | 0.01 | -- | -- |
| | Neurological | 1 | 0.54 | 0.54 | 5.88 | 5.88 | -- | -- |
| | Respiratory | 1 | 5.88 | 5.88 | 7,115.39 | 7,115.39 | -- | -- |
| Pesticide Active Ingredient | Developmental | 18 | 243.16 | 253.21 | 29,933.52 | 30,798.68 | 4.13% | 2.89% |
| | Endocrine | 4 | 12.11 | 10.41 | 30.27 | 26.02 | -14.01% | -14.01% |
| | Hematological | 11 | 1.50 | 1.05 | 9.24 | 10.97 | -29.91% | 18.67% |
| | Immunological | 17 | 39.74 | 26.98 | 2,318.27 | 4,693.19 | -32.13% | 102.44% |
| | Kidney | 15 | 22.98 | 15.64 | 77,076.31 | 76,990.73 | -31.94% | -0.11% |
| | Liver | 17 | 239.70 | 138.44 | 1,694.79 | 572.42 | -42.24% | -66.22% |
| | Neurological | 19 | 472.42 | 276.53 | 11,882.01 | 14,659.88 | -41.47% | 23.38% |
| | Ocular | 4 | 10.48 | 8.34 | 17.46 | 19.07 | -20.43% | 9.21% |
| | Reproductive | 12 | 11.46 | 31.80 | 3,224.22 | 5,892.22 | 177.50% | 82.75% |
| | Respiratory | 20 | 2,583.47 | 1,235.58 | 427,008.17 | 317,560.88 | -52.17% | -25.63% |
| | Skeletal | 4 | 4.51 | 5.52 | 150.19 | 183.96 | 22.48% | 22.48% |
| | Spleen | 2 | 0.26 | 0.36 | 263.80 | 362.40 | 37.38% | 37.38% |
| | Thyroid | 6 | 5.79 | 1.08 | 1,930.14 | 361.64 | -81.26% | -81.26% |
| | Whole body | 7 | 7.95 | 8.19 | 440.96 | 359.05 | 2.95% | -18.57% |
| Manufacture of Nutritional Yeast | Immunological | 2 | <0.01 | <0.01 | <0.01 | <0.01 | -- | -- |
| | Respiratory | 2 | 48.79 | 48.79 | 5,420.52 | 5,420.52 | -- | -- |

**Table 3.** Noncancer toxicity comparison by MACT standard (Continued).

| MACT Standard | Target System | # Sites | Mass Emissions (tpy) | | Cancer Toxicity- Weighted Emissions | | % Emissions Change | % Toxicity Change |
|---|---|---|---|---|---|---|---|---|
| | | | 2002 | 2005 | 2002 | 2005 | | |
| Solvent Extraction for Vegetable Oil Production | Developmental | 29 | 59.32 | 127.37 | 1,877.98 | 4,828.84 | 114.70% | 157.13% |
| | Endocrine | 2 | <0.01 | <0.01 | <0.01 | <0.01 | -- | -- |
| | Hematological | 21 | 0.08 | 0.38 | 4.12 | 18.99 | 360.37% | 360.37% |
| | Immunological | 38 | 1.81 | 3.05 | 17,945.13 | 15,706.67 | 68.39% | -12.47% |
| | Kidney | 26 | 0.11 | 0.12 | 4,653.62 | 4,862.73 | 8.45% | 4.49% |
| | Liver | 23 | 0.35 | 0.79 | 6.04 | 28.83 | 129.20% | 377.48% |
| | Neurological | 47 | 8,156.71 | 9,397.34 | 47,056.90 | 54,266.89 | 15.21% | 15.32% |
| | Ocular | 3 | 0.01 | 0.01 | 0.01 | 0.01 | 3.56% | 1.66% |
| | Reproductive | 5 | 0.01 | 0.01 | 3.19 | 0.36 | -19.34% | -88.67% |
| | Respiratory | 51 | 8,460.22 | 10,060.71 | 102,874.97 | 147,075.79 | 18.92% | 42.97% |
| | Skeletal | 8 | 59.85 | 57.58 | 1,994.99 | 1,919.22 | -3.80% | -3.80% |
| | Thyroid | 1 | 0.38 | 0.40 | 127.35 | 134.67 | 5.75% | 5.75% |
| Boat Manufacturing | Developmental | 57 | 32.27 | 32.92 | 42.89 | 48.96 | 2.01% | 14.15% |
| | Endocrine | 10 | 0.62 | 0.67 | 1.55 | 1.67 | 8.02% | 8.02% |
| | Hematological | 10 | 0.03 | 0.03 | 0.02 | 0.03 | 0.45% | 26.15% |
| | Immunological | 29 | 0.33 | 0.46 | 1,134.38 | 3,098.12 | 40.65% | 173.11% |
| | Kidney | 20 | 0.65 | 0.70 | 5.60 | 14.14 | 7.70% | 152.69% |
| | Liver | 28 | 6.86 | 7.40 | 39.04 | 39.42 | 7.96% | 0.97% |
| | Neurological | 245 | 6,358.78 | 10,658.09 | 29,636.46 | 54,126.82 | 67.61% | 82.64% |
| | Reproductive | 19 | 155.94 | 156.35 | 7,796.84 | 7,817.50 | 0.26% | 0.26% |
| | Respiratory | 160 | 590.43 | 965.82 | 18,024.36 | 78,308.56 | 63.58% | 334.46% |
| | Spleen | 5 | 0.13 | 0.13 | 129.37 | 128.43 | -0.72% | -0.72% |
| Flexible Polyurethane Foam Fabrication | Developmental | 2 | 0.18 | 0.18 | 0.43 | 0.19 | -0.01% | -56.63% |
| | Immunological | 2 | 8.49 | 8.49 | 282.83 | 282.84 | -- | -- |
| | Liver | 2 | 0.75 | 0.75 | 0.75 | 0.75 | -- | -- |
| | Neurological | 2 | 5.86 | 6.22 | 387.10 | 528.21 | 6.18% | 36.45% |
| | Respiratory | 4 | 27.00 | 36.02 | 1,575.16 | 2,010.24 | 33.41% | 27.62% |
| | Skeletal | 1 | <0.01 | <0.01 | <0.01 | <0.01 | -- | -- |
| | Thyroid | 2 | 1.12 | 1.55 | 373.53 | 515.23 | 37.93% | 37.93% |
| | Whole body | 1 | 0.43 | 0.43 | 7.17 | 7.17 | -- | -- |
| Polymers and Resins III | Developmental | 21 | 1,336.96 | 322.63 | 469.17 | 236.75 | -75.87% | -49.54% |
| | Endocrine | 2 | 0.62 | 0.78 | 1.55 | 1.94 | 24.70% | 24.70% |
| | Hematological | 4 | 0.67 | 0.66 | 0.25 | 0.26 | -0.36% | 1.82% |
| | Immunological | 12 | 2.29 | 10.76 | 3,293.10 | 3,929.98 | 370.65% | 19.34% |
| | Kidney | 9 | 1.29 | 1.47 | 73.41 | 81.63 | 14.18% | 11.20% |
| | Liver | 18 | 722.81 | 94.00 | 3,610.71 | 466.94 | -87.00% | -87.07% |

**Table 3.** Noncancer toxicity comparison by MACT standard (Continued).

| MACT Standard | Target System | # Sites | Mass Emissions (tpy) | | Cancer Toxicity- Weighted Emissions | | % Emissions Change | % Toxicity Change |
|---|---|---|---|---|---|---|---|---|
| | | | 2002 | 2005 | 2002 | 2005 | | |
| Polymers and Resins III (Cont.) | Neurological | 14 | 311.43 | 113.36 | 2,349.89 | 959.19 | -63.60% | -59.18% |
| | Ocular | 4 | 0.30 | 0.49 | 15.15 | 24.48 | 61.57% | 61.57% |
| | Reproductive | 3 | 146.77 | 3.48 | 7,338.71 | 174.09 | -97.63% | -97.63% |
| | Respiratory | 22 | 298.92 | 153.52 | 71,270.05 | 36,504.31 | -48.64% | -48.78% |
| | Whole body | 3 | 0.91 | 0.43 | 1.52 | 0.72 | -52.46% | -52.46% |
| Pulp & Paper Production[2] | Developmental | 143 | 45,412.50 | 54,765.80 | 366,673.95 | 371,635.90 | 20.60% | 1.35% |
| | Endocrine | 35 | 61.29 | 49.53 | 247.51 | 218.12 | -19.18% | -11.88% |
| | Hematological | 74 | 6.97 | 11.51 | 349.41 | 576.50 | 65.13% | 64.99% |
| | Immunological | 123 | 258.13 | 333.13 | 620,649.14 | 1,649,599.82 | 29.06% | 165.79% |
| | Kidney | 101 | 167.21 | 198.77 | 308,020.92 | 88,695.70 | 18.88% | -71.20% |
| | Liver | 130 | 1,615.75 | 1,919.24 | 18,075.73 | 20,106.36 | 18.78% | 11.23% |
| | Neurological | 132 | 1,902.93 | 2,180.50 | 2,568,034.28 | 1,391,404.57 | 14.59% | -45.82% |
| | Ocular | 50 | 49.83 | 37.54 | 82.90 | 62.45 | -24.67% | -24.68% |
| | Reproductive | 47 | 30.03 | 26.46 | 2,115.21 | 1,691.84 | -11.90% | -20.02% |
| | Respiratory | 142 | 12,849.90 | 11,930.61 | 8,913,961.96 | 9,526,014.80 | -7.15% | 6.87% |
| | Skeletal | 35 | 259.26 | 174.09 | 8,642.10 | 5,803.05 | -32.85% | -32.85% |
| | Spleen | 3 | 0.01 | 0.01 | 11.17 | 10.91 | -2.31% | -2.31% |
| | Thyroid | 4 | 1.80 | 1.47 | 5,198.09 | 5,087.53 | -18.38% | -2.13% |
| | Whole body | 65 | 628.85 | 569.14 | 1,074.04 | 974.52 | -9.50% | -9.27% |
| OVERALL | Developmental | 407 | 47,193.69 | 55,581.31 | 429,673.57 | 436,971.10 | 17.77% | 1.70% |
| | Endocrine | 58 | 85.93 | 67.32 | 309.11 | 262.59 | -21.66% | -15.05% |
| | Hematological | 143 | 14.42 | 19.19 | 621.61 | 884.60 | 33.10% | 42.31% |
| | Immunological | 301 | 327.30 | 397.30 | 716,412.95 | 1,768,798.00 | 21.39% | 146.90% |
| | Kidney | 208 | 204.30 | 224.55 | 428,483.30 | 258,583.09 | 9.91% | -39.65% |
| | Liver | 245 | 2,592.61 | 2,167.39 | 23,689.18 | 21,496.09 | -16.40% | -9.26% |
| | Neurological | 552 | 18,008.40 | 23,104.46 | 2,988,153.73 | 1,725,299.61 | 28.30% | -42.26% |
| | Ocular | 62 | 66.69 | 52.45 | 125.64 | 116.12 | -21.36% | -7.58% |
| | Reproductive | 114 | 710.96 | 435.57 | 38,815.45 | 26,449.79 | -38.73% | -31.86% |
| | Respiratory | 525 | 26,568.56 | 25,615.39 | 9,971,893.48 | 10,615,689.72 | -3.59% | 6.46% |
| | Skeletal | 84 | 954.03 | 754.45 | 31,801.14 | 25,148.25 | -20.92% | -20.92% |
| | Spleen | 10 | 0.40 | 0.50 | 404.34 | 501.74 | 24.09% | 24.09% |
| | Thyroid | 18 | 9.79 | 5.20 | 7,859.16 | 6,328.78 | -46.89% | -19.47% |
| | Whole body | 76 | 638.14 | 578.19 | 1,523.68 | 1,341.46 | -9.40% | -11.96% |

**--** = no change

[1] Includes 1 facility also subject to the Boat Manufacturing MACT.

[2] Chemical Recovery Combustion Sources at Kraft, Soda, Sulfite, and Stand-alone Semichemical Pulping Mills.