

DATE: April 15, 2015

TO: Tania Steele

FROM: Eshetu Beshada, Ph.D., P.Eng.
Environmental Engineer
Mines and Wastewater Section
123 Main Street
Ste. 160 Union Station
Winnipeg, Mb R3C 1A5
Ph:204 945-7023

SUBJECT: **Structural Composite Technologies Ltd. – Information for Public Registries**

Tania,

Please find attached additional correspondence related to the Structural Composite Technologies file (5594.00) for distribution to the public registries. The documents included are:

Information:

- April 16, 2015 memo from Environmental Compliance and Enforcement, 1 page
- March 27, 2015 email from Muntaseer Ibn Azkar, 1 page
- March 27, 2015 email from Tony Ma, 2 pages
- March 20, 2015 email from Ajay Madan with attachments, 32 pages
- September 16, 2014 memo from Environmental Compliance and Enforcement, 1 page
- September 15, 2014 email from Muntaseer Ibn Azkar, 1 page
- September 5, 2014 email from Tony Ma with attachments, 35 pages

73 pages total

Thank you.

Eshetu Beshada, Ph.D., P. Eng.

DATE: April 16, 2015

TO: Eshetu Beshada
Environmental Approvals
Conservation and Water Stewardship
123 Main St Suite 160 (Box 80)
Winnipeg MB R3C 1A5

FROM: Environmental Compliance and Enforcement
Conservation and Water Stewardship
1007 Century St
Winnipeg MB R3H 0W4

SUBJECT: Environment Act Proposal – Response to Additional Information – Structural Composite Technologies Ltd (Client File: 5594.00)

Environmental Compliance and Enforcement (Central Region) has reviewed the above noted Environment Act Proposal (EAP). Please find the following comments regarding the proposal.

1) Regarding Odour Emissions and Control:

- Ongoing odour emission reductions, such as the reduction in VOCs, should be implemented as part of any Environment Act Licence issued

Beshada, Eshetu (CWS)

From: Ibn Azkar, Muntaseer (CWS)
Sent: March-27-15 12:06 PM
To: Beshada, Eshetu (CWS)
Cc: Molod, Rommel (CWS)
Subject: RE: SCTL EAP review

Hello Eshetu,

I have reviewed the response regarding updated PM emission calculations and modeling results. I do not have any more comment on this issue.

Thank you.

Muntaseer Ibn Azkar
Air Quality Specialist
Environmental Programs and Strategies Branch
Manitoba Conservation and Water Stewardship
1007 Century Street, Winnipeg MB R3H 0W4
Phone : 204 945 4102
Fax : 204 948 2420
Email : muntaseer.ibnazkar@gov.mb.ca

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Beshada, Eshetu (CWS)

From: Tony Ma <tma@sctfrp.com>
Sent: Friday, March 27, 2015 2:26 PM
To: Beshada, Eshetu (CWS)
Cc: amadan@pinchin.com
Subject: RE: SCTL EAP review - Missing response

Eshetu,

Thanks for the update. With respect to:

Environmental Compliance and Enforcement (Central Region) has reviewed the above noted Environment Act Proposal (EAP). Please find the following comments regarding the proposal.

1) Regarding Odour Emissions and Control:

- Please provide more information and detail regarding the reduction of the targeted odour sources. How much of a reduction is expected? How much of this has been implemented already?
- Please provide more details on how the spraying is controlled.
- Further options to reduce odours within the process may require future Notices of Alteration of the licence.

Our response is:

- The resins applied to our products are at times specified by our clients for their specific application. This specification includes resin manufacturers (especially on our corrosion products). This is quite common in the fiberglass industry. We have partnered with some of our resin manufacturers to look for a “greener” resin for some of our commodity products. There is opportunity to test and incorporate “low odour” resins. The acceptance of these resins must go through third party approval by way of CSA or NSF to ensure product integrity is not compromised. Using alternative products will be an on going process to develop and improve. As an example we have already incorporated a low styrene gelcoat for our bathware product line.
- We have been ensuring that the overspray of product is minimized. There is both an environmental and financial benefit to ensure we minimize overspray and ensure all resin is sprayed onto the part and not wasted in surrounding areas. The methods employed include, continued training for gun operators. An example of the training can be found at the following link:
 - <http://www.ccpcompositesus.com/index.php/ccp-university/schedule> (specifically Gelcoat Application and Spray Pattern) We have had CCP on site to provide operator training.
- We have targetted additional capital investment to update/replace our guns and resin delivery systems with newer more efficient models. Again, this is to ensure we maximize efficiency of spraying to minimize wasted overspray that will ultimately produce additional emissions.
- We have invested and promoted more use of closed and specially sealed containers usage in the shop. This again has both environmental and financial benefits as there is less evaporation of media and therefore less waste and odour is emitted.
- We have reduced our amount of resins on our premises. The shop floor scheduling has been made more efficient by scheduling workflow and just in time delivery of resins to only build and use what is required each day. Again, this effort limits the amount of resin use at any given time in the shop.

The above comments all contribute to using less resin to meet our needs. The comments from the ECEB are noted and understood. We at this time do not have the data to quantify the improvements. It is planned to have data collected by way of resin consumption monitoring. The capital investments will need to be monitored for the value of return. This return is measured by way of reduction in resin usage which directly impacts emission amounts.

Regards,

Tony Ma, P. Eng.
Engineering Manager



tma@sctfrp.com

Ph. (204) 668-9320 ext. 207

Fax. (204) 663-9115

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From: Beshada, Eshetu (CWS) [<mailto:Eshetu.Beshada@gov.mb.ca>]

Sent: March-27-15 1:09 PM

To: Tony Ma; Madan, Ajay

Subject: RE: SCTL EAP review - Missing response

Hello Tony,

Your response on the Air Dispersion model has been reviewed and there is no further comments. However, you did miss addressing the additional information requested from ECE Branch. Please see attached the original email with the attachments. Please get back to me as soon as possible.

Regards

***Eshetu Beshada, PhD, PEng.
Environmental Engineer***

Ph: (204) 945-7023

Fx: (204) 945-5229

s email in error, please notify the sender.

Beshada, Eshetu (CWS)

From: Madan, Ajay [<mailto:amadan@Pinchin.com>]

Sent: March-20-15 3:45 PM

To: Beshada, Eshetu (CWS); Tony Ma

Subject: RE: SCTL EAP review

Hello Eshetu,

To address the most recent questions for the air quality section I have attached the following:

- Most recent list of questions from Manitoba Conservation (Air Quality on Response.pdf);
- Updated Emission Summary table showing updated emission results, including for PM2.5, updated datasheets, and Emissions Modelling Result table. From the attachment it can be seen that PM2.5 has been updated, and is below its respective Canada Wide Standard. As a very conservative approach had been used to estimate particulate emissions, the estimates have been revised to use a methodology developed by the Composite Fabricators Association (CFA) (81397 - Structural Composite Technologies ECA Summary Tables.pdf);
- CFA Particulate Matter estimation technique, which includes a report (CFA PM Emissions Report.pdf) and spreadsheet developed by CFA (openmolding – clean.xls);
- One generic contour plot for reference (SCT Contour.JPG), and
- All contour plots for the facility's generic base model (Base.AD.zip).

As discussed with Muntaseer, our approach had been to use a conservative "Base" model to develop a dispersion factor for all contaminants (as detailed in the original report). As such the contour plots are for this generic model where each source was modelled with a 1 g/s emission rate. In our discussions, Muntaseer confirmed that he was okay with this approach.

I trust that the information provided should satisfy the requirements of Manitoba Conservation's review. Should there be any further questions or comments please let me know. Please be aware that I will be on vacation March 26 to April 2nd (which is followed by the long weekend). Should there be any questions while I am way, I will do my best to answer them all promptly upon my return.

Have a great weekend.

Best Regards,
Ajay

Ajay Madan, P.Eng., TSRP

Senior Project Engineer, Emissions Reduction & Compliance

Pinchin Ltd. | T: 905.363.1462 | C:416.471.1466

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Table A3. Emission Summary Table

Contaminant	CAS #	Total Facility Emission Rate (g/s)	Air Dispersion Model Used	Maximum POI Concentration ($\mu\text{g}/\text{m}^3$)	Averaging Period (h)	POI Limit ($\mu\text{g}/\text{m}^3$)	Limiting Effect	Reg. Sch. No.	% of POI Limit	Ambient Air Concentration ** ($\mu\text{g}/\text{m}^3$)	% of POI Limit (Including Ambient Air)
Styrene	100-42-5	6.04E-01	AERMOD	1.56E+02	24	400	-	AAQC	39%	3.70E-02	39%
Nitrogen Oxides	10102-44-0	1.50E-01	AERMOD	6.71E+01	24	200	-	AAQC	34%	-	-
			AERMOD	3.24E+02	1	400	-	AAQC	81%	-	-
			AERMOD	1.98E+01	annual	60	-	AAQC	33%	-	-
Methanol	67-56-1	8.10E-03	AERMOD	2.07E+00	24	4000	Health	3	0.1%	-	-
Hydrogen Peroxide	7722-84-1	1.16E-02	AERMOD	2.95E+00	24	30	Health	G	10%	-	-
Methyl Ethyl Ketone	78-93-3	2.31E-02	AERMOD	5.90E+00	24	1000	Health	3	1%	-	-
PM2.5 (Particulate Matter <= 2.5)	n/a	3.41E-02	AERMOD	8.70E+00*	24	30	-	AAQC	29%	7.32E+00	53%
PM10 (Particulate Matter <= 10)	n/a	3.41E-02	AERMOD	8.70E+00*	24	50	-	AAQC	17%	7.32E+00	32%
Particulate Matter (Total)	n/a	3.41E-02	AERMOD	8.70E+00	24	60	-	AAQC	14%	7.32E+00	27%

*PM2.5 and PM10 conservatively assumed to be equivalent to Total Particulate Matter.

**Ambient air concentration values for the most recent year available (2007). Values are the average for Winnipeg. Values can be downloaded at the following site: <http://maps-cartes.ec.gc.ca/rnsps-naps/data.aspx?lang=en>

Reg. Sch. or Regulation Schedule: 3 Standard - Schedule 3 of Ontario Regulation 419.

AAQC Guideline published by Manitoba Conservation, July 2005.

G Guideline - Summary of Standards and Guidelines to support Ontario Regulation 419: Air Pollution - Local Air Quality, April 2012

Emissions from Resin Spraying

Source ID: EF1
Description: Emissions from resin spraying and glass lay-up are vented through one (1) of four (4) general production exhausts (EF1 to EF4), which are equipped with filters. This datasheet provides emission estimates for emissions vented through EF1.

Process Operating Conditions

Actual operating times: 12 hours per day
Spray rate (fibreglass lay-up): 8.33 kg/20-min
Spray rate (laminating resin): 25 kg/20-min
Spray rate (roving & laminate resin): 18.3 kg/20-min
Styrene emission factor: 354 lb/tonne of resin
Amount of time sprayed: 20 minutes within a 1-hour period
Filter efficiency (initial): 20 %
Filter efficiency (after filter): 30 %

Emission Estimation Methodology

Multiple resins are sprayed, each having different formulations. For a worst-case scenario, the maximum composition of each contaminant from all the resins was used to determine the emission rates (Refer to "Product Formulations" datasheet for a listing of all resins and their components). Emissions calculations were also based on the following assumptions:

- All spray guns are spraying simultaneously
- A transfer efficiency of 95% was assumed to determine the Particulate Matter emissions.
- Individual solid components (and non-volatiles) of the spray have been deemed insignificant since they are expected to remain in the product.
- Volatile components were assumed to be 100% emitted to atmosphere.
- Emissions for the individual solids components of the resins was determined by multiplying the Particulate Matter emission rate by the maximum percent composition of the individual component.
- Emissions of styrene were determined using an emission factor developed by the Composite Fabricator's Association. The emission factor for mechanical atomized spraying was used as the spray guns are equipped with atomizers.
- The resulting emission rates have been divided by 4 to account for the emissions being equally distributed among 4 exhausts.
- Resulting emission rates have been multiplied by 12/24 to convert to a 24-h averaging period, since the plant only operates 12 hours in a 24-h period.

Worst-case MSDS Material Blend (does not include gel coat, which exhausts solely through EF3)

Contaminant	CAS #	Max. Wt. Percent	Maximum Emission Rate (g/s)
Methyl Ethyl Ketone Peroxide*	1338-23-4	35%	insignificant
Dimethyl Phthalate	131-11-3	60%	insignificant
Phlegmatizer**	Proprietary	26%	insignificant
Hydrogen Peroxide	7722-84-1	1%	2.89E-03
Methyl Ethyl Ketone	78-93-3	2%	5.79E-03
Fibreglass	65997-17-3	100%	insignificant
Polyester	25038-59-9	25%	insignificant
Styrene	100-42-5	50%	1.39E-01
Cobalt	7440-48-4	1%	insignificant
Methanol	67-56-1	1%	2.03E-03

*Emissions from Methyl Ethyl Ketone Peroxide are considered insignificant since the role of this chemical is to act as a hardener and stabilizer for the resin, and must remain in the resin to perform it's function.

**Emissions from phlegmatizer are considered insignificant since the role of the phlegmatizer is as a stabilizer and therefore must remain in the product.

Emissions from Resin Spraying

Sample Calculations

$$\begin{aligned} \text{Particulate Matter Emission Rate} &= \text{CFA Emission Rate} \times 0.4536 \text{ kg/lb} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 5.36 \text{ lbs/20-min} \times 0.4536 \text{ lbs/kg} \times (20\text{min}/60\text{min}) \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \\ &\quad \text{g/kg} \div 60 \text{ s/min} \\ &= 0.0084 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Hydrogen Peroxide Emission Rate} &= \text{Spray Rate (Fiberglass Lay-up)} \times \text{Amount of Time Sprayed} \times \text{Max. Wt. Percent} \div \\ &\quad \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 8.33 \text{ kg/20-min} \times 20\text{-min}/60\text{-min} \times 1 \% \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \text{ g/kg} \div 60 \\ &\quad \text{s/min} \\ &= 0.00289 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Styrene Emission Rate} &= \text{Spray Rate (Laminating Resin)} \times \text{Styrene Emission Factor} \times \text{Amount of Time} \\ &\quad \text{Sprayed} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 25 \text{ kg/20-min} \times 354 \text{ lb/tonne of resin} \times 20\text{min}/60\text{min} \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times \\ &\quad 0.4536 \text{ kg/lb} \div 1000 \text{ kg/tonne} \times 1000 \text{ g/kg} \div 60 \text{ s/min} \\ &= 0.139 \text{ g/s} \end{aligned}$$

Process Emissions Summary

Contaminant	CAS #	Maximum Emission Rate (g/s)	Emission Estimation Technique	Data Quality
Particulate Matter	n/a	8.44E-03	EC	ADQ
Styrene	100-42-5	1.39E-01	EC	ADQ
Methanol	67-56-1	2.03E-03	EC	ADQ
Hydrogen Peroxide	7722-84-1	2.89E-03	EC	ADQ
Methyl Ethyl Ketone	78-93-3	5.79E-03	EC	ADQ

EC: Engineering Calculation

ADQ: Average Data Quality

References

- 1) Spray rates provided by Structural Composite Technologies. January 14, 2014 and February 19, 2014. via e-mail.
- 2) MSDSs provided by Structural Composite Technologies. January 23, 2014. via e-mail.
- 3) Transfer efficiency and filter efficiencies provided by Structural Composite Technologies. February 24, 2014, February 25, 2014 and February 27, 2014. via email.

Emissions from Resin Spraying

Source ID: EF2
Description: Emissions from resin spraying and glass lay-up are vented through one (1) of four (4) general production exhausts (EF1 to EF4), which are equipped with filters. This datasheet provides emission estimates for emissions vented through EF2.

Process Operating Conditions

Actual operating times: 12 hours per day
Spray rate (fibreglass lay-up): 8.33 kg/20-min
Spray rate (laminating resin): 25 kg/20-min
Spray rate (roving & laminate resin): 18.3 kg/20-min
Styrene emission factor: 354 lb/tonne of resin
Amount of time sprayed: 20 minutes within a 1-hour period
Filter efficiency (initial): 20 %
Filter efficiency (after filter): 30 %

Emission Estimation Methodology

Multiple resins are sprayed, each having different formulations. For a worst-case scenario, the maximum composition of each contaminant from all the resins was used to determine the emission rates (Refer to "Product Formulations" datasheet for a listing of all resins and their components). Emissions calculations were also based on the following assumptions:

- All spray guns are spraying simultaneously
- A transfer efficiency of 95% was assumed to determine the Particulate Matter emissions.
- Individual solid components (and non-volatiles) of the spray have been deemed insignificant since they are expected to remain in the product.
- Volatile components were assumed to be 100% emitted to atmosphere.
- Emissions for the individual solids components of the resins was determined by multiplying the Particulate Matter emission rate by the maximum percent composition of the individual component.
- Emissions of styrene were determined using an emission factor developed by the Composite Fabricator's Association. The emission factor for mechanical atomized spraying was used as the spray guns are equipped with atomizers.
- The resulting emission rates have been divided by 4 to account for the emissions being equally distributed among 4 exhausts.
- Resulting emission rates have been multiplied by 12/24 to convert to a 24-h averaging period, since the plant only operates 12 hours in a 24-h period.

Worst-case MSDS Material Blend (does not include gel coat, which exhausts solely through EF3)

Contaminant	CAS #	Max. Wt. Percent	Maximum Emission Rate (g/s)
Methyl Ethyl Ketone Peroxide*	1338-23-4	35%	insignificant
Dimethyl Phthalate	131-11-3	60%	insignificant
Phlegmatizer**	Proprietary	26%	insignificant
Hydrogen Peroxide	7722-84-1	1%	2.89E-03
Methyl Ethyl Ketone	78-93-3	2%	5.79E-03
Fibreglass	65997-17-3	100%	insignificant
Polyester	25038-59-9	25%	insignificant
Styrene	100-42-5	50%	1.39E-01
Cobalt	7440-48-4	1%	insignificant
Methanol	67-56-1	1%	2.03E-03

*Emissions from Methyl Ethyl Ketone Peroxide are considered insignificant since the role of this chemical is to act as a hardener and stabilizer for the resin, and must remain in the resin to perform it's function.

**Emissions from phlegmatizer are considered insignificant since the role of the phlegmatizer is as a stabilizer and therefore must remain in the product.

Emissions from Resin Spraying

Sample Calculations

$$\begin{aligned} \text{Particulate Matter Emission Rate} &= \text{CFA Emission Rate} \times 0.4536 \text{ kg/lb} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 5.36 \text{ lbs/20-min} \times 0.4536 \text{ lbs/kg} \times (20\text{min}/60\text{min}) \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \\ &\quad \text{g/kg} \div 60 \text{ s/min} \\ &= 0.0084 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Hydrogen Peroxide Emission Rate} &= \text{Spray Rate (Fiberglass Lay-up)} \times \text{Amount of Time Sprayed} \times \text{Max. Wt. Percent} \div \\ &\quad \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 8.33 \text{ kg/20-min} \times 20\text{-min}/60\text{-min} \times 1 \% \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \text{ g/kg} \div 60 \\ &\quad \text{s/min} \\ &= 0.00289 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Styrene Emission Rate} &= \text{Spray Rate (Laminating Resin)} \times \text{Styrene Emission Factor} \times \text{Amount of Time Sprayed} \\ &\quad \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 25 \text{ kg/20-min} \times 354 \text{ lb/tonne of resin} \times 20\text{min}/60\text{min} \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times \\ &\quad 0.4536 \text{ kg/lb} \div 1000 \text{ kg/tonne} \times 1000 \text{ g/kg} \div 60 \text{ s/min} \\ &= 0.139 \text{ g/s} \end{aligned}$$

Process Emissions Summary

Contaminant	CAS #	Maximum Emission Rate (g/s)	Emission Estimation Technique	Data Quality
Particulate Matter	n/a	8.44E-03	EC	ADQ
Styrene	100-42-5	1.39E-01	EC	ADQ
Methanol	67-56-1	2.03E-03	EC	ADQ
Hydrogen Peroxide	7722-84-1	2.89E-03	EC	ADQ
Methyl Ethyl Ketone	78-93-3	5.79E-03	EC	ADQ

EC: Engineering Calculation

ADQ: Average Data Quality

References

- 1) Spray rates provided by Structural Composite Technologies. January 14, 2014 and February 19, 2014. via e-mail.
- 2) MSDSs provided by Structural Composite Technologies. January 23, 2014. via e-mail.
- 3) Transfer efficiency and filter efficiencies provided by Structural Composite Technologies. February 24, 2014, February 25, 2014 and February 27, 2014. via email.

Emissions from Resin Spraying

Source ID: EF3
Description: Emissions from resin spraying and glass lay-up are vented through one (1) of four (4) general production exhausts (EF1 to EF4), which are equipped with filters. Emissions from gel coat spraying are also vented through EF3. This datasheet provides emission estimates for emissions vented through EF3.

Process Operating Conditions

Actual operating times:	12 hours per day	
Spray rate (fibreglass lay-up):	8.33	kg/20-min
Spray rate (laminating resin):	25	kg/20-min
Spray rate (roving & laminate resin):	18.3	kg/20-min
Spray rate (gel coat):	8.33	kg/20-min
Maximum styrene emission factor:	354	lb/tonne of resin
Amount of time sprayed:	20 minutes	within a 1-hour period
Filter efficiency (initial):	20	%
Filter efficiency (after filter):	30	%

Emission Estimation Methodology

Multiple resins are sprayed, each having different formulations. For a worst-case scenario, the maximum composition of each contaminant from all the resins was used to determine the emission rates (Refer to "Product Formulations" datasheet for a listing of all resins and their components). Emissions calculations were also based on the following assumptions:

- All spray guns are spraying simultaneously
- A transfer efficiency of 95% was assumed to determine the Particulate Matter emissions.
- Individual solid components (and non-volatiles) of the spray have been deemed insignificant since they are expected to remain in the product.
- Volatile components were assumed to be 100% emitted to atmosphere.
- Emissions for the individual solids components of the resins was determined by multiplying the Particulate Matter emission rate by the maximum percent composition of the individual component.
- Emissions of styrene were determined using an emission factor developed by the Composite Fabricator's Association. The emission factor for mechanical atomized spraying was used as the spray guns are equipped with atomizers. To be conservative the mechanical atomized emission factor was applied to the gel coat and the resin spraying applications. This is conservative since the emission factor for gel coat spraying (based on the weight percent of styrene in the gel coat) is less than the emission factor for mechanical atomized spraying.
- The resulting emission rates (with the exception of emissions from gel coat spraying) have been divided by 4 to account for the emissions being equally distributed among 4 exhausts.
- Resulting emission rates have been multiplied by 12/24 to convert to a 24-h averaging period, since the plant only operates 12 hours in a 24-h period.

Worst-case MSDS Material Blend

Contaminant	CAS #	Max. Wt. Percent	Maximum Emission Rate (g/s)
Methyl Ethyl Ketone Peroxide*	1338-23-4	35%	insignificant
Dimethyl Phthalate	131-11-3	60%	insignificant
Phlegmatizer**	Proprietary	26%	insignificant
Hydrogen Peroxide	7722-84-1	1%	2.89E-03
Methyl Ethyl Ketone	78-93-3	2%	5.79E-03
Fibreglass	65997-17-3	100%	insignificant
Polyester	25038-59-9	25%	insignificant
Styrene	100-42-5	50%	1.86E-01
Titanium Dioxide	13463-67-7	20%	insignificant
Silica	7631-86-9	5%	insignificant
Silica Gel	112926-00-8	5%	insignificant
Aluminum Oxide	1344-28-1	5%	insignificant
Cobalt	7440-48-4	1%	insignificant
Methanol	67-56-1	1%	2.03E-03

*Emissions from Methyl Ethyl Ketone Peroxide are considered insignificant since the role of this chemical is to act as a hardener and stabilizer for the resin, and must remain in the resin to perform its function.

**Emissions from phlegmatizer are considered insignificant since the role of the phlegmatizer is as a stabilizer and therefore must remain in the product.

Emissions from Resin Spraying

Sample Calculations

$$\begin{aligned} \text{Particulate Matter Emission Rate} &= \text{CFA Emission Rate} \times 0.4536 \text{ kg/lb} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 5.56 \text{ lbs/20-min} \times 0.4536 \text{ lbs/kg} \times (20\text{min}/60\text{min}) \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times \\ &\quad 1000 \text{ g/kg} \div 60 \text{ s/min} \\ &= 0.0088 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Hydrogen Peroxide Emission Rate} &= \text{Spray Rate (Fiberglass Lay-up)} \times \text{Amount of Time Sprayed} \times \text{Max. Wt. Percent} \div \\ &\quad \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 8.33 \text{ kg/20-min} \times 20\text{-min}/60\text{-min} \times 1 \% \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \text{ g/kg} \div \\ &\quad 60 \text{ s/min} \\ &= 0.00289 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Styrene Emission Rate} &= \text{Spray Rate (Laminating Resin \& Gel Coat)} \times \text{Styrene Emission Factor} \times \text{Amount} \\ &\quad \text{of Time Sprayed} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= (25 + 8.33) \text{ kg/20-min} \times 354 \text{ lb/tonne of resin} \times 20\text{min}/60\text{min} \div 4 \text{ exhausts} \times 12\text{-} \\ &\quad \text{h}/24\text{-h} \times 0.4536 \text{ kg/lb} \div 1000 \text{ kg/tonne} \times 1000 \text{ g/kg} \div 60 \text{ s/min} \\ &= 0.186 \text{ g/s} \end{aligned}$$

Process Emissions Summary

Contaminant	CAS #	Maximum Emission Rate (g/s)	Emission Estimation Technique	Data Quality
Particulate Matter	n/a	8.76E-03	EC	ADQ
Styrene	100-42-5	1.86E-01	EC	ADQ
Methanol	67-56-1	2.03E-03	EC	ADQ
Hydrogen Peroxide	7722-84-1	2.89E-03	EC	ADQ
Methyl Ethyl Ketone	78-93-3	5.79E-03	EC	ADQ

EC: Engineering Calculation

ADQ: Average Data Quality

References

- 1) Spray rates provided by Structural Composite Technologies. January 14, 2014 and February 19, 2014. via e-mail.
- 2) MSDSs provided by Structural Composite Technologies. January 23, 2014. via e-mail.
- 3) Transfer efficiency and filter efficiencies provided by Structural Composite Technologies. February 24, 2014, February 25, 2014 and February 27, 2014. via email.

Emissions from Resin Spraying

Source ID: EF4
Description: Emissions from resin spraying and glass lay-up are vented through one (1) of four (4) general production exhausts (EF1 to EF4), which are equipped with filters. This datasheet provides emission estimates for emissions vented through EF4.

Process Operating Conditions

Actual operating times:	12 hours per day	
Spray rate (fibreglass lay-up):	8.33	kg/20-min
Spray rate (laminating resin):	25	kg/20-min
Spray rate (roving & laminate resin):	18.3	kg/20-min
Styrene emission factor:	354	lb/tonne of resin
Amount of time sprayed:	20 minutes	within a 1-hour period
Filter efficiency (initial):	20	%
Filter efficiency (after filter):	30	%

Emission Estimation Methodology

Multiple resins are sprayed, each having different formulations. For a worst-case scenario, the maximum composition of each contaminant from all the resins was used to determine the emission rates (Refer to "Product Formulations" datasheet for a listing of all resins and their components). Emissions calculations were also based on the following assumptions:

- All spray guns are spraying simultaneously
- A transfer efficiency of 95% was assumed to determine the Particulate Matter emissions.
- Individual solid components (and non-volatiles) of the spray have been deemed insignificant since they are expected to remain in the product.
- Volatile components were assumed to be 100% emitted to atmosphere.
- Emissions for the individual solids components of the resins was determined by multiplying the Particulate Matter emission rate by the maximum percent composition of the individual component.
- Emissions of styrene were determined using an emission factor developed by the Composite Fabricator's Association. The emission factor for mechanical atomized spraying was used as the spray guns are equipped with atomizers.
- The resulting emission rates have been divided by 4 to account for the emissions being equally distributed among 4 exhausts.
- Resulting emission rates have been multiplied by 12/24 to convert to a 24-h averaging period, since the plant only operates 12 hours in a 24-h period.

Worst-case MSDS Material Blend (does not include gel coat, which exhausts solely through EF3)

Contaminant	CAS #	Max. Wt. Percent	Maximum Emission Rate (g/s)
Methyl Ethyl Ketone Peroxide*	1338-23-4	35%	insignificant
Dimethyl Phthalate	131-11-3	60%	insignificant
Phlegmatizer**	Proprietary	26%	insignificant
Hydrogen Peroxide	7722-84-1	1%	2.89E-03
Methyl Ethyl Ketone	78-93-3	2%	5.79E-03
Fibreglass	65997-17-3	100%	insignificant
Polyester	25038-59-9	25%	insignificant
Styrene	100-42-5	50%	1.39E-01
Cobalt	7440-48-4	1%	insignificant
Methanol	67-56-1	1%	2.03E-03

*Emissions from Methyl Ethyl Ketone Peroxide are considered insignificant since the role of this chemical is to act as a hardener and stabilizer for the resin, and must remain in the resin to perform it's function.

**Emissions from phlegmatizer are considered insignificant since the role of the phlegmatizer is as a stabilizer and therefore must remain in the product.

Emissions from Resin Spraying

Sample Calculations

$$\begin{aligned} \text{Particulate Matter Emission Rate} &= \text{CFA Emission Rate} \times 0.4536 \text{ kg/lb} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 5.36 \text{ lbs/20-min} \times 0.4536 \text{ lbs/kg} \times (20\text{min}/60\text{min}) \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \\ &\quad \text{g/kg} \div 60 \text{ s/min} \\ &= 0.0084 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Hydrogen Peroxide Emission Rate} &= \text{Spray Rate (Fiberglass Lay-up)} \times \text{Amount of Time Sprayed} \times \text{Max. Wt. Percent} \div \\ &\quad \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 8.33 \text{ kg/20-min} \times 20\text{-min}/60\text{-min} \times 1 \% \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times 1000 \text{ g/kg} \div 60 \\ &\quad \text{s/min} \\ &= 0.00289 \text{ g/s} \end{aligned}$$

$$\begin{aligned} \text{Styrene Emission Rate} &= \text{Spray Rate (Laminating Resin)} \times \text{Styrene Emission Factor} \times \text{Amount of Time} \\ &\quad \text{Sprayed} \div \text{Number of Exhausts} \times \text{Conversion to 24-h} \\ &= 25 \text{ kg/20-min} \times 354 \text{ lb/tonne of resin} \times 20\text{min}/60\text{min} \div 4 \text{ exhausts} \times 12\text{-h}/24\text{-h} \times \\ &\quad 0.4536 \text{ kg/lb} \div 1000 \text{ kg/tonne} \times 1000 \text{ g/kg} \div 60 \text{ s/min} \\ &= 0.139 \text{ g/s} \end{aligned}$$

Process Emissions Summary

Contaminant	CAS #	Maximum Emission Rate (g/s)	Emission Estimation Technique	Data Quality
Particulate Matter	n/a	8.44E-03	EC	ADQ
Styrene	100-42-5	1.39E-01	EC	ADQ
Methanol	67-56-1	2.03E-03	EC	ADQ
Hydrogen Peroxide	7722-84-1	2.89E-03	EC	ADQ
Methyl Ethyl Ketone	78-93-3	5.79E-03	EC	ADQ

EC: Engineering Calculation

ADQ: Average Data Quality

References

- 1) Spray rates provided by Structural Composite Technologies. January 14, 2014 and February 19, 2014. via e-mail.
- 2) MSDSs provided by Structural Composite Technologies. January 23, 2014. via e-mail.
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Table E3-1. AERMOD Outputs (24-h results)

Contaminant	CAS #	EF1		EF2		EF3		EF4		VS1		VS2		VS3	
		Emission Rate (g/s)	Dispersion Factor 177 ug/m3	Emission Rate (g/s)	Dispersion Factor 232 ug/m3	Emission Rate (g/s)	Dispersion Factor 288 ug/m3	Emission Rate (g/s)	Dispersion Factor 323 ug/m3	Emission Rate (g/s)	Dispersion Factor 989 ug/m3	Emission Rate (g/s)	Dispersion Factor 638 ug/m3	Emission Rate (g/s)	Dispersion Factor 637 ug/m3
Styrene	100-42-5	1.39E-01	2.47E+01	1.39E-01	3.23E+01	1.86E-01	5.36E+01	1.39E-01	4.50E+01	-	-	-	-	-	-
Nitrogen Oxides	10102-44-0	-	-	-	-	-	-	-	-	2.96E-03	2.93E+00	2.96E-03	1.89E+00	1.48E-03	9.44E-01
Methanol	67-56-1	2.03E-03	3.59E-01	2.03E-03	4.69E-01	2.03E-03	5.84E-01	2.03E-03	6.54E-01	-	-	-	-	-	-
Hydrogen Peroxide	7722-84-1	2.89E-03	5.13E-01	2.89E-03	6.70E-01	2.89E-03	8.34E-01	2.89E-03	9.34E-01	-	-	-	-	-	-
Methyl Ethyl Ketone	78-93-3	5.79E-03	1.03E+00	5.79E-03	1.34E+00	5.79E-03	1.67E+00	5.79E-03	1.87E+00	-	-	-	-	-	-
Particulate Matter	n/a	8.44E-03	1.50E+00	8.44E-03	1.95E+00	8.76E-03	2.52E+00	8.44E-03	2.73E+00	-	-	-	-	-	-

$$\begin{aligned}
 \text{Styrene POI Concentration} &= \text{Sum} [(\text{emission rate from source group}) \times (\text{dispersion factor for source group})] \\
 &= (0.139 \text{ g/s} \times 177 \text{ } (\mu\text{g}/\text{m}^3)/(\text{g}/\text{s})) + (0.139 \text{ g/s} \times 232 \text{ } (\mu\text{g}/\text{m}^3)/(\text{g}/\text{s})) + (0.186 \text{ g/s} \times 288 \text{ } (\mu\text{g}/\text{m}^3)/(\text{g}/\text{s})) + (0.139 \text{ g/s} \times 323 \text{ } (\mu\text{g}/\text{m}^3)/(\text{g}/\text{s})) \\
 &= 156 \text{ } \mu\text{g}/\text{m}^3
 \end{aligned}$$

Table E3-1. AERMOD Outputs (24-h results)

Contaminant	CAS #	VS4		VS5		VS6		VS7		VS8		Total POI Concentration ($\mu\text{g}/\text{m}^3$)
		Emission Rate (g/s)	Dispersion Factor 468 $\mu\text{g}/\text{m}^3$	Emission Rate (g/s)	Dispersion Factor 394 $\mu\text{g}/\text{m}^3$	Emission Rate (g/s)	Dispersion Factor 353 $\mu\text{g}/\text{m}^3$	Emission Rate (g/s)	Dispersion Factor 340 $\mu\text{g}/\text{m}^3$	Emission Rate (g/s)	Dispersion Factor 1928 $\mu\text{g}/\text{m}^3$	
Styrene	100-42-5	-	-	-	-	-	-	-	-	-	-	1.56E+02
Nitrogen Oxides	10102-44-0	1.17E-02	5.49E+00	4.67E-02	1.84E+01	3.20E-02	1.13E+01	4.67E-02	1.59E+01	5.34E-03	1.03E+01	6.71E+01
Methanol	67-56-1	-	-	-	-	-	-	-	-	-	-	2.07E+00
Hydrogen Peroxide	7722-84-1	-	-	-	-	-	-	-	-	-	-	2.95E+00
Methyl Ethyl Ketone	78-93-3	-	-	-	-	-	-	-	-	-	-	5.90E+00
Particulate Matter	n/a	-	-	-	-	-	-	-	-	-	-	8.70E+00



Draft Guide to the Estimation and Permitting of Particulate Emissions from the Manufacture of Reinforced Plastic Composites

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ECRM

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1. Introduction

Among the substances routinely emitted from composite plastics fabrication plants, particulate matter has received little attention. Because USEPA does not consider this industry to be a significant contributor to the nationwide particulate emission inventory, the agency has sponsored no research to develop or catalog particulate emission factors for this industry. Nevertheless, all states regulate these emissions and enforce compliance through terms and conditions specified on air permits. All but the very smallest composites plants are required to have air permits, so the need for guidance on this subject is critical. Accordingly, the Composite Fabricators Association (CFA) retained Environmental Compliance and Risk Management (ECRM) to develop practical guidance on the estimation and permitting of particulate matter emissions from typical composite fabrication plants.

This report provides an initial overview of current Federal and state regulations affecting particulate sources, and then addresses particulate emissions from the following processes:

- Application of gel coat, resin and reinforcement during open molding.
- Application of paints and coatings to formed parts.
- Sawing, grinding, and surface finishing of formed parts.

For each process, methods are presented to calculate allowable particulate emissions (based on state rules), potential emissions (based on maximum process throughput), and actual emissions. All critical assumptions are addressed. This report is best used in conjunction with the Excel spreadsheet workbook “PM Emission Calculation” to complete and document all estimates. “Screen shots” of that workbook are included as technical exhibits to illustrate the methods presented. The fully documented workbook can be downloaded from the CFA website as a separate file.

The overriding goal of this guidance is to simplify the acquisition of air permits for particulate sources. Sound practice requires that a regulator only grant a permit if convinced that enforcement of applicable emission limitations will be ensured by compliance with permit conditions, i.e. that emissions calculated as specified in the permit would not exceed allowable emissions. Permittees must therefore convince regulators that emissions would not be underestimated during such calculations. The easiest approach is to calculate emissions based on the most conservative assumptions that do not yield an exceedance or trigger a new requirement. This guidance presents methods whereby allowable emissions may be quickly compared to maximum potential emissions calculated using any given set of assumptions. It also provides a way for users to “work backward” by calculating the least conservative value of any parameter that will ensure compliance with a given limit.

2. Regulation of Particulate Emissions

USEPA defines particulate matter emissions as “all finely divided solid or liquid material, other than uncombined water, emitted to the ambient air as measured by applicable reference methods.”[1]. Particulates actually consist of three overlapping but separately regulated entities: total suspended particulates (TSP), inhalable particulate matter less than 10 microns in diameter (PM10), and fine particulate matter less than 2.5 microns in diameter (PM2.5).

All forms of particulate emissions are Federally regulated as *criteria pollutants*, so called because USEPA has set concentration-based National Ambient Air Quality Standards (NAAQS) for each based on a published criteria document. Nationwide, USEPA has classified each county relative to attainment of each standard. For PM10 and PM2.5, NAAQS have been set at two levels, primary and secondary. Primary standards are designed protect public health, secondary standards to protect environmental values. For TSP, there is only a secondary standard.

Under Title 1 of the CAA, USEPA oversees the development by each state of an implementation program (SIP) that includes provisions (state regulations) designed to ensure that each region achieves and maintains compliance with all ambient standards. SIPs currently address only TSP and PM10. SIP provisions for PM 2.5 have been delayed by court action and the lack of a Federal Reference Method for emission analysis. Until such provisions are developed by states and approved by USEPA, the regulated community will be unaffected by the PM2.5 standard.

In practice the distinction between TSP and PM10 is somewhat blurred. Since few emission sources have reliable PM size distribution data, common permitting practice assumes that TSP equals PM10, i.e. all PM is PM10. Further, “default” efficiencies accepted by regulators for typical PM control devices reflect expected performance on airstreams laden with PM10. In effect, all PM emissions at any facility are simultaneously covered by all rules targeting both TSP and PM10. For these reasons, this report refers to both TSP and PM10 as PM.

For PM, all SIPs now include regulations that limit emissions from various source categories, and enforce those limitations through air permit programs. These programs require facilities to obtain one-time certificates or permits to construct or modify PM sources, and renewable permits to operate them. SIPs also include regulations that mirror Federal rules targeting major PM sources and new sources subject to performance standards (NSPS).

For composite fabricators, a major source of PM would be any plant (or process within a plant) with potential to emit (at full permitted capacity and control level) more than 250 TPY if located in a PM attainment area, and a lower level (generally 100 TPY, but less in some areas) if located in a nonattainment area. Given the nature of composite fabrication, few such plants will be major PM sources, and most of those will be located in areas where PM nonattainment is severe. Further, no current or proposed NSPS covers PM emissions from composite fabrication. For these reasons, neither Federal major PM source rules nor NSPS will be considered further.

State PM rules of concern to composite fabricators are those that limit general process emissions. Most states derive allowable emission limits as a numerical function of process rate, the rate in tons per hour at which all materials (not just PM) flow through the process. A small minority of states set PM limits based on concentration at the stack or, as determined by dispersion modeling, at some point offsite. However derived, these limits are enforced through air permits.

Composite fabricators emitting more than 10 tons of the hazardous air pollutant (HAP) styrene, 25 tons of total HAP, or (generally) 100 tons of volatile organic compounds will require special air permits under Title V of the CAA. Even if plants are minor PM sources, such permits must include applicable PM limits enforced by rigorous recordkeeping and exceedance reporting.

3. Composite Fabrication Processes Emitting PM

Reinforced plastic composites consist of a mixture of fibrous reinforcement that provides strength and plastic matrix that binds and protects the reinforcement. Composites may be formed (laid up) in molds as laminates (layers of matrix and reinforcement) or cast in molds as homogeneous mixtures. For most products fiberglass is used as reinforcement, although carbon and aramid fibers have gained acceptance in specialized applications. Reinforcement may be incorporated within products in three forms: as randomly oriented chopped fibers, woven cloth, or fiber bundles (roving). Plastic matrix is formed from the curing (chemical reaction) of liquid resin mixture, which contain a blend of resins (unconnected plastic subunits), monomers (connecting links between subunits), and various agents that promote curing and affect the properties of the resin mix. Fillers may also be added to a resin mix to improve fire rating or other physical characteristics. During the curing process, the resins polymerize (connect through monomer crosslinkage) to form a tough solid plastic [2].

Operations at a typical composites plant may include any of the following process categories:

- Mixing of resins and pastes, and production of sheet or bulk mold compounds.
- Primary fabrication (molding) of unfinished parts, through a variety of processes.
- Secondary operations such as sawing of parts or core material, grinding and polishing.
- Painting of finished formed parts.
- Cleanup via knockdown of dust deposited on surfaces within the plant.

Mixing/compounding emissions are the subject of a separate CFA-sponsored report. Dust cleanup emissions are extremely difficult to characterize. Clearly, fugitive dust heavy enough to settle out within a plant will resuspend if disturbed, then resettle. Good housekeeping practices can minimize dust resuspension. However, if compressed air is used to knock down dust, essentially all of it will be resuspended, and significant quantities could be emitted before resettling. Exactly how much is determined by site-specific conditions that cannot be generalized. It is sound practice to minimize cleanup emissions by improving capture efficiency of local process exhausts and avoiding cleanup methods, such as use of compressed air, that excessively mobilize dust.

Given the above limitations, ECRM has focused this report on primary, secondary, and painting operations. Within these, PM may be emitted wherever fine solids are produced. Note that although it is theoretically possible for some portion of emitted styrene vapor to condense to form very fine particulate (PM_{2.5}), there is no firm evidence of this mechanism, and it will not be considered further.

The various primary fabrication processes fall (for the most part) into two classes. In open molding, resin and reinforcement are applied to one-sided molds, producing parts with one “good” side (facing the mold surface). In closed molding resin and reinforcement are either placed and pressed, injected or drawn through sealed molds, resulting in parts which are good on all sides.

Among the many primary processes employed, only open molding via atomized spray application of resin or gelcoat is considered likely to emit significant PM. Here PM is produced as suspended resin droplets not deposited on part or mold surfaces. These free aerosols lose much of their free monomer and solidify. If chopper guns are used to disperse glass fibers within the resin stream, free glass particles could form. However, these particles are likely to be too

large to remain suspended long enough to be emitted as PM of regulatory significance [3]. Similarly, there are no PM emissions generated during application of resin or gelcoat by flowcoaters, by hand, or any other method that does not atomize applied liquid, because droplets small enough to become suspended or entrained by ventilation airflows virtually never form.

Secondary operations abrade the material removed, forming dry dust that can be carried outside the plant as PM emissions. Sawing “chews up” all of the material directly in front of the saw blade as it advances. Grinding to remove flashing or smooth edges can remove a great deal of material. However, because heavy sawing and grinding operations may be readily vented to filters and/or settling chambers, post-control PM emissions from such sources may be low.

At many facilities, the secondary operation emitting the most PM may be polishing [3]. Buffing compounds and the resulting abraded materials are fine-grained and hence easily suspended; moreover, the handheld polishing equipment typically used cannot easily be equipped with effective dust capture.

Conventional painting operations produce PM in the same way as does open molding: oversprayed paint droplets lose their solvent content to form fine paint aerosols.

4. Calculation of PM Emissions

This section presents methods to calculate allowable and potential PM emissions from primary, secondary, and painting processes. Potential and actual emissions calculated by the same equations (with different parameter values), hence the methods presented apply for both.

Since the ultimate goal of this guidance is to simplify permitting, the first issue to be resolved is whether permits are needed. While virtually all primary processes will require air permits, secondary processes may be exempt by definition or because potential uncontrolled emissions are below permitting thresholds. Before proceeding, users should check for such exemptions. If exemption is based on a permitting threshold, then the methods presented below should be used to calculate potential emissions for comparison.

The methods and formulas presented in this section have been incorporated within the Excel spreadsheet workbook “PM Emission Calculation,” hereafter referred to as the workbook. Examples given in Section 6 will illustrate the use of the workbook to calculate PM emissions at a hypothetical facility.

Allowable Emissions

Of the 48 continental states, 37 currently calculate allowable PM emissions (E) in pounds per hour based upon process rate (P), defined effectively as the weight in tons per hour at which raw materials flow through the process. The general equation employed by all such states is:

$$E = aP^b + c$$

where a, b, and c are constants specified in each rule. There are currently seven common sets of values for these constants, meaning that there are seven specific equations used to calculate allowable PM emissions by process rate. Most states employ one of these equations for existing sources below a defined process rate threshold (often 30 tons per hour) and another for new sources (constructed after the PM rule became effective), larger existing sources, and/or existing sources located in designated counties. For instance, allowable PM emissions in Michigan (per rule 336.1331 Table 32) are calculated as:

$$\begin{aligned} E &= 4.1P^{0.67} && \text{for } P < 30 \text{ tons per hour} \\ E &= 55P^{0.11} - 40 && \text{for } P \geq 30 \text{ tons per hour} \end{aligned}$$

The workbook allows the user to select the appropriate equation, from which allowable emissions are calculated for a given P.

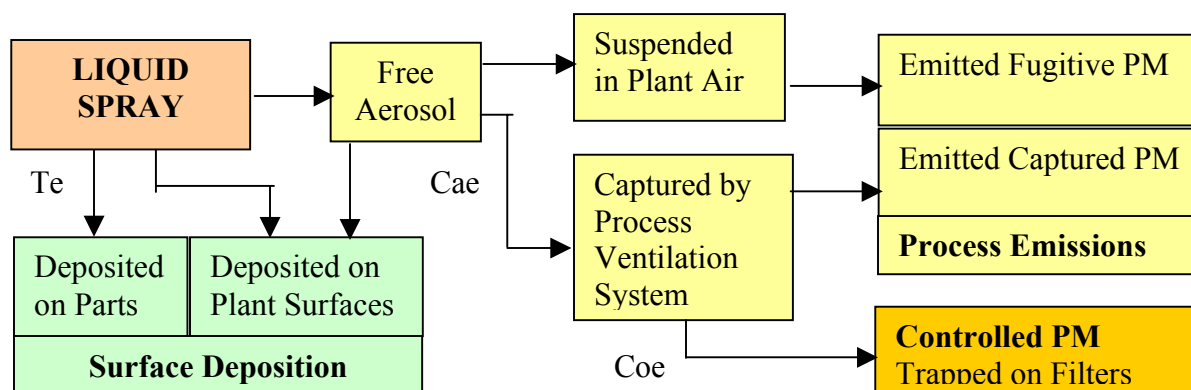
Most of the states that do not use process rate equations set allowable limits based on PM concentration in grains per dry standard cubic feet of process exhaust. For these sources, the workbook allows users to back-calculate allowable emissions in pounds per hour by specifying the concentration limit and dry process exhaust flow.

Remaining states (a small minority) set allowable PM emissions based on lookup tables or ambient PM concentration offsite estimated by dispersion modeling. The workbook does not support calculation of such site-specific limits.

Potential Emissions

PM Aerosols from Open Molding and Painting

As noted previously, spray application of liquids such as composite resins or paints to solid surfaces produces aerosols (fine droplets). The fate of this airborne material is depicted below.



Most of the liquid sprayed adheres to the part being coated. The ratio of liquid deposited on parts to liquid sprayed is commonly termed the transfer efficiency (Te). Another portion of the liquid sprayed settles immediately on part supports (hangers, mold flanges) and enclosure surfaces. The balance floats free; some being captured by the process ventilation system, with the remainder either settling out within the plant or being carried outside along with general plant ventilation airflow. Captured process air is typically routed to a fibrous filter to which most of its PM adheres (i.e. is controlled); the rest is released as process exhaust.

Assuming that none of the aerosol settling inside the plant is resuspended long enough to be emitted and none of the volatiles (resin monomers or paint solvents) remain in the emitted PM, we can calculate PM emissions from liquid spray processes by Equation 1 [adapted from Reference 4]:

$$E = [\text{Captured Emissions}] + [\text{Fugitive Emissions}]$$

$$E = [MS(1-De)Cae(1-Coe)] + [MS(1-De)(1-Cae)] \tag{Eq.1}$$

Where:

- E = PM emission rate, pounds per hour
- M = Usage rate of material sprayed, pounds per hour
- S = Solids content, expressed as a ratio
- De = Deposition efficiency of material on surfaces, ratio
- Cae = Capture efficiency of process ventilation system, ratio
- Coe = PM control efficiency of process ventilation system, ratio

Potential to emit PM is determined by evaluating the above equation at maximum M and S (worst-case liquid) for given De, Cae, and Coe. For resins with monomer content M (ratio), S may be estimated as (1-M). For paints, S may be estimated in terms of VOC content V (pounds per gallon) and paint density D (pounds per gallon) as (1-V/D).

Particulate mass transfer is dominated by surface deposition, so it is critical to estimate De realistically. Clearly, deposition efficiency De is somewhat greater than transfer efficiency Te; the bulk of the particulate deposited on surfaces will be transferred to parts. The non-transfer portion of deposition will vary with spray droplet size, density, airflow, and room configuration. Te itself is a function of part geometry, equipment configuration/setup, and operator skill. For resin application, CFA has devised a set of “Controlled Spray” procedures designed to reduce overspray and minimize atomization of resin. In a recent study conducted by the Indiana Clean Manufacturing Technology and Safe Materials Institute [5], strict adherence to Controlled Spray techniques increased transfer efficiency from 92% to 99%. On this basis, deposition efficiency could approach 95% for uncontrolled spray, and exceed 99% for controlled spray.

How reasonable are claims of deposition efficiency exceeding transfer efficiency? Calculate the assumed quantity of particulate accumulating on non-parts as $MS(De-Te)$. That value must be consistent with observed conditions within the facility. For instance, if we employ non-controlled spray application of 100 pounds per hour resin at 50% solids, and we claim that deposition efficiency is 95% given a transfer efficiency of 92%, then $(100)(0.5)(0.95-0.92) = 1.5$ pounds per hour would be deposited on surfaces somewhere in the plant. If resin is applied for 2000 hours annually, then 3,000 pounds of solids would accumulate each year unless removed.

Capture efficiency Cae is dependent on process vent airflow, the proximity of vent pickups to the spray operation, and extent to which baffles or enclosures (booths) isolate the process from crossflows. Capture efficiency may be determined by enclosing the process within a temporary total enclosure and performing an emission test as specified in USEPA Method 204 [6]. Such tests are costly, time-consuming, and hence best avoided. As spray enclosures approach Method 204 enclosures in performance, capture efficiencies should approach 100%. For processes served by ventilation systems designed per practices recommended by ACGIH [7] a capture efficiency of at least 80% may be assumed. At least one state (Minnesota) has formalized acceptance of this assumption in permit rules [8].

Control efficiency Coe will typically be 95% or higher for spray aerosols, as long as filter media are properly sized, installed, and replaced. Many states require that differential pressure be monitored across filter media to establish a normal operating range, and then require reporting of excursions from this range. Regulators will assume that systems operating within their normal range are providing the control efficiency claimed in permit applications. Alternatively, states may allow operators to determine a filter replacement frequency sufficient to ensure that differential pressure remains within range, and then incorporate the resulting replacement schedule in the permit. Finally, some states will assume that PM controls are effective if installed as designed and operated/maintained in accordance with a program defined by the facility. These accommodations eliminate the need to conduct emission tests for compliance demonstration, and greatly simplify recordkeeping. All such options should be explored.

The workbook allows users to calculate captured, fugitive, and total PM emissions using the equation presented above. Users enter values for M, S, Te, and Cae and select Coe based on filter medium.

PM Emissions from Secondary Operations

Equation 1 may be simplified for use on secondary processes such as grinding, sawing, and finish polishing. Here we define M as the rate of material abrasion in pounds per hour. All of this is solid matter, so $S = 1$ and can be ignored. Since this material is being removed rather than deposited to make good parts, De now represents settling of fugitive dust within the plant. PM emissions from such processes can be calculated using Equation 2:

$$\begin{aligned} E &= [\text{Captured Emissions}] + [\text{Fugitive Emissions}] \\ E &= [M(1-De)Cae(1-Coe)] + [M(1-De)(1-Cae)] \end{aligned} \quad (\text{Eq.2})$$

The workbook enables users to calculate secondary process emissions by entering equation parameters. The workbook uses Equation 1, but once the subject operation is tagged by the user as secondary, it automatically enters a value of 1 for S.

Deriving Worst-Case Parameter Values for Given Allowable Emissions

Sometimes it is useful to know the highest or lowest value of a parameter such that calculated potential emissions equal allowable emissions. Given that allowable and values for all other parameters in Equation 1, that “worst-case” parameter value can be calculated by backsolving Equation 1 for the desired value. This yields five equations, each of which is incorporated within Table 3 of the workbook, the Backsolver.

For instance, consider a buffing process removing solids at a rate of 100 pounds per hour, in a process with a calculated permit-allowable emission rate of 9.03 pounds per hour. If deposition efficiency is 50% and capture efficiency is determined to be 90%, Equation 5 can be used to calculate the lowest control efficiency (Coe) that must be provided so that potential emissions do not exceed allowable emissions. The resulting value is 91%. Suppose we provide that level of control, but the state drops the allowable PM limit for this process to 4.5 pounds per hour. Backsolver calculates the maximum solids removal rate that can be permitted to be just under 50 pounds per hour as the process is currently configured.

Example Calculations Using the Workbook

The following pages illustrate use of the workbook form, including data from a hypothetical plant with two primary resin spray operations, two paint spray booths, and two secondary operations. Operating parameters have been entered to illustrate the way the form works, and are not meant to represent real-world shop conditions.

Table 1 of the workbook is depicted below, along with accessory Lookup Tables 1A and 1B. Note that onscreen the lookup tables are to the right of the supported main table. Source descriptions and parameter values are entered in the unshaded cells. Column headers shaded green indicate entries that users must choose from lookup tables, also shaded green. Values displayed in other shaded cells are either copied from Table 1 (plain text in tan cells), copied from lookup tables (plain text in green cells) or final calculation results (bold text in yellow cells).

Table 1: ALLOWABLE PARTICULATE MATTER (PM) EMISSIONS										
Enter for All Sources			Enter for Process Weight-Based Limits				Enter for Conc. Limits		PM Allowable (E), lb/hr	
Source #	Description	Process Code (Table 1A)	Process Rate (P), ton/hr	Process Rate Eq # (Table 1B)	Equation Constants			Vent Dry SCFM		Limit gr/DSCF
					a	b	c			
1	Gel Coat Booth	rs	5.00	1	3.59	0.62	0.00			9.74
2	Lamination	rs	6.00	3	4.10	0.67	0.00			13.62
3	Paint Spray Booth 1	ps	40.00	4	55.00	0.11	-40.00			42.53
4	Paint Spray Booth 2	ps						10,000	0.05	4.29
5	Part Cutoff Saw	sf	3.00	8	4.00	0.70	0.00			8.63
6	Finishing	sf	2.38	6	5.05	0.67	0.00			9.03

Table 1A: Process Codes		
Code	Process	Mat'l Generating PM
rs	Resin Spray	Resin Applied
ps	Paint Spray	Paint Applied
sf	Secondary Fabrication	Fine Material Abraded

Table 1B: Equation E = a*P^b + c			
Eq #	Process Rate Constants		
	a	b	c
1	3.59	0.62	0
2	17.3	0.16	0
3	4.1	0.67	0
4	55	0.11	-40
5	2.54	0.534	0
6	5.05	0.67	0
7	66	0.11	-48
8	4	0.7	0

E = Allowable PM Emissions, lb/hr
P = Process Rate, ton/hr
a,b,c = constants

If other constants needed, insert in this row

Use Table 1 to calculate allowable PM emissions in lb/hr based on either process rate or exhaust concentration, whichever is appropriate in your state -consult the rules.

Table 2 is used to calculate potential emissions. Here source descriptions have been carried over from Table 1, and parameter values are entered in unshaded cells. Other cells display as before. If total potential emissions exceed the allowable emissions calculated in Table 1, the value is displayed in bold red text. Again, the accessory table (2A) is normally displayed onscreen to the right of the main table.

For secondary operations, “Mat’l Rate” (M in Equation 2) is sometimes hard to quantify. For sawing operations it can be calculated as (saw-cut width or kerf) x (saw cut length) x (saw cut depth) x (density) x (parts sawed per hour). For finishing operations, it can be calculated as (part area abraded) x (depth of abraded layer) x (density of abraded material) x (parts finished per hour). Alternatively, where operations are served by a dust collector, one can measure D, the rate at which dust is collected during part processing (pounds dust per hour). Then M may be estimated as D/(CoeCae).

Source #	Description	Material Generating PM	Matl Rate, lb/hr	Solids Content	Deposition Efficiency	Capture Efficiency	Control Code (Table 2a)	Control Efficiency	PM Emitted, lb/hr		
									Captured (Stack)	Uncaptured (Fugitive)	TOTAL
1	Gel Coat Booth	Resin Applied	400.00	56.0%	99.0%	80.0%	ff	95.0%	0.09	0.45	0.54
2	Lamination	Resin Applied	600.00	65.0%	95.0%	80.0%	ff	95.0%	0.78	3.90	4.68
3	Paint Spray Booth 1	Paint Applied	500.00	55.0%	85.0%	80.0%	ff	95.0%	1.65	8.25	9.90
4	Paint Spray Booth 2	Paint Applied	240.00	48.0%	75.0%	80.0%	ff	95.0%	1.15	5.76	6.91
5	Part Cutoff Saw	Fine Material Abraded	2.00		50.0%	50.0%	cf	99.0%	0.01	0.50	0.51
6	Finishing	Fine Material Abraded	100.00		50.0%	90.0%	oth	75.0%	11.25	5.00	16.25

NOTE: PM EMISSIONS EXCEEDING ALLOWABLES ARE DISPLAYED IN BOLD RED

Code	PM Control	Efficiency
cf	Cloth Filter	0.99
ff	Fiber Filter	0.95
cyh	Cyclone -HE	0.90
cym	Cyclone - ME	0.80
cyl	Cyclone - LE	0.60
na	No Control	0.00
oth	Other	0.75

For other control measures, enter efficiency value in lower right cell above.

Table 3, the Backsolver, is used to calculate the worst-case value for any of the five process parameters such that potential emissions just equal a given allowable level at given values for the other four parameters. Two examples are shown.

In the first example, we backsolve for the lowest acceptable control efficiency, based on the allowable rate and other parameters from Table 1.

Table 3: BACKSOLVER										
Source#	Description	Allowable PM, lb/hr	Matl Rate, lb/hr	Solids Content	Deposition Efficiency	Capture Efficiency	Control Efficiency	Value of Unknown at Allowable PM, Given Known Values		Use Other Allowable? y/n
6	Finishing	9.03	100.00	1.00	0.500	0.900	?	0.910	Control Efficiency	n
Note: Enter Source#, then any four parameter values. For unknown, enter ?										

Note that the user enters the Source# number first, the same number used in Tables 1 and 2. The Description (of the source) is automatically carried over. The user then enters values for the known parameters (Matl Rate, Solids Content, Deposition Efficiency, and Capture Efficiency), and “?” for the unknown parameter to be solved for (Control Efficiency). As long as the value in the “Use Other Allowable?” field is “n”, the allowable emission rate calculated in Table 1 is copied into the “Allowable PM” field and used along with other known parameters to calculate the unknown, which is indicated in bold text in the cells shaded yellow.

In the second example, we backsolve the highest acceptable process rate, but based on an alternative value of the allowable level specified by the user. This would be useful to evaluate the impact of proposed rules reducing allowable PM on permitted production levels.

Table 3: BACKSOLVER											
Source#	Description	Allowable PM, lb/hr	Matl Rate, lb/hr	Solids Content	Deposition Efficiency	Capture Efficiency	Control Efficiency	Value of Unknown at Allowable PM, Given Known Values		Use Other Allowable? y/n	Enter Lb/Hr Here
6	Finishing	4.50	?	1.00	0.500	0.900	0.910	49.724	Matl Rate, lb/hr	y	4.5
Note: Enter Source#, then any four parameter values. For unknown, enter ?											

Note here that we enter “y” in the “Use Other Allowable?” field, which opens a field in which to enter the allowable value in pounds per hour. This value is then copied over into the “Allowable PM” field and used as before to calculate the unknown.

5. References

1. 40 CFR 51.100
2. Lipiro, D.J., "Non-Economic Impacts on the Reinforced Plastic Composites Industry of Emission Control by Oxidation Systems," Composite Fabricators Association, April 2000.
3. Haberlein, R.A., personal communication.
4. Emission Inventory Improvement Program, Volume II, Chapter 8, USEPA, 1998
5. "The Effectiveness of Controlled Spray Training in the Fiber Reinforced Plastics Industry," Pollution Prevention Review, Winter 2001. Available for download at www.enc.purdue.edu/CMTI
6. 40 CFR Part 51, Appendix M
7. Industrial Ventilation – A Manual for Recommended Practices, 21st Edition, ACGIH
8. Minnesota Air Pollution Control Agency, Permit Application Form CR-02

Open Molding Emission Calculation Instructions

Instructions for Composite Resin Open Molding Operation Emission Calculations

- 1) These spreadsheets are designed to help you determine the potential to emit for composite resin open molding operations. There are many ways in which you can calculate emissions from open molding operations. This spreadsheet is provided as an example and may be modified to fit your needs.
- 2) Calculate the potential gallons of throughput for each material by using the following equation:
$$(8,760 \text{ hours}) / (\text{actual annual hours of operation}) \times (\text{actual annual throughput}) = \text{potential gallons of throughput.}$$

If you do not have information on actual hours of operation and actual annual throughput, you can estimate your potential throughput by the output capacity of your spray guns or by the predicted amount of material you would consume operating your facility 8,760 days a year at full capacity. If you have questions in determining your potential throughput, call the Air Quality Division at (877) 834-0474 or (402) 471-2189.
- 3) For each material, enter the specific gravity, density of the material and percentage of volatile organic compounds (VOC). This information will be included on your material safety data sheets (MSDS) or environmental data sheets. If the MSDS does not include the density of the material, multiply the specific gravity by 8.34. An example is provided in cells F8 and G8. The VOC emissions will be calculated automatically for each material. Add columns as necessary to account for all of the materials utilized.
- 4) Enter the weight percent of hazardous air pollutants for each material. This information will be included on your MSDS sheets or environmental data sheets. If a range is given, you must use the highest value.
- 5) Enter the appropriate UEF emission factor from the UEF Table Worksheet and the application method. The UEF emission factors are categorized depending on the method of application and the amount of styrene and methyl methacrylate present in the material. The Composites Fabricators Association and EPA developed these emission factors to better represent the emissions from open molding processes. The UEF Table is dated 7/23/01.
- 6) The potential emissions will be calculated in the yellow shaded boxes for each pollutant and each material. The emissions summary for each pollutant and the total HAPs in pounds is located in cells H28 through H33. The totals in tons are located in column I.

DISCLAIMER: NDEQ does not guarantee the accuracy and is not responsible for errors/omissions in the information contained herein. All calculations are subject to review by NDEQ.

Open Molding Emission Calculation Instructions

7) You will also have to calculate the particulate matter (PM) and particulate matter less than 10 microns (PM10) emissions for your facility. PM and PM10 emissions are generated from spraying resins and gel coats and from trimming and sanding resin parts. Use the PM & PM10 worksheet to calculate your emissions. The annual throughput of resins and gel coats can be referenced from the Open Molding Worksheet as in this example. You will need to enter the percent solids of each material found on the MSDS sheet. The estimated controlled and uncontrolled emissions will be automatically calculated. To calculate the trim booth emissions, enter the amount of fiberglass consumed per year. The amount of resins and gel coats are summed in this example for you (B6:E6). It is assumed that 1% of the material used will be emitted from abrasion processes (sanding, grinding, sawing, and trimming).

8) If you have other composite resin processes such as hand layup, spray layup, continuous lamination, pultrusion, filament winding, marble casting, closed molding, bulk resin storage, and bulk resin mixing, use the emission factors provided below. If you have questions calculating the potential emissions from these other operations, please contact the Air Quality Division at (877) 834-0474 or (402) 471-2189.

EMISSION FACTORS FOR POLYESTER RESIN PRODUCT FABRICATION**				
	Resin		Gel Coat	
	NonVapor-Suppressed	Vapor-suppressed	NonVapor-Suppressed	Vapor-suppressed
Hand Layup (weight % emitted)	10	7	35	25
Spray Layup (weight % emitted)	13	9	35	25
Continuous Lamination (weight % emitted)	7	5		
Pultrusion (weight % emitted)	7	5		
Filament Winding (weight % emitted)	10	7		
Marble Casting (weight % emitted)	3	2		
Closed Molding (weight % emitted)	3	2		
Resin Storage (bulk) (lb/ton)	0.059			
Resin Mixing (bulk) (lb/ton)	0.78			

** The emission factors for resin processes are from AP-42 4.4-2 1/95. The bulk resin storage and mixing are from Composite Fabricators Association Emission estimates for SMC compounding and molding 7/01.

9) Save a copy of your maximum potential emission calculations electronically and as a printout. If you need to apply for a permit, please submit a copy of your calculations with your permit application. Please note that if your operations change, you will have to reevaluate if you need an air quality permit. If you have any questions, please call the Air Quality Division at (877) 834-0474 or (402) 471-2189.

DISCLAIMER: NDEQ does not guarantee the accuracy and is not responsible for errors/omissions in the information contained herein. All calculations are subject to review by NDEQ.

Open Molding Potential Emissions Calculations

Open Molding VOC & HAP Emission Calculations								
	Resins		Gel Coat		Other chemicals used		Total Emissions (lbs/yr)	Total Emissions (tons/yr)
	H834-RWA-30 Resin	Mod Vinyl Ester Resin	Polycor Black Tooling	Polycor L/F Orange Tooling	Black Hi Gloss Coating	Clear Hi-Gloss Additive		
Annual Throughput (gal/yr)	4630.00	49.00	5.00	5.00	1.00	1.00		
Specific gravity	1.10	1.30	1.08	1.09	1.07	1.02		
Density of chemical (lbs/gal)	9.18	10.84	8.99	9.10	8.92	8.51		
Annual Throughput (lbs/yr)	42498.8	531.16	44.96	45.50	8.92	8.51		
% VOC	35.00	44.90	47.65	47.60	38.60	47.80		
VOC emissions (lbs/yr)*	14874.57	238.49	21.42	21.66	3.44	4.07	15163.65	7.58

*The VOC emissions is the total of the HAPs, unless a non-HAP VOC has been identified.

WEIGHT PERCENT OF HAZARDOUS AIR POLLUTANTS

Pollutant (CAS #)						
Cobalt Compounds	1.00					
Methyl ethyl ketone (78933)					6.30	14.20
Methyl methacrylate (80626)			4.00	6.00		
Styrene (100425)	35.00	44.90	43.65	41.60	32.10	33.60
Xylenes (1330207)					0.20	

OPEN MOLDING EMISSION FACTORS FROM THE UEF TABLE (LBS/TON)**

Methyl methacrylate (80626)			60.00	90.00		
Styrene (100425)	77.00	108.00	522.00	481.00		
	Mechanical Non-atomized	Mechanical Non-atomized	Mechanical Atomized	Mechanical Atomized		

ESTIMATED POTENTIAL EMISSIONS FOR HAZARDOUS AIR POLLUTANTS

Pollutant (CAS #)	(lbs/year)	(lbs/year)	(lbs/year)	(lbs/year)	(lbs/year)	(lbs/year)	(lbs/yr)	(tons/yr)
Cobalt Compounds	424.99	0.00	0.00	0.00	0.00	0.00	424.99	0.2125
Methyl ethyl ketone (78933)	0.00	0.00	0.00	0.00	0.56	1.21	1.77	0.0009
Methyl methacrylate (80626)	0.00	0.00	1.35	2.05	0.00	0.00	3.40	0.0017
Styrene (100425)	1636.20	28.68	11.73	10.94	0.00	0.00	1687.56	0.8438
Xylenes (1330207)	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.0000
Total:							2117.74	1.06

**The UEF factors are used by EPA for the MACT (NESHAP) for the Resin Composites which was promulgated April 21, 2003 (40 CFR 635780).

These factors were created by testing done by EPA and the Composites Fabricators Association, and their consultants.

The UEF factors used in the above calculations were dated July 23, 2001.

DISCLAIMER: NDEQ does not guarantee the accuracy and is not responsible for errors/omissions in the information contained herein. All calculations are subject to review by NDEQ.

Unified Emission Factors for Open Molding of Composites

July 23, 2001

Emission Rate in Pounds of Styrene Emitted per Ton of Resin or Gelcoat Processed

Styrene content in resin/gelcoat, % ⁽¹⁾	<33 ⁽²⁾	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	>50 ⁽²⁾
Manual	0.126 x %styrene x 2000	83	89	94	100	106	112	117	123	129	134	140	146	152	157	163	169	174	180	((0.286 x %styrene) - 0.0529) x 2000
Manual w/ Vapor Suppressed Resin VSR ⁽³⁾	Manual emission factor [listed above] x (1 - (0.50 x specific VSR reduction factor for each resin/suppressant formulation))																			
Mechanical Atomized	0.169 x %styrene x 2000	111	126	140	154	168	183	197	211	225	240	254	268	283	297	311	325	340	354	((0.714 x %styrene) - 0.18) x 2000
Mechanical Atomized with VSR ⁽³⁾	Mechanical Atomized emission factor [listed above] x (1 - (0.45 x specific VSR reduction factor for each resin/suppressant formulation))																			
Mechanical Atomized Controlled Spray ⁽⁴⁾	0.130 x %styrene x 2000	86	97	108	119	130	141	152	163	174	185	196	207	218	229	240	251	262	273	0.77 x ((0.714 x %styrene) - 0.18) x 2000
Mechanical Controlled Spray with VSR	Mechanical Atomized Controlled Spray emission factor [listed above] x (1 - (0.45 x specific VSR reduction factor for each resin/suppressant formulation))																			
Mechanical Non-Atomized	0.107 x %styrene x 2000	71	74	77	80	83	86	89	93	96	99	102	105	108	111	115	118	121	124	((0.157 x %styrene) - 0.0165) x 2000
Mechanical Non-Atomized with VSR ⁽³⁾	Mechanical Non-Atomized emission factor [listed above] x (1 - (0.45 x specific VSR reduction factor for each resin/suppressant formulation))																			
Filament application	0.184 x %styrene x 2000	122	127	133	138	144	149	155	160	166	171	177	182	188	193	199	204	210	215	((0.2746 x %styrene) - 0.0298) x 2000
Filament application with VSR ⁽³⁾	0.120 x %styrene x 2000	79	83	86	90	93	97	100	104	108	111	115	118	122	125	129	133	136	140	0.65 x ((0.2746 x %styrene) - 0.0298) x 2000
Gelcoat Application	0.445 x %styrene x 2000	294	315	336	356	377	398	418	439	460	481	501	522	543	564	584	605	626	646	((1.03646 x %styrene) - 0.195) x 2000
Gelcoat Controlled Spray Application ⁽⁴⁾	0.325 x %styrene x 2000	215	230	245	260	275	290	305	321	336	351	366	381	396	411	427	442	457	472	0.73 x ((1.03646 x %styrene) - 0.195) x 2000
Gelcoat Non-Atomized Application ⁽⁸⁾	SEE Note 9 below	196	205	214	223	232	241	250	259	268	278	287	296	305	314	323	332	341	350	((0.4506 x %styrene) - 0.0505) x 2000
Covered-Cure after Roll-Out	Non-VSR process emission factor [listed above] x (0.80 for Manual <or> 0.85 for Mechanical)																			
Covered-Cure without Roll-Out	Non-VSR process emission factor [listed above] x (0.50 for Manual <or> 0.55 for Mechanical)																			

Emission Rate in Pounds of Methyl Methacrylate Emitted per Ton of Gelcoat Processed

MMA content in gelcoat, % ⁽⁶⁾	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	≥20
Gel coat application ⁽⁷⁾	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	0.75 x %MMA x 2000

Notes

- Including styrene monomer content as supplied, plus any extra styrene monomer added by the molder, but before addition of other additives such as powders, fillers, glass,...etc.
-

Formulas for materials with styrene content < 33% are based on the emission rate at 33% (constant emission factor expressed as percent of available styrene), and for styrene content > 50% on the emission rate based on the extrapolated factor equations; these are not based on test data but are believed to be conservative estimates. The value for "% styrene" in the formulas should be input as a fraction. For example, use the input value 0.30 for a resin with 30% styrene content by wt.

- The VSR reduction factor is determined by testing each resin/suppressant formulation according to the procedures detailed in the *CFA Vapor Suppressant Effectiveness Test*.
- SEE the *CFA Controlled Spray Handbook* for a detailed description of the controlled spray procedures.
- The effect of vapor suppressants on emissions from filament winding operations is based on the *Dow Filament Winding Emissions Study*.
- Including MMA monomer content as supplied, plus any extra MMA monomer added by the molder, but before addition of other additives such as powders, fillers, glass,...etc.
- Based on gelcoat data from *NMMA Emission Study*.
- SEE the July 17, 2001 EECS report *Emission Factors for Non-Atomized Application of Gel Coats used in the Open Molding of Composites* for a detailed description of the non-atomized gelcoat testing.
- Use the equation $((0.4506 \times \%styrene) - 0.0505) \times 2000$ for gelcoats with styrene contents between 19% and 32% by wt.; use the equation $0.185 \times \%styrene \times 2000$ for gelcoats with less than 19% styrene content by wt.

PM/PM10 Calculations

PM/PM₁₀ Emission Calculations				
	<i>Resins</i>		<i>Gel Coat</i>	
	H834-RWA-30 Resin	Mod Vinyl Ester Resin	Polycor Black Tooling	Polycor L/F Orange Tooling
Annual Throughput (lbs/yr) (M)	42,498.77	531.16	44.96	45.50
% solids (S)	65	55.1	52.349	52.405
Deposition efficiency (uncontrolled spraying)(%) (De)	95	95	95	95
Capture efficiency of spray booth (%) (Cae)	80	80	80	80
PM/PM ₁₀ Control efficiency of filters (%) (Coe)	95	95	95	95
Non-deposited PM/PM ₁₀ emissions (uncontrolled) (lbs/year)	1,381.21	14.63	1.18	1.19
Total uncontrolled PM/PM ₁₀ emissions (lbs/year)	1398.21			
Total uncontrolled PM/PM ₁₀ emissions (tons/year)	0.7			
Estimated controlled PM/PM ₁₀ emissions (lbs/yr) (E)	480.24	5.9	0.5	0.5

Total controlled PM/PM₁₀ emissions (lbs/year) 487.14

Total controlled PM/PM₁₀ emissions (tons/year) 0.24

$$E = [\text{Captured Emissions}] + [\text{Fugitive Emissions}] = [\text{MS}(1-\text{De})(\text{Cae})(1-\text{Coe})] + [\text{MS}(1-\text{De})(1-\text{Cae})]$$

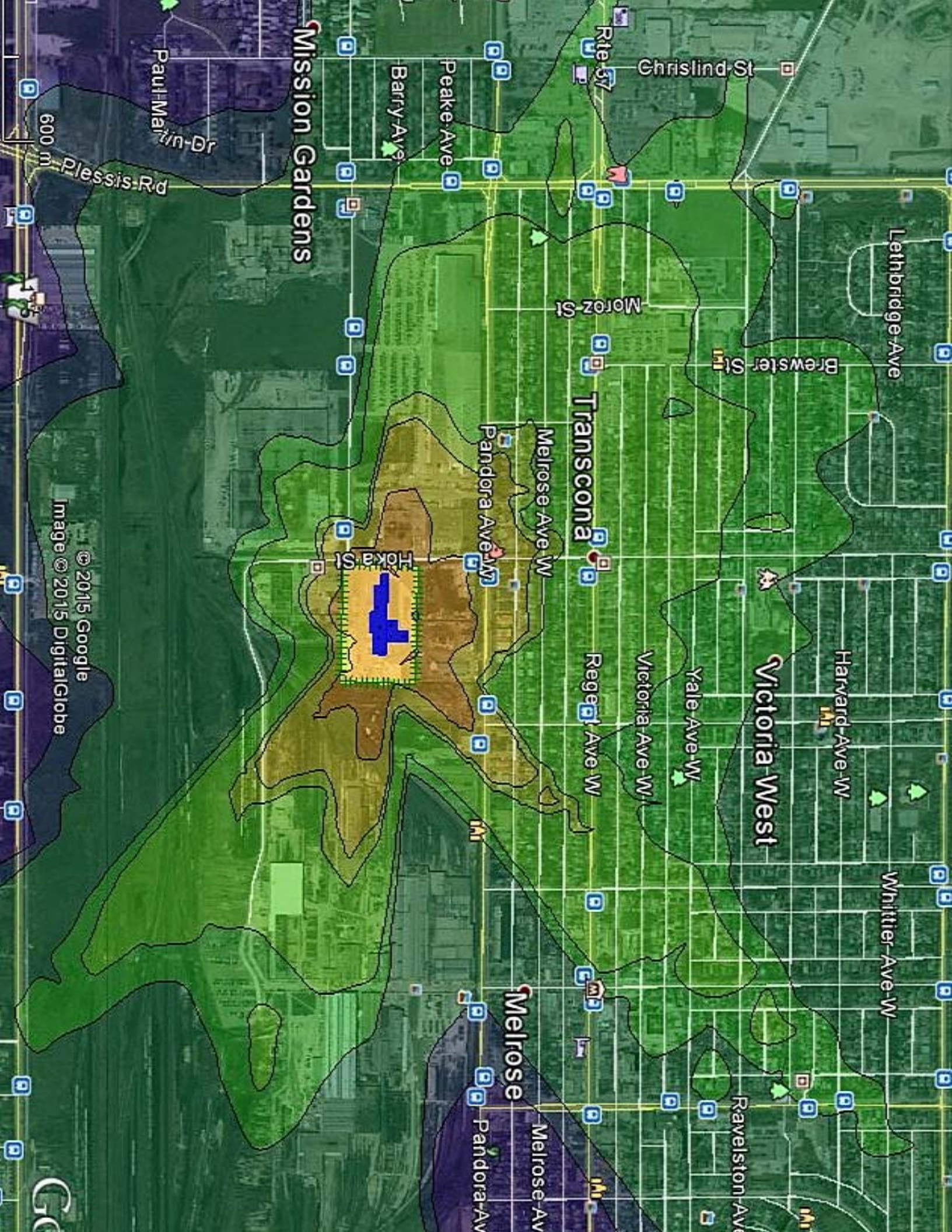
Where S, De, Cae, and Coe are in ratios (instead of percentages; use 0.95 for 95%).

Emission rate formula and default values for deposition efficiency, capture efficiency, and control efficiency are from the Composite Fabricators Association's, Draft Guide to the Estimation and Permitting of Particulate Emissions from the Manufacture of Reinforced Plastic Composites, August 2001.

Calculations for PM emissions from trim booths

Total actual gel coats & resins throughput =	43,120 lbs/yr
Total fiberglass throughput =	0 lbs/yr
Total annual throughput =	43,120 lbs/yr

Assume 1% is abraded from sanding, grinding, sawing, and buffing.	
Uncontrolled PM from trimming =	431.20388 lbs/yr
	0.22 tons/yr



Mission Gardens

Victoria West

Melrose

Transcona

Paul Malin Dr

Barry Ave

Peake Ave

Rie St

Chrislind St

Lethbridge Ave

Brewster St

Moroz St

Melrose Ave W

Pandora Ave W

Hoka St

Regent Ave W

Victoria Ave W

Yale Ave W

Harvard Ave W

Whittier Ave W

Ravelston Ave

Melrose Av

Pandora Av

600 m

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GC

DATE: September 16, 2014

TO: Eshetu Beshada
Environmental Approvals
Conservation and Water Stewardship
123 Main St Suite 160 (Box 80)
Winnipeg MB R3C 1A5

FROM: Environmental Compliance and Enforcement
Conservation and Water Stewardship
123 Main St Suite 160 (Box 60)
Winnipeg MB R3C 1A5

SUBJECT: Environment Act Proposal – Response to Comments – Structural Composite Technologies Ltd (Client File: 5594.00)

Environmental Compliance and Enforcement (Central Region) has reviewed the above noted Environment Act Proposal (EAP). Please find the following comments regarding the proposal.

1) Regarding Odour Emissions and Control:

- Please provide more information and detail regarding the reduction of the targeted odour sources. How much of a reduction is expected? How much of this has been implemented already?
- Please provide more details on how the spraying is controlled.
- Further options to reduce odours within the process may require future Notices of Alteration of the licence.

Beshada, Eshetu (CWS)

From: Ibn Azkar, Muntaseer (CWS)
Sent: September-15-14 1:07 PM
To: Beshada, Eshetu (CWS)
Cc: Molod, Rommel (CWS); Froese, Julie (CWS)
Subject: RE: File 5594 - Structural Composite Technology - EAP Review Comment Response

Hello Eshetu,

Air Quality Section has the following comments on the response received from SCT:

- If it is assumed that all PM is PM2.5, then the model result should compare with PM2.5 standard value. According to Manitoba Ambient Air Quality Criteria (MAAQC), 24-hour average PM2.5 standard is 30 $\mu\text{g}/\text{m}^3$. Model result of 24-hour average PM2.5 listed in Table A3 (Appendix A) is 52.5 $\mu\text{g}/\text{m}^3$ and in Table E3-1 (Appendix E) is 60.1 $\mu\text{g}/\text{m}^3$ which means predicted PM2.5 concentrations are not within the air quality guideline.
- Contour plots are not created separately. These plots should automatically come out as model output and can be used as an effective assessment tool for pollutant's dispersion.

Thanks for the opportunity to review.

Regards,

Muntaseer Ibn Azkar
Air Quality Specialist
Environmental Programs and Strategies Branch
Manitoba Conservation and Water Stewardship
1007 Century Street, Winnipeg MB R3H 0W4
Phone : 204 945 4102
Fax : 204 948 2420
Email : muntaseer.ibnazkar@gov.mb.ca

Beshada, Eshetu (CWS)

From: Tony Ma [<mailto:tma@sctfrp.com>]

Sent: September-05-14 4:09 PM

To: Beshada, Eshetu (CWS)

Subject: RE: File 5594 - Structural Composite Technology - EAP review Comments to be addressed

Hello Eshetu,

Please find attached our response to comments regarding our EAP. I apologize for the separate files. Our scanner was having problems scanning everything into a single file, therefore I had to break them up into individual files.

Regards,

Tony Ma, P. Eng.

Engineering Manager



tma@sctfrp.com

Ph. (204) 668-9320 ext. 207

Fax. (204) 663-9115

GDisclaimer:

The contents of this communication, including any attachment(s), are confidential and may be privileged. If you are not the intended recipient (or are not receiving this communication on behalf of the intended recipient), please notify the sender immediately and delete or destroy this communication without reading it, and without making, forwarding, or retaining any copy or record of it or its contents. Thank you.

- SCTL EAP**
- **Comments from MB Conservation and Water Stewardship (See attached two Memorandums from province.)**
 - **Comments from general public in surrounding neighborhood**

Comments from general public in surrounding neighborhood:

- 1- Why is the area in the EAP defined as "rural". The area is urban with residential condo units directly north of SCTL.
- 2- Why is the meteorological data used from the Bismark, North Dakota weather station? The predominant wind direction in Winnipeg is south especially in the summer month and this is when we have the greatest impact of the emissions from this plant. Using Winnipeg meteorological data would provide true local wind speeds and direction.
3. Why is the acetone not listed in the dispersion modelling? Acetone is 100% volatile and is a loss from the process. It should form part of the dispersion modeling and though it may occur over a very short time period, it should not be averaged over a longer time period.
4. With respect to Styrene and Duranap Cobalt 6, the dispersion model is insufficient. It appears to be done using the 24 hour criteria. I believe the industry standard is to use a ½ hour POI criterial and in the case of many odour causing chemicals, the modeling is done on 10 minute and 2 minute time periods. Why was the ½ hour POI limit not modeled? I also find it troubling that the highest modeling results were excluded from the report to account for extreme, rare and transient meteorological conditions. Although dispersion modeling regulations allow for the exclusion of the 8 highest readings, many consultants include them to reflect tur real world conditions. I think given the close proximity to residential housing, this would be an automatic inclusion.
5. We need actual ambient air testing and not modeling to truly assess these emissions.
6. The table for Worst-Case MSDS Material Blend for various contaminants states that the maximum emission is deemed insignificant or a number is stated. Are there related adverse health effects from this exposure?
7. The report notes, on several occasions, the resulting emission rates were multiplied by 12/24 to convert to a 24h averaging period, since the plant only operates for 12 hours, doesn't this conversion dilute the resulting average?
8. Emissions from resin spraying are vented through 1 of 4 general production exhausts, which are equipped with filters. Filter efficiency is estimated to be 20-30%. What happens to the rest of the 70 to 80% emissions?
9. Styrene levels are monitored in the plant (section 5.2-Monitoring and Reporting). What about the levels emitted to the outside?

10. The modelling includes anticipated emission levels for styrene, methanol, hydrogen peroxide, methyl ethyl ketone and particulate matter. How much of each is being released and what are the health risks associated with each of these emissions?
11. It states that polyvinyl alcohol (PVA) is used as a mold release agent that causes odours, and acetone is used for testing and cleanup. Why were these not included in the dispersion model?
12. Sanding and cutting parts cause dust particles, which can become airborne. How is this particulate filtered and what is the total quantity emitted to the outside air?
13. Table A3 – emission Summary Table provides an overview of specific emissions from the plant. What are the adverse health effects of each of these contaminants?

DATE: 09 June 2014

TO: Eshetu Beshada
Environmental Approvals
Conservation and Water
Stewardship
160-123 Main Street, Winnipeg

FROM: Muntaseer Ibn Azkar
Air Quality–Environmental Programs
& Strategies
Conservation and Water Stewardship
1007 Century Street, Winnipeg

**SUBJECT: Structural Composite Technologies Ltd. – Fiberglass Reinforced Plastic
Products Manufacturing Facility (File 5594.00)**

Air Quality Section has reviewed the above proposal and provides the following comments:

- There was no mention of size fraction of particulate matter used in the modeling work. There are three size fractions of particulate matter (PM_{2.5}, PM₁₀, and SPM) listed in the Manitoba Ambient Air Quality Criteria (MAAQC).
- Modeling results submitted is in tabular format and no contour plot is provided. It is suggested that contour plots be included as it is an effective assessment tool regarding emission dispersion in the plant's area of influence.
- Multi-Chemical Utility of AERMOD model may give more authentic concentration of each pollutant rather than using base emission rate of 1 g/s. Multi-Chemical Utility allow to specify multiple pollutant emissions from different sources with varied emission rates.
- There was no mention in the submitted proposal on the year of meteorological data used in the modeling work.

DATE: May 23, 2014

TO: Eshetu Beshada
Environmental Approvals
Conservation and Water Stewardship
123 Main St Suite 160 (Box 80)
Winnipeg MB R3C 1A5

FROM: Environmental Compliance and Enforcement
Conservation and Water Stewardship
123 Main St Suite 160 (Box 60)
Winnipeg MB R3C 1A5

**SUBJECT: Environment Act Proposal – Structural Composite Technologies Ltd (Client File:
5594.00)**

Environmental Compliance and Enforcement (Central Region) has reviewed the above noted Environment Act Proposal (EAP). Please find the following comments regarding the proposal.

1) Regarding Odour Emissions and Control:

This facility operates in close proximity to a residential neighbourhood. We request further information regarding how the proponent proposes to reduce the odour emissions in the neighbouring community.



Response to Public Comments

1. The area is defined as rural because a 3km radius is investigated and the predominant land type is chosen for modeling. The predominant land type in a 3km radius is rural even though the area immediately surrounding the site is urban. Using the rural dispersion factor results in more conservative dispersion and thus more conservative POI concentrations.
2. The meteorological data is from Bismark because that is the closest weather station that provides surface data **and** upper air data. The Winnipeg weather station does not provide the data needed for the model. This methodology was suggested by Manitoba Conservation. The acceptable practice is to use both surface and upper air data from the same station.
3. Emissions of acetone are expected to be insignificant based on the amount of time the acetone containers are open and the fact that emissions are not directly exhausted. Acetone is only used in the cleaning of small rollers and brushes. The acetone is kept in closed containers at point of use and is collected and stored at the end of each shift. SCTL has recently implemented a more efficient acetone reclaim system as a means of reducing its consumption of acetone.
4. Cobalt was considered insignificant since it's expected to remain in the product (the overspray is not expected to decompose into individual components). Styrene emissions were compared to a 24-h standard because the health-based standard is 24-hours. The 24-hour standards are more stringent than the 0.5-hour standards and it is why they have been phased-in. It can be argued that removing the meteorological outliers is more consistent with "real world" results, since outliers only occur one day in a year. In addition, the report only removed outliers for PM, so this does not affect the styrene results (or any other chemical result). The styrene results (and other VOC results) are especially conservative because it was modeled in a "base case" – to generate a dispersion factor. These contaminants were not modeled individually.
5. One could conduct ambient air testing or source testing, but it is very expensive and is not a requirement of the regulations. The method used to calculate emissions and modeled is conservative and thus is actually giving a higher output than what you would find doing source testing. The model is known to be on the conservative side and the calculations also are conservative (i.e. assuming 100% of volatiles are emitted, 100% of styrene emitted is exhausted when in reality it is less than 100%)
6. Individual solid components and non-volatiles were deemed insignificant since they are not expected to come out of product. Since they are bound in the fiberglass they are not expected to be emitted.
7. Converting to a 24-hour average period does dilute the emission over the time period, but this is done because the limit is based on a 24-hour averaging period. If the limit was 0.5-hour or 12-hour, it would be higher. We are comparing to a lower limit, and thus averaging over the limit's time period.

8. There are actually two filters. One has an efficiency of 20% and one has an efficiency of 30%. The emissions that are not captured by the filter are assumed to be exhausted to atmosphere. The model applies filter MERV ratings that typically result in much more conservative findings.
9. The styrene levels outside are what is given in the Emission Summary Table. It is a conservative estimate (meaning actual levels are expected to be less).
10. How much of each is being released can be found in the Emission Summary Table (Appendix A -- Table A3). It is up to the Provincial Ministry to set thresholds for potential health effects.
11. This can most likely be deemed insignificant based on low usage rate and low volatility (in fact, the MSDS for polyvinyl alcohol lists 0% volatile). The use of PVA is actively being reduced and replaced with honey wax as a de-molding agent.
12. The facility uses a shear cutting method (hand shears) which is not expected to produce fine particles. The grinding emissions are vented through a dust collector and then routed back into the facility (does not get outside). Visible particulate (anything over 44 microns) is not expected to exhaust outside as these larger particles fall to ground for cleanup and are not exhausted outside.
13. Attached are articles from the;
 - Canadian Council of Ministers of the Environment
 - Environment Canada
 - Harvard Center for Risk Analysis

These are only a few articles that discuss the health risks of Styrene. A relevant and significant source of information can also be found with the Styrene Information and Research Center (SIRC). SCTL is a proponent of safe practices not only for the benefit of its own employees but also to the surrounding public.

Response to Air Quality – Environmental Programs & Strategies Comments

- With lack of better information, it was assumed that all PM is PM2.5 (and used the lowest limit for comparison)
- Modelling files can be sent to Manitoba Conservation for the creation of their contour plots.
- A base model for all contaminants (other than PM) for ease of modeling. This method results in more conservative concentrations (therefore, we are even more below limits). Thus, this method is generally acceptable.
- 1992 to 1996 (the most recent years available) data was used.

Response to Environmental Compliance and Enforcement Comments

- Some sources of odour such as PVA and acetone have already been targeted for reduction. A more efficient acetone reclaim system has been purchased that allows for reducing acetone consumption. Replacing PVA with honey wax as a de-molding agent has been adapted to reduce the use of PVA.

Controlled spraying and continued operator training has been a focus to manage and reduce the amount of overspray in shop spray applications. Less overspray results in less media being exhausted from the facility.

Filter change overs continue to be managed to ensure filter and exhaust system is functioning as designed for trapping particulate matter.

The odour is being addressed with our resin manufacturers to review options for reduction without adversely affecting the product performance.

Comments regarding Odour Event Logs

SCTL is one business of multiple businesses that exhaust process air out into the atmosphere. Attached are some examples of other businesses that may contribute to the odours in the Transcona area. Examples include other nearby fiberglass shops, businesses that use paint, welding or metals manufacture are all within the vicinity of the area for the Odour Event Logs.



Canadian Water Quality Guidelines for the Protection of Aquatic Life

STYRENE

Styrene (CAS 100-42-5, molecular weight 104.14) is a volatile, monoaromatic hydrocarbon with the structural formula of $C_6H_5CH=CH_2$, vapour pressure of 880 Pa, Henry's law constant of $305.48 \text{ Pa}\cdot\text{m}^3\cdot\text{mol}^{-1}$, and a log octanol-water partition coefficient of 3.05. Synonyms for styrene include vinylbenzene, vinylbenzol, phenylethylene, styrolene, styrol, styrole, ethenylbenzene, cinnamene, cinnamenol and cinnamol (Government of Canada 1993). Pure styrene has a sweet aromatic odour at low concentrations (0.02 ppm) (Hoshika et al. 1993) and a disagreeable odour at higher concentrations (e.g., 100 ppm) (EPS 1984; Bond 1989). Styrene is only sparingly soluble in water at approximately $300\text{--}350 \text{ mg}\cdot\text{L}^{-1}$ (Mackay et al. 1993).

The dominant use of styrene is to make polymers for the manufacture of plastics, synthetic rubbers, and latexes such as polystyrene, acrylonitrile-butadiene-styrene (ABS), styrene-acrylonitrile (SAN), and styrene-butadiene (SB). These finished products are used in packaging material, disposable food and drink containers (molded expandable polystyrene, EPS), pipes (ABS), automobile instrument panel windows, clear housewear items (SAN), automobile tires (SB elastomer), paint (SB latexes and styrene-maleic anhydride), ion exchange resins for water treatment (styrene divinylbenzene resins), other plastic products, and fibrous glass products (Santodonato et al. 1980; USEPA 1992; Government of Canada 1993). Styrene is also an ingredient in floor waxes and polishes, paints, adhesives, putty, metal cleaners, autobody fillers, fibreglass boats, and varnishes (Howard 1989).

Styrene is produced in Canada at two plants in Ontario and one in Alberta (Government of Canada 1993). Canadian production of styrene in 1990 was reported to be 718 kt, of which approximately 490 kt were exported (CIS 1991). It is used in several industries across Canada (Ontario, Quebec, Alberta, British Columbia, and Nova Scotia) (Government of Canada 1993).

Styrene can be released into the environment during any stage of its manufacture, transport, disposal, or use. In addition to anthropogenic sources, styrene occurs naturally in the sap of styraceous trees, in bituminous-coal, and in shale-oil tars (RSC 1989), and is a natural by-product of the fungal and microbial metabolisms of a few species (Chen and Pepler 1956; Clifford et al. 1969).

In 1994, Environment Canada's National Pollutant Release Inventory (NPRI) recorded emissions of 1793 t of styrene (NPRI homepage: <http://www.ec.gc.ca/pdb/npri.html>).

Styrene concentrations are low in surface waters, generally below $1 \mu\text{g}\cdot\text{L}^{-1}$ (detection limit $0.2 \mu\text{g}\cdot\text{L}^{-1}$) (Government of Canada 1993), but can reach higher levels due to localized discharge events (e.g., $47.0 \mu\text{g}\cdot\text{L}^{-1}$) (Barton 1994).

Dissolved styrene will rapidly volatilize to the atmosphere (Mackay et al. 1993). Fu and Alexander (1992) estimated the half-life for styrene in lake water and distilled water as 1–3 h and 6–7 h, respectively. The shorter half-life in lake water was explained as significant aerobic biodegradation in addition to volatilization. The half-life of styrene in rivers has been estimated at 3 h (Howard et al. 1991), which is strongly affected by water mixing. In ponds (shallow water) and lakes (deep water), the half-life of styrene has been modeled to be 3 d and 13 d, respectively (USEPA 1984).

Styrene can also partition into animal tissue, however, the log BCFs of 0.83 and 1.13 determined from goldfish (Ogata et al. 1984) indicate that the bioconcentration of styrene in aquatic organisms is not likely to be significant. Although the K_{ow} indicates a moderate tendency for styrene to partition into fat, the low BCF is likely a result of the relatively rapid metabolism and excretion of styrene from the organism (USEPA 1992).

Styrene is known to cause tainting in fish tissue. The concentration in water impairing the flavour of yellow perch (*Perca flavescens*) was reported to range from 0.15 to $0.25 \text{ mg}\cdot\text{L}^{-1}$ (Persson 1984). A concentration of

Table 1. Water quality guidelines for styrene for the protection of aquatic life (Environment Canada 1998).

Aquatic life	Guideline value ($\mu\text{g}\cdot\text{L}^{-1}$)
Freshwater	72*
Marine	NRG†

* Interim guideline.

† No recommended guideline.

0.037 mg·L⁻¹ was found to impart an odour to water in one older study (Rosen et al. 1963), while Persson (1984) found odours detectable at 0.11 mg·L⁻¹.

Water Quality Guideline Derivation

The interim Canadian water quality guideline for styrene for the protection of freshwater life was developed based on the 1991 protocol (CCME 1991). For more details, see the supporting document (Environment Canada 1998).

Freshwater Life

The interim guideline for styrene for the protection of freshwater life is 72 µg·L⁻¹.

Rainbow trout (*Oncorhynchus mykiss*) fry were the most sensitive fish species tested, with a 96-h LC₅₀ of 4.1 mg·L⁻¹ (Exxon Biomedical 1993) and a 96-h LC₅₀ of 2.5 mg·L⁻¹ (Qureshi et al. 1982). For fathead minnows (*Pimephales promelas*), 96-h LC₅₀s of 10 mg·L⁻¹ and 32 mg·L⁻¹ are reported by Machado (1995) and Mattson et al. (1976), respectively. For bluegill sunfish (*Lepomis macrochirus*), goldfish (*Carassius auratus*), and guppies (*Lebistes reticulatus*), the 96-h LC₅₀ values were 25, 65, and 75 mg·L⁻¹, respectively (Pickering and Henderson 1966).

The cladoceran *Daphnia magna* was the most sensitive of the invertebrates studied. The 48-h EC₅₀s (immobilization) are reported at 4.7 mg·L⁻¹ (Putt 1995a),

23 mg·L⁻¹ (LeBlanc 1980), and 59 mg·L⁻¹ (Qureshi et al. 1982). *Hyalella azteca* was less sensitive than *D. magna*, with a 96-h LC₅₀ of 9.5 mg·L⁻¹ (Putt 1995b). Erben and Pišl (1993) reported a 48-h LC₅₀ of 69 mg·L⁻¹ for the isopod *Asellus aquaticus* and 580 mg·L⁻¹ for the snail *Lymnaea stagnalis*.

The only plant used in acceptable toxicity studies was the green alga *Selenastrum capricornutum*. The 72-h EC₅₀ (inhibition of cell density, chronic) was found to be 1.4 mg·L⁻¹, and the 96-h EC₅₀ was 0.72 mg·L⁻¹ (Hoberg 1995). This is the most sensitive organism in the available data set, and the interim guideline value was calculated by multiplying the 96-h EC₅₀ of 0.72 mg·L⁻¹ by a safety factor of 0.1, yielding an interim guideline value of 72 µg·L⁻¹.

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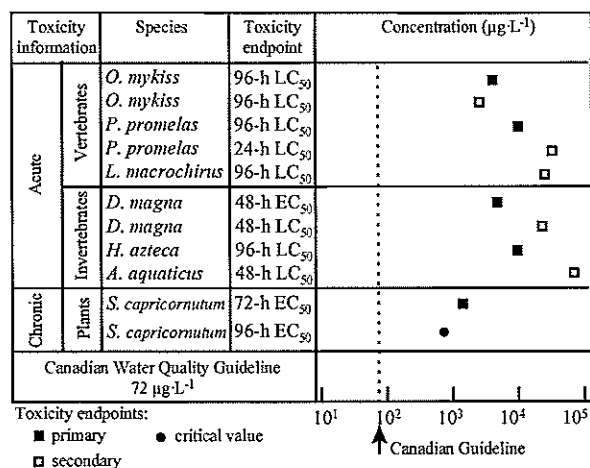


Figure 1. Select freshwater toxicity data for styrene.

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Reference listing:

Canadian Council of Ministers of the Environment. 1999. Canadian water quality guidelines for the protection of aquatic life: Styrene. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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Follow-up Report on a PSL1 Substance for Which There Was Insufficient Information to Conclude Whether the Substance Constitutes a Danger to the Environment

Styrene

May 2003

(PDF Version - 262 KB)

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List of Acronyms and Abbreviations

Table of Acronyms and Abbreviations

Table of Acronyms and Abbreviations

Acronym or abbreviation	Definition
CEPA	Canadian Environmental Protection Act
CEPA 1999	Canadian Environmental Protection Act, 1999
CTV	Critical Toxicity Value
EC ₅₀	median effective concentration
EEV	Estimated Exposure Value
ENEV	Estimated No-Effects Value

Acronym or abbreviation	This Web page has been archived on the Web.
kg-bw	kilogram body weight
LC ₅₀	median lethal concentration
NOAEL	No-Observed-Adverse-Effect Level
PSL	Priority Substances List
PSL1	first Priority Substances List
PSL2	second Priority Substances List

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Synopsis

Styrene, which appeared on the first Priority Substances List (PSL1), was assessed to determine whether it should be considered "toxic" as defined under the Canadian Environmental Protection Act (CEPA). It was concluded that styrene was not "toxic" under Paragraphs 11(b) or 11(c) of CEPA; however, there was insufficient information to conclude whether it constituted a danger to the environment under Paragraph 11(a). Information was lacking about the potential effects of styrene on aquatic organisms, on terrestrial vegetation through atmospheric exposure, and on wildlife through media other than air.

Since 1994, additional toxicity tests have been carried out on aquatic organisms. The results of these tests indicate that aquatic organisms are unlikely to be adversely affected by the concentrations of styrene found in Canadian surface waters. No information is available about the effects of styrene on wildlife. Based on toxicity studies conducted on laboratory animals, it is unlikely that wildlife would be adversely affected by the concentrations of styrene reported in food organisms or water in Canada. No information was identified about the potential effects of styrene on plants exposed through the atmosphere. Based on toxicity information available for several PSL1 substances that are structurally similar to styrene, it is concluded that terrestrial plants are unlikely to be adversely affected by the concentrations of styrene in air reported in Canada.

Based on the information available, it is concluded that styrene is not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Therefore, styrene is not considered "toxic" as defined in Paragraph 64(a) of the Canadian Environmental Protection Act, 1999.

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1. Introduction

Styrene appeared on the first Priority Substances List (PSL1) of the Canadian Environmental Protection Act (CEPA), which was published in the Canada Gazette, Part I, on February 11, 1989. Assessments were performed to determine whether the substance should be considered "toxic" as defined under CEPA and were completed in 1993 (Government of Canada, 1993a). It was concluded that styrene does not constitute a danger either to the environment on which human life depends or to human life or health, and, therefore, it was not found to be "toxic" under Paragraphs 11(b) and 11(c) of CEPA. Available information was insufficient to conclude whether styrene constituted a danger to the environment under Paragraph 11(a) of CEPA. In particular, there was a lack of information about the potential effects of styrene on aquatic organisms and on wildlife through media other than air. There was also insufficient information to determine if styrene constituted a danger to terrestrial vegetation through atmospheric exposure.

Since 1994, additional toxicity tests have been carried out on aquatic organisms. A literature search was recently undertaken to identify information about the toxicity of styrene and its breakdown products to terrestrial plants through atmospheric exposure, but no such information was found. Information about releases of styrene from industrial sources and data on concentrations of styrene in air from across Canada were obtained from Canadian databases.

This report examines this new information about the entry, exposure and effects of styrene in the Canadian environment in order to determine if the substance is likely to have a harmful effect on aquatic organisms and wildlife. The report also examines information about analogues of styrene that were included in the first Priority Substances List in order to determine if styrene is likely to have a harmful effect on terrestrial vegetation through atmospheric exposure.

A draft follow-up report was made available for a 60-day public comment period (between September 28, 2002 and November 27, 2002). No comments were received.

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2. Entry Characterization

Total on-site environmental releases of styrene reported to the National Pollutant Release Inventory amounted to 808 000 tonnes in 1996, with most, 729 000 tonnes, released into air (NPRI, 1999). Total on-site releases amounted to 731 000 tonnes in 1995 (NPRI, 1999).

The Canadian Chemical Producers' Association (1999) reported total styrene emissions of 78 tonnes from member companies in 1998 and 88 tonnes in 1997, compared with total releases of 134 tonnes in 1992.^[1]

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3. Exposure Characterization

3.1 Environmental Fate

3.1.1 Air

The fate of styrene in the atmosphere is determined by its chemical and photochemical reactivity and the prevailing physical and chemical conditions in the atmosphere. Hydroxyl radicals are major reactants, and the predicted half-life for reaction with styrene is about 3.6 hours (Atkinson et al., 1982). Although hydroxyl radicals are major reactants, the ozone concentrations in polluted air in cities may be sufficiently high for ozone to destroy styrene more readily than hydroxyl radicals (Alexander, 1990). The half-life of styrene due to its reaction with ozone is about 9 hours (U.S. EPA, 1984). In the atmosphere, the products of the styrene reaction with ozone are benzaldehyde, formaldehyde, benzoic acid and trace amounts of formic acid (Grosjean, 1985).

3.1.2 Biota

A bioconcentration factor of 64 was estimated for styrene (Government of Canada, 1993a) using the method presented by Veith et al. (1979), indicating a low bioaccumulation potential.

3.2 Environmental Concentrations

3.2.1 Ambient Air

Styrene was detected (detection limit 0.1 µg/m³) in 6260 (or 52%) of 12 013 24-hour samples collected from 1994 to 1998, inclusive, from rural, suburban and urban locations in seven provinces under the National Air Pollution Surveillance program (Dann, 1999). The highest 24-hour average concentration measured was 43.6 µg/m³, in a sample collected at Toronto, Ontario, in 1995.

3.2.2 Surface Water

Concentrations of styrene up to 1.7 µg/L have been reported in Canadian surface waters (Otson, 1992).

3.2.3 Biota

There are few data available on the concentration of styrene in biota. Bonner and Meresz (1981) reported whole-body concentrations of styrene ranging up to 100 µg/kg in fish from the St. Clair River. Assuming a bioconcentration factor of 64, biota living in surface waters having a concentration of 1.7 µg/L would have a whole-body concentration of 109 µg/kg. This estimate is very close to the highest concentration reported for fish in the St. Clair River.

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4. Effects Characterization

4.1 Terrestrial Plants

~~In August 1999, a literature search was conducted to identify information on the effects of styrene and its atmospheric breakdown products, benzaldehyde, formaldehyde and benzoic acid, on plants through atmospheric exposure. No information was identified pertaining to styrene, benzaldehyde or benzoic acid.~~

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Information was found pertaining to formaldehyde. This substance enters the Canadian environment from natural sources (including forest fires), from direct human sources, such as fuel combustion and industrial on-site uses, and from secondary formation as a result of the oxidation of natural and anthropogenic organic compounds. Formaldehyde was included on the second CEPA Priority Substances List (PSL2) and was considered not to be "toxic" as defined in Paragraph 64(a) of the Canadian Environmental Protection Act, 1999 (CEPA 1999). Therefore, no further consideration will be given to this substance in the assessment of possible environmental effects of styrene.

In the absence of toxicity data for styrene and its breakdown products other than formaldehyde, one approach is to use existing data for substances similar in structure to styrene. Several PSL1 substances are similar in structure to styrene: aniline, toluene, benzene and xylenes. [Appendix A](#) presents the molecular structures of these substances. A summary of their toxicity data follows:

- Aniline: Exposure of loblolly pines (*Pinus taeda* L.) to aniline at a concentration of 400 000 – 10 000 000 $\mu\text{g}/\text{m}^3$ for 21–35 days resulted in damage to the needles, including necrosis and needle drop (Cheeseman et al., 1980, cited in Government of Canada, 1994).
- Toluene: Chlorosis and growth inhibition of terrestrial plants may occur at concentrations above 6 000 000 $\mu\text{g}/\text{m}^3$ (Slooff and Blokzijl, 1988, cited in Government of Canada, 1992a). Young barley, tomato and carrot plants were damaged by toluene vapours at concentrations of 6 400 000 – 12 000 000 $\mu\text{g}/\text{m}^3$ following a 0.25- to 3-hour exposure (Currier, 1951, cited in Government of Canada, 1992b). Barley and tomato plants were more sensitive than carrots. Damage included leaf tip darkening, loss of turgor and chlorophyll bleaching in sunlight.
- Benzene: Acute effects of benzene on terrestrial plants have been reported at atmospheric concentrations above 10 000 000 $\mu\text{g}/\text{m}^3$ (Miller et al., 1976, cited in Government of Canada, 1993b). Benzene induced a positive, negative or neutral growth response, depending upon concentration and plant species. Some degree of recovery from sublethal effects was observed within 1–4 weeks following short-term exposures of 0.5–4 hours. Gross signs of benzene toxicity included darkening of leaf tops, loss of turgor and bleaching of chlorophyll (Currier, 1951, cited in Government of Canada, 1993b).
- Xylenes: Exposure of barley to xylene vapour at 20 000 000 $\mu\text{g}/\text{m}^3$ for 4 hours resulted in 80% injury of leaves within 24 hours. Leaves recovered to 10% injury 4 weeks after exposure (Currier, 1951; Currier and Peoples, 1954; both cited in Government of Canada, 1993c).

4.2 Wildlife

The lowest No-Observed-Adverse-Effect Level (NOAEL) for non-neoplastic effects in animals following oral exposure to styrene via drinking water was 12 000 $\mu\text{g}/\text{kg}\text{-bw}$ per day, based on reproductive effects in a three-generation study with Sprague-Dawley rats (Beliles et al., 1985, cited in Government of Canada, 1993a). This value was used by Health Canada to develop a tolerable daily intake for humans (Government of Canada, 1993a).

4.3 Aquatic Organisms

Before 1993, there were very few reliable studies conducted on the toxicity of styrene to aquatic organisms. Almost all studies used nominal concentrations and failed to minimize or account for losses of styrene through volatilization. Studies undertaken since then were designed to minimize volatilization and reported results based on measured concentrations of styrene. The most sensitive organism tested was the green alga, *Selenastrum capricornutum*, with a 96-hour EC_{50} of 720 $\mu\text{g}/\text{L}$ (Hoberg, 1995). Reported 96-hour LC_{50} values for rainbow trout (*Oncorhynchus mykiss*) are 2500 $\mu\text{g}/\text{L}$ (Qureshi et al., 1982) and 4100 $\mu\text{g}/\text{L}$ (Exxon Biomedical Sciences Inc., 1993). The fathead minnow (*Pimephales promelas*) was somewhat less sensitive, with a 96-hour LC_{50} of 10 000 $\mu\text{g}/\text{L}$ (Machado, 1995). The 48-hour LC_{50} for the cladoceran, *Daphnia magna*, was 4700 $\mu\text{g}/\text{L}$ (Putt, 1995a). *Hyalella azteca* was somewhat less sensitive, with a 96-hour LC_{50} of 9500 $\mu\text{g}/\text{L}$ (Putt, 1995b).

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5. Assessment of "Toxic" Under CEPA 1999

The environmental risk assessment of a PSL substance is based on the procedures outlined in Environment Canada (1997). Analysis of exposure pathways and subsequent identification of sensitive receptors are used to select environmental assessment endpoints (e.g., adverse reproductive effects on sensitive fish species in a community). For each endpoint, a conservative Estimated Exposure Value (EEV) is selected and an Estimated No-Effects Value (ENEV) is determined by dividing a Critical Toxicity Value (CTV) by an application factor. A conservative (or hyperconservative) quotient (EEV/ENEV) is calculated for each of the assessment endpoints in order to determine whether there is potential ecological risk in Canada. If these quotients are

less than one, it can be concluded that the substance poses no significant risk to the environment and the risk assessment is completed. If, however, the quotient is greater than one for a particular assessment endpoint, then the risk assessment for that endpoint proceeds to an analysis where more realistic assumptions are used and the probability and magnitude of effects are considered. This latter approach involves a more thorough consideration of sources of variability and uncertainty in the risk analysis.

5.1 Assessment Endpoints

The assessment endpoints for this report are adverse effects on terrestrial plants exposed to styrene through the air, on wildlife and on aquatic organisms.

5.2 Terrestrial Plants

For a hyperconservative risk characterization for terrestrial plants, the EEV is $43.6 \mu\text{g}/\text{m}^3$, the highest 24-hour average concentration of styrene reported in the Canadian atmosphere from 1994 to 1998, inclusive.

No internationally accepted protocols are available for testing the effects of chemicals on plants through atmospheric exposure, nor are there any other plant effects data for styrene using any other test methods. There are, however, some terrestrial plant data on substances which are close chemical analogues of styrene, which were examined on a case-by-case basis and deemed to be acceptable.

The CTV is $400\,000 \mu\text{g}/\text{m}^3$, the lowest concentration of compounds structurally similar to styrene (aniline, toluene, benzene and xylenes) that caused adverse effects in terrestrial plants. Dividing this CTV by a factor of 100 (to account for the uncertainty associated with using aniline toxicity as a surrogate for styrene toxicity, extrapolation from laboratory to field conditions, and interspecies and intraspecies variations in sensitivity) gives an ENEV of $4000 \mu\text{g}/\text{m}^3$.

The hyperconservative quotient (EEV/ENEV) is then $43.6/4000 = 0.01$. Styrene is therefore unlikely to cause significant harm to terrestrial vegetation in Canada as a result of atmospheric exposure.

The review of the existing information shows that there is no indication of concern for plants exposed to styrene. At the same time there are no accepted international protocols for testing the effect of chemicals on plants via atmospheric exposure. Indeed such data is not required in other international programs such as the Organization for Economic Co-operation and Development Screening Information Data Set (OECD SIDS) program to screen chemicals for hazard to environment or humans. It is considered that this route of exposure not be considered further for this substance.

5.3 Wildlife

For wildlife, the EEVs are $100 \mu\text{g}/\text{kg}$, the highest whole-body concentration of styrene reported for fish from the St. Clair River, and $1.7 \mu\text{g}/\text{L}$, the highest concentration of styrene reported for Canadian surface waters.

The CTV is $12\,000 \mu\text{g}/\text{kg-bw}$ per day, the lowest NOAEL in a three-generation oral exposure study using rats, based on reproductive effects. Dividing the CTV by a factor of 10 (to account for the extrapolation from laboratory to field conditions and interspecies and intraspecies variations in sensitivity) gives an ENEV of $1200 \mu\text{g}/\text{kg-bw}$ per day.

To reach the ENEV of $1200 \mu\text{g}/\text{kg-bw}$ per day, an animal would each day have to eat 12 times its own weight of food containing styrene at a concentration of $100 \mu\text{g}/\text{kg}$ ($1200 \mu\text{g}/\text{kg-bw}$ per day divided by $100 \mu\text{g}/\text{kg} = 12$) or drink more than 700 times its own weight of water containing $1.7 \mu\text{g}$ styrene/L ($1200 \mu\text{g}/\text{kg-bw}$ per day divided by $1.7 \mu\text{g}/\text{L} = 706$), assuming that all of the styrene in the food and water was assimilated. In its original assessment, the Government of Canada (1993a) concluded that the maximum concentration of styrene measured in air from a rural site in Canada was over 800 times lower than the effects threshold estimated for wild mammals exposed by inhalation. It is therefore unlikely that wildlife would be adversely affected by the concentrations of styrene occurring in the Canadian environment.

5.4 Aquatic Organisms

For a hyperconservative risk characterization for aquatic organisms, the EEV is $1.7 \mu\text{g}/\text{L}$, the highest concentration of styrene reported for Canadian surface waters.

The CTV for aquatic organisms is $720 \mu\text{g}/\text{L}$, the 96-hour EC_{50} for the green alga, *Selenastrum capricornutum*. Dividing this CTV by a factor of 10 (to account for the extrapolation from laboratory to field conditions and interspecies and intraspecies variations in sensitivity) gives an ENEV of $72 \mu\text{g}/\text{L}$. This study was also used by the Canadian Council of Ministers of the Environment to set an interim Canadian water quality guideline of $72 \mu\text{g}/\text{L}$ for the protection of aquatic life (CCME, 1999).

The conservative quotient (EEV/ENE) was 1.7/72 = 0.02. Therefore, styrene concentrations in water in Canada are unlikely to cause adverse effects on populations of aquatic organisms.

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5.5 Discussion of Uncertainty

The ENEV for terrestrial plants was based on the toxicity of aniline. The uncertainty of using a surrogate substance was taken into account in determining the ENEV. Styrene could be a more or less potent toxicant than aniline.

Despite some limitations in the data relating to the environmental effects and exposure of styrene, data available at this time are considered adequate for reaching a conclusion on the environmental risk of styrene in Canada.

5.6 Conclusions

CEPA 1999 64(a): Based on available data, it is concluded that styrene is not entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. Therefore, styrene is not considered "toxic" as defined in CEPA 1999 Paragraph 64(a).

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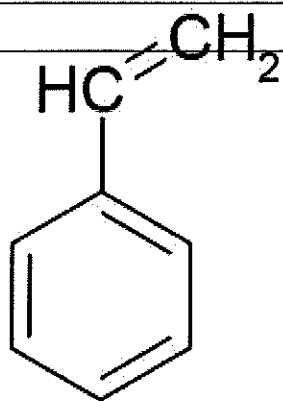
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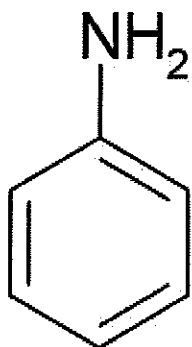
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Appendix A: Molecular Structures of Styrene and its Analogues

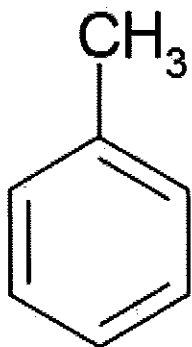
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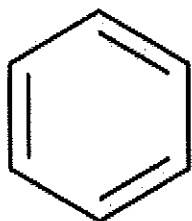
Styrene



Aniline

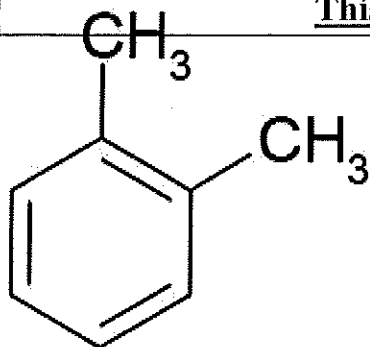


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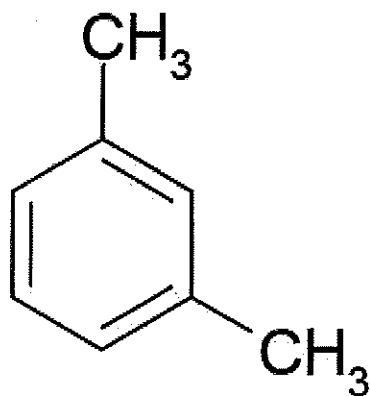


Benzene

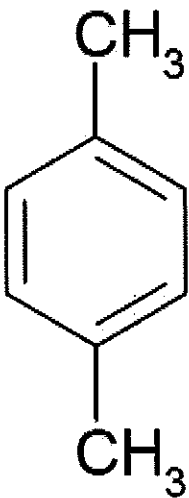
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Ortho-Xylene



Meta-Xylene



Para-Xylene

Footnote

^[1] The PSL1 Assessment Report for styrene is available on the following website: www.hc-sc.gc.ca/hecs-sesc/exsd/psl1.htm.

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Risk in Perspective

EVALUATING THE RISK TO WORKERS AND THE PUBLIC FROM STYRENE EXPOSURE



Joshua Cohen, Ph.D.

*“Styrene’s
carcinogenicity
in humans
cannot be ruled
out at this time.
However, styrene
exposure levels
among the
general
population and
among most
workers are for
the most part
very low.”*

Introduction

Styrene is used in the manufacture of a wide variety of products, including construction and packaging materials, tires and automotive parts, and household and office appliances. Annual production in the United States is approximately 10 billion pounds. Small quantities can be found in food and ambient air nearly everywhere. Larger exposures occur in the air inside some styrene-related manufacturing facilities. To evaluate the risk these exposures might pose to workers or the public, the Harvard Center for Risk Analysis (HCRA) convened a panel of scientists with expertise in epidemiology, toxicology, exposure assessment, and risk assessment in 1999.

The panel reviewed the extensive health literature on styrene and found that the epidemiological literature failed to demonstrate an association between styrene exposure and cancer. Data from laboratory animal experiments were ambiguous: styrene failed to cause cancer in rats at very high levels of exposure, but there was an association between styrene

exposure and lung tumors in mice. Because the panel could not identify what makes mice more susceptible than rats to styrene-induced tumors, they could not rule out the possibility that styrene might also cause cancer in humans. Finally, the panel concluded that at occupational levels of exposure, styrene may have a subtle impact on color vision.

The Panel

In 1999, the Styrene Information and Research Center (SIRC) awarded HCRA a grant to convene a panel of independent experts to investigate styrene’s potential health effects. The panel was chaired by Daniel Krewski, Director of the McLaughlin Centre for Population Health Risk Assessment at the University of Ottawa. Other members of the panel were: Gary Carlson (School of Health Sciences at Purdue University), David Coggon (MRC Environmental Epidemiology Unit at the University of Southampton, UK), Elizabeth Delzell (Department of Epidemiology and International Health at the University of Alabama, Birmingham), Helmut Greim (GSF-

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Institute of Toxicology, Neuerberg, Germany), Michele Medinsky, Richard Monson (Department of Epidemiology at the Harvard School of Public Health), Dennis Paustenbach (Exponent, Menlo Park, CA), Barbara Petersen (Novigen Sciences, Inc., Washington, DC), Stephen Rappaport (Department of Environmental Sciences and Engineering at the University of North Carolina, Chapel Hill), Lorenz Rhomberg (Gradient Corporation, Cambridge, MA), and P. Barry Ryan (Department of Environmental and Occupational Health, Rollins School of Public Health of Emory University). HCRA

scientific staff included Gail Charnley (Health Risk Strategies, Washington, DC), Joshua Cohen, John Graham, and Kimberly Thompson.

HCRA selected the experts, compiled and disseminated the literature they studied, convened three meetings of the panel between October, 1999 and May, 2000, and wrote up the report of the panels findings. That report was published as a special issue of the Journal of Toxicology and Environmental Health in January, 2002. This issue of Risk in Perspective summarizes that work.

Findings

Exposure

Small amounts of styrene are present in air, food, water, consumer products, and waste materials. For the majority of the general public, inhalation is thought to be the most important route of exposure. Most airborne styrene exposure comes from industrial activities and motor vehicle exhaust, with typical ambient concentrations reaching around 1 part per billion (ppb). For smokers, the dominant source of inhaled styrene can be cigarettes, which can increase average exposures for these individuals to 6 ppb. The panel estimated that under a pessimistic set of conditions, individuals living near a large styrene manufacturing facility could be exposed to lifetime average ambient concentrations exceeding 200 ppb.

Dietary exposure can come from the naturally occurring styrene found in foods such as strawberries, beef, and spices.

Federal regulations also permit low concentrations of styrene in food both as a direct additive and as an indirect additive due to migration from food packaging. Because of its rapid biodegradation, concentrations of styrene in drinking water are extremely low.

Occupational exposure to styrene has steadily declined over the years due to improved industrial hygiene and more stringent regulations, but it remains substantially higher than exposure to the general public. In the fiberglass-reinforced plastics segment of the styrene industry, where exposures are greatest, measurements indicate that airborne concentrations are now less than 20 parts per million (ppm). In other styrene industry segments, exposures are estimated to be 5 ppm or less.

The Consequences the Panel Considered

Cancer

The strongest evidence for styrene's potential to cause cancer via inhalation is its impact on the incidence of lung tumors in mice. In a recently published study, female mice exposed to between 20 and 160 ppm

styrene, and male mice exposed to between 40 and 160 ppm styrene, had a lung tumor incidence statistically greater than the corresponding control group rates. In a very similar experiment conducted by the same

investigators, however, rats exposed to styrene concentrations as high as 1,000 ppm did not have an elevated incidence of tumors in the lung or at any other site.

Two studies have reported that mice exposed to inhaled styrene developed mammary tumors. However, the panel concluded that these reported associations are unlikely to be causal because:

- The dose-response relationship was not monotonically increasing in one of the studies that reported a positive finding.
- The control group mammary tumor incidence rate in the other positive study appeared to be depressed relative to past studies in the same lab.
- The two positive studies are inconsistent with a substantial number of other studies that have reported negative findings.

Administering large doses of the metabolic product styrene oxide to rats via stomach tubes has consistently resulted in cancer of the forestomach, but those findings are not considered to be relevant to humans because the most important route of exposure for humans is inhalation, and because metabolic detoxification of styrene oxide makes a substantial build-up of this metabolite in the stomach implausible.

Investigators have also conducted extensive studies of occupationally exposed populations to see if styrene might cause cancer in humans. Studies of workers in the reinforced plastics industry are thought to be the most informative because these workers are exposed to the highest level of styrene. While those studies did reveal an elevated incidence of respiratory tract cancer in general, and lung cancer in particular, for two reasons the panel concluded these associations were not caused by styrene exposure. First, the elevated incidence rates were limited to workers with only moderate levels of styrene exposure and did not appear to extend to the most heavily exposed workers. Second, workers with elevated lung cancer rates also had an

elevated incidence of conditions thought to be associated with lifestyle factors (*e.g.*, cardiovascular disease).

Some studies have also shown that styrene workers have an elevated incidence of lymphatic and hematopoietic (LH) cancers. However, those studies are difficult to interpret because the number of such cancers is generally small and because of confounding by other industrial exposures that could cause cancer (*e.g.*, exposure to butadiene used in the production of styrene-butadiene rubber). Moreover, the data show no evidence of a monotonically increasing dose-response relationship. In particular, no elevation in LH cancers was observed among workers in the reinforced plastics industry where styrene exposures are highest.

The panel concluded that epidemiology studies to date do not provide clear evidence that styrene causes cancer. But they also noted that their statistical power is inadequate to rule out an elevation in cancer consistent with the magnitude of the risk implied by the mouse lung tumor data. That is, if the mouse lung tumor findings correctly characterize the amount by which styrene exposure increases the risk of cancer in humans, the effect may be too small to have shown up in even the best and largest epidemiology studies conducted to date.

Non-cancer:

Styrene exposures greater than 100 ppm have been shown to cause a variety of nervous system effects (*e.g.*, nervous system depression, drowsiness, headaches, and disturbance of balance). However, at levels relevant to human exposure, the evidence of non-cancer effects is more limited. Some studies have reported that occupational styrene exposure can affect hearing. However, because those studies failed to control for exposure to noise, the panel did not find their results compelling. On the other hand, the panel did conclude that occupational exposure to styrene does have a subtle effect on color vision.

Other non-cancer effects that the panel considered included respiratory tract toxicity, immune system toxicity, reproductive toxicity, and developmental toxicity. While there is evidence in animals that styrene can cause these effects at sufficiently high levels of

exposure, the panel could find no evidence that these effects occur in humans at relevant levels of exposure. Finally, the panel concluded that the current weight of the evidence does not suggest that styrene exhibits any hormonal activity.

Cancer Mode of Action

In order to better understand styrene's potential to cause cancer in humans, the panel reviewed evidence characterizing the molecular mechanisms by which it might act. First, the panel looked at whether styrene can directly damage DNA. If it can, then it can probably cause cancer in a wide range of species, including humans. Second, the panel investigated what it is about mice that makes them so much more susceptible than rats to the development of styrene-induced tumors. Even if styrene cannot cause cancer in a wide range of species, it might be able to cause cancer in humans if humans are more like mice than rats in terms of how our bodies process and eliminate styrene.

Regarding styrene's potential to cause genetic damage, the panel noted that although styrene does not appear to react with DNA, styrene oxide does bind to DNA molecules. The panel also concluded that styrene exposure increases the frequency of one type of chromosomal change (chromosomal aberrations). However, whether any of these changes can cause cancer is not clear. Styrene oxide causes mutations in isolated cells in a test tube, but the panel concluded that the evidence for styrene's mutagenicity in animals and humans is less definitive.

As to the susceptibility of mice to the development of lung tumors, the panel concluded that hyperplasia (organ enlargement due to rapid cell growth) plays a key role. In particular, it appears that styrene oxide injures mouse lung tissue. That damage in turn accelerates cell growth as the mouse lungs repair themselves, increasing the

likelihood of DNA copying errors and mutations leading to cancer. While styrene exposure causes hyperplasia in mice, it does not do so in rats.

For two reasons, the panel was unable to definitively rule out the possibility that styrene might cause cancer in humans. First, even though hyperplasia is predominantly responsible for the development of lung tumors in mice, it is possible that genotoxicity might also contribute to these tumors, albeit to a much lesser extent. So even if hyperplasia does not occur in humans, it is still possible that styrene exposure could cause a low incidence of lung cancer (or other cancers) due to genotoxicity.

Second, it is not clear whether humans are susceptible to styrene-induced hyperplasia like mice, or resistant, like rats. Factors that contribute to the susceptibility of mice fall into two categories referred to as pharmacokinetics (the way in which the body distributes, metabolizes, and eliminates a substance) and pharmacodynamics (the extent to which the target tissue is sensitive to the active agent's effects). Some investigators have claimed that because of pharmacokinetic differences between mice and rats, rats exposed to styrene have much lower styrene oxide concentrations in their lungs than do mice, and humans might have even lower styrene oxide concentrations in their lungs than rats. So it would seem that if pharmacokinetic factors explain the difference in the susceptibility of mice and rats, they would also suggest humans are relatively immune to such tumors.

To test this hypothesis, the panel developed a physiologically based pharmacokinetic model to describe the toxicokinetics of styrene and styrene oxide in mice and rats. The panel model showed that the concentration of styrene oxide in the lungs of mice exposed to inhaled styrene is indeed higher than the corresponding concentrations in rats. However, the concentration of styrene oxide in the lungs of mice exposed to 40 ppm styrene (mice that did develop tumors) was lower than the corresponding concentration in rats exposed to 1,000 ppm styrene (rats that did not develop tumors). As a result, the panel concluded that pharmacodynamics must also play a role in the susceptibility of mice. Because it is not known whether humans share the pharmacodynamic characteristics of mice or rats, it is not clear whether humans would be susceptible to the development of styrene-induced cancer

After the panel completed its work, another group of investigators developed a more realistic pharmacokinetic model to describe how styrene is metabolized, distributed, and eliminated by mice, rats, and humans. That model indicates that the pharmacokinetic differences between rats and mice are larger than the panel model suggested, but the panel judged that the differences are still not large enough to explain the difference in susceptibility. Nor did the panel believe that the uncertainty in the newer model has been sufficiently addressed. In any case, however, even if humans are susceptible to the development of styrene-induced tumors, the new model indicates that they are likely to be substantially less susceptible than mice.

Risk Characterization

The panel concluded that evidence for styrene's carcinogenicity in humans is "suggestive," meaning that its carcinogenicity cannot be ruled out. To determine whether human exposure to styrene is high enough to warrant concern *if* styrene turns out to be carcinogenic, the panel estimated the "margin of exposure" (MOE) for several exposure scenarios. The MOE is the ratio of a "comparison exposure" to the level of actual exposure. The greater the MOE ratio, the less the potential concern. Depending on the nature of the health effect (its severity, whether it is reversible, *etc.*), MOE values above 100 may be considered satisfactory in an occupational setting. For the general public, MOE values above 1,000 may be considered satisfactory. The panel also computed MOE values for the non-cancer health effect that appears to occur at the lowest level of exposure, *i.e.*, subtle loss of color vision.

The comparison exposure is often taken to be the lowest exposure at which any adverse effect can be observed in a study. For cancer, the

panel estimated the lowest dose in the mouse lung tumor experiment that could produce a statistically detectable elevation in the lung tumor incidence above background. When converted to its human equivalent, that dose corresponded to an atmospheric concentration of 2 to 20 ppm. For noncancer, the panel used the lowest exposure level at which color vision in workers was affected, which turned out to be 50 ppm.

Cancer MOE values for members of the general population were generally very large. The MOE for styrene in food ranged from 5,000 to 50,000. As shown in Table 1, the MOE values for general population ambient air exposure were also very large for the most part. The one exception is a pessimistic hypothetical scenario involving individuals living near a very large styrene manufacturing facility. Cancer MOE values for occupational settings ranged from 100 to 1,000 for workers not employed in the reinforced plastics segment of the styrene industry. For those workers, the MOE values ranged from 1 to 20.

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For the general population, noncancer MOE values were for the most part 1,000 or larger, depending on the specific exposure scenario. Once again, the hypothetical scenario involving individuals living in the vicinity of a large styrene plant

yielded a much lower MOE value of 20. Occupational exposures in industry segments other than reinforced plastics ranged from 14 to 250. Within the reinforced plastics industry segment, the MOE value was 1.5.

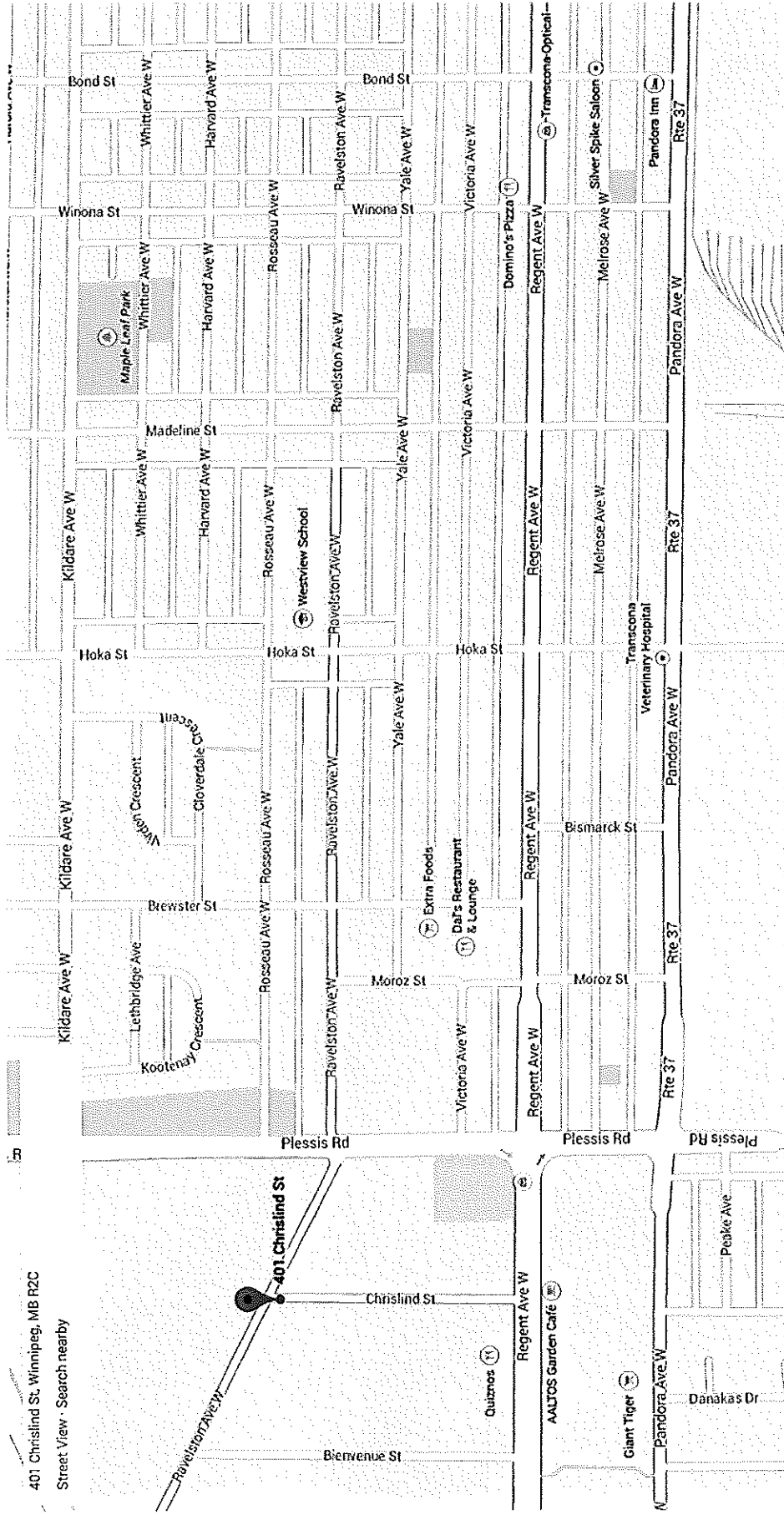
Conclusion

The panel concluded that styrene's carcinogenicity in humans cannot be ruled out at this time. However, styrene exposure levels among the general population and among most workers are for the most part very low. In addition, even if styrene is carcinogenic in humans,

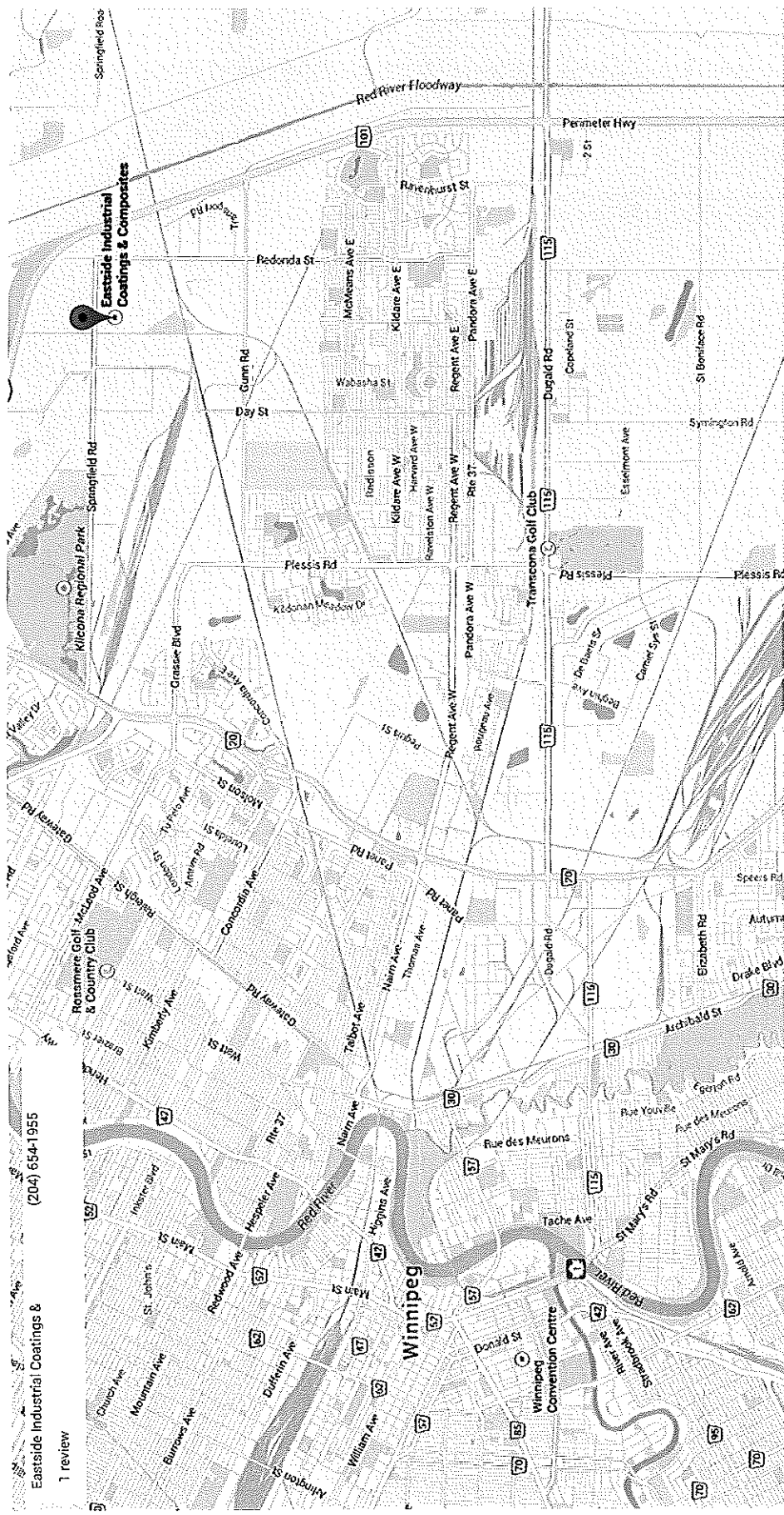
pharmacokinetic considerations indicate that humans may be at less risk than mice. Noncancer effects at relevant levels of exposure are limited to subtle decrements in color vision, with only the most highly exposed workers likely to experience this impact.

Table 1
Non-Occupational Margins of Exposure

	Lifetime Average Exposure	Cancer MOE Corresponding to a Comparison Dose Producing an Estimated 10% Increase in Mouse Lung Tumor Incidence		
		Low-End Comparison Dose Value: 2 ppm	Most Likely Comparison Dose Value: 5 ppm	High-End Comparison Dose Value: 20 ppm
Typical ambient exposure	1 ppb	2,000	5,000	20,000
Exposure to styrene from lifetime smoking	6 ppb	400	800	3,000
Living 100 meters from a hypothetical 100,000 pound per year emission facility (high exposure scenario, 95 th percentile individual) ^e	3 ppb	700	2,000	7,000
Living at the point of greatest exposure in the vicinity of a hypothetical 1 million pound per year emission facility (high exposure scenario, 95 th percentile individual) ^e	220 ppb	10	20	100



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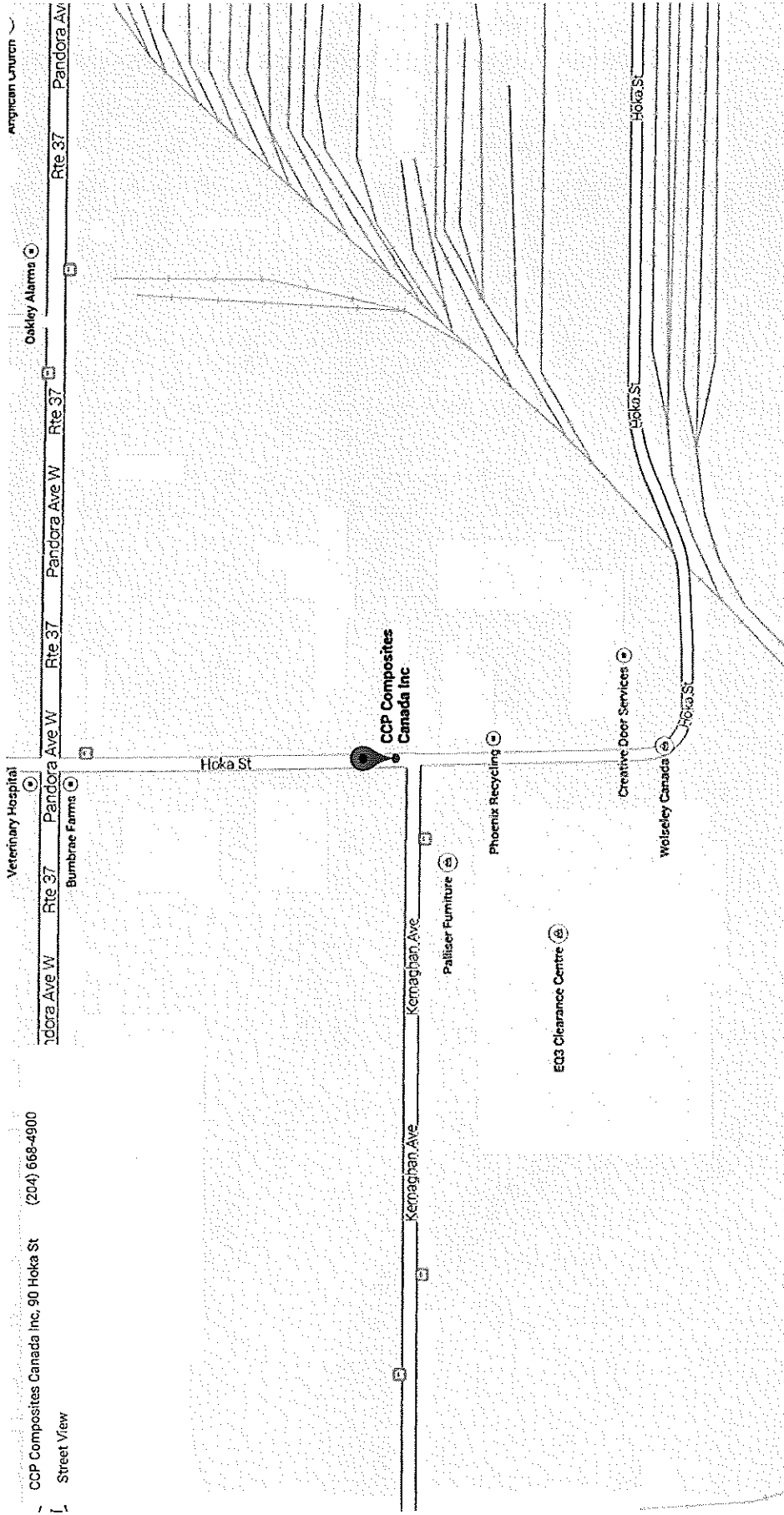
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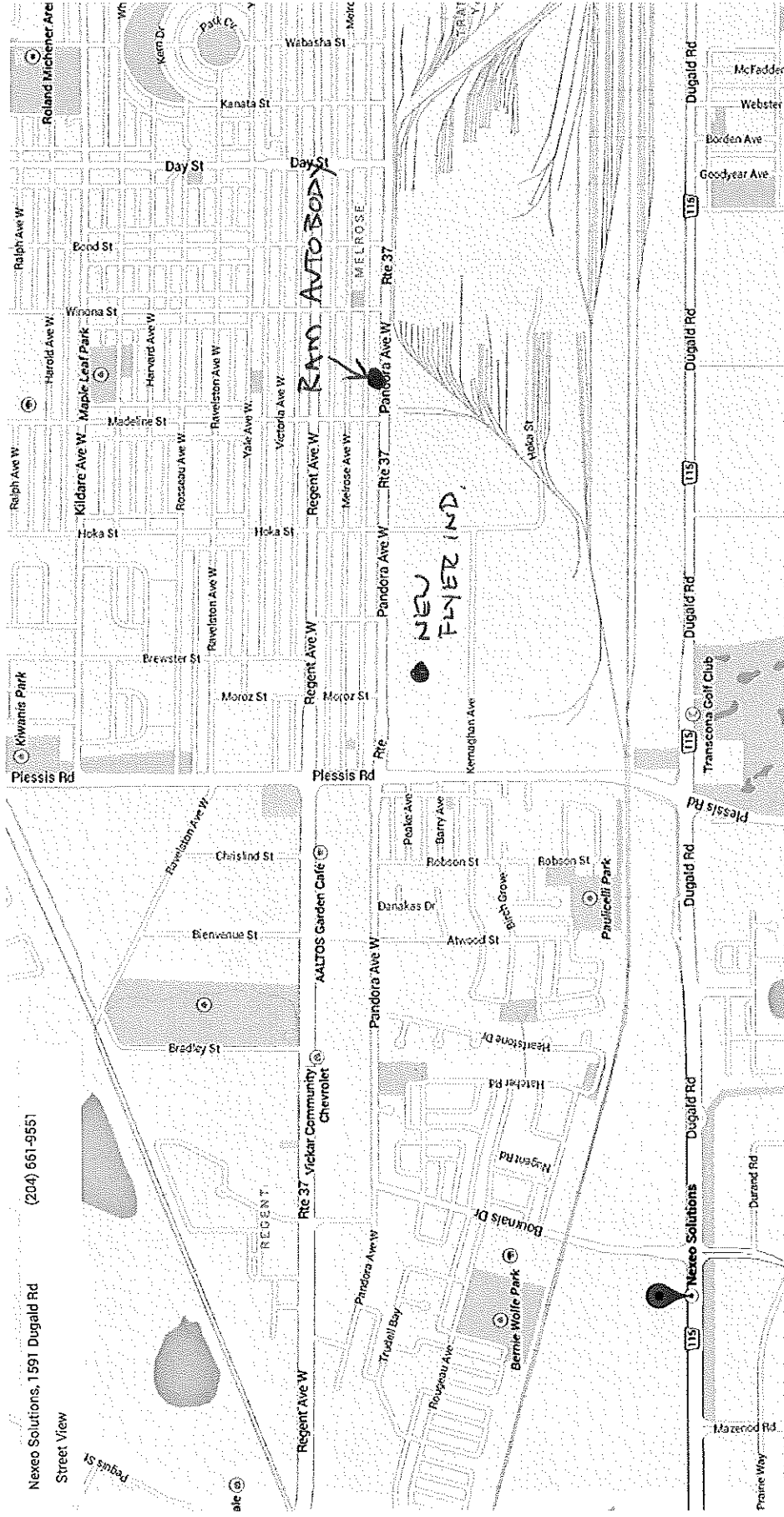


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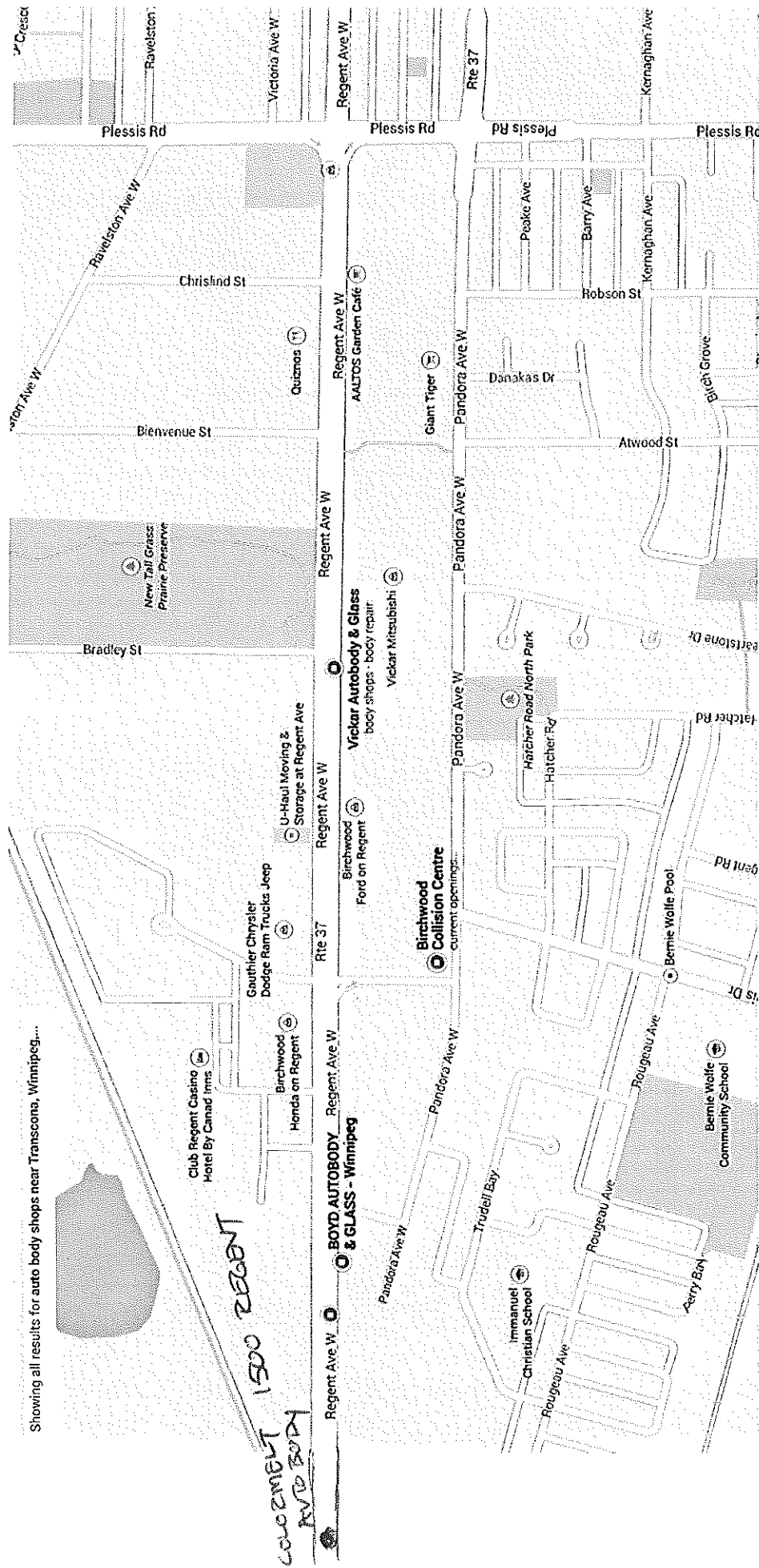
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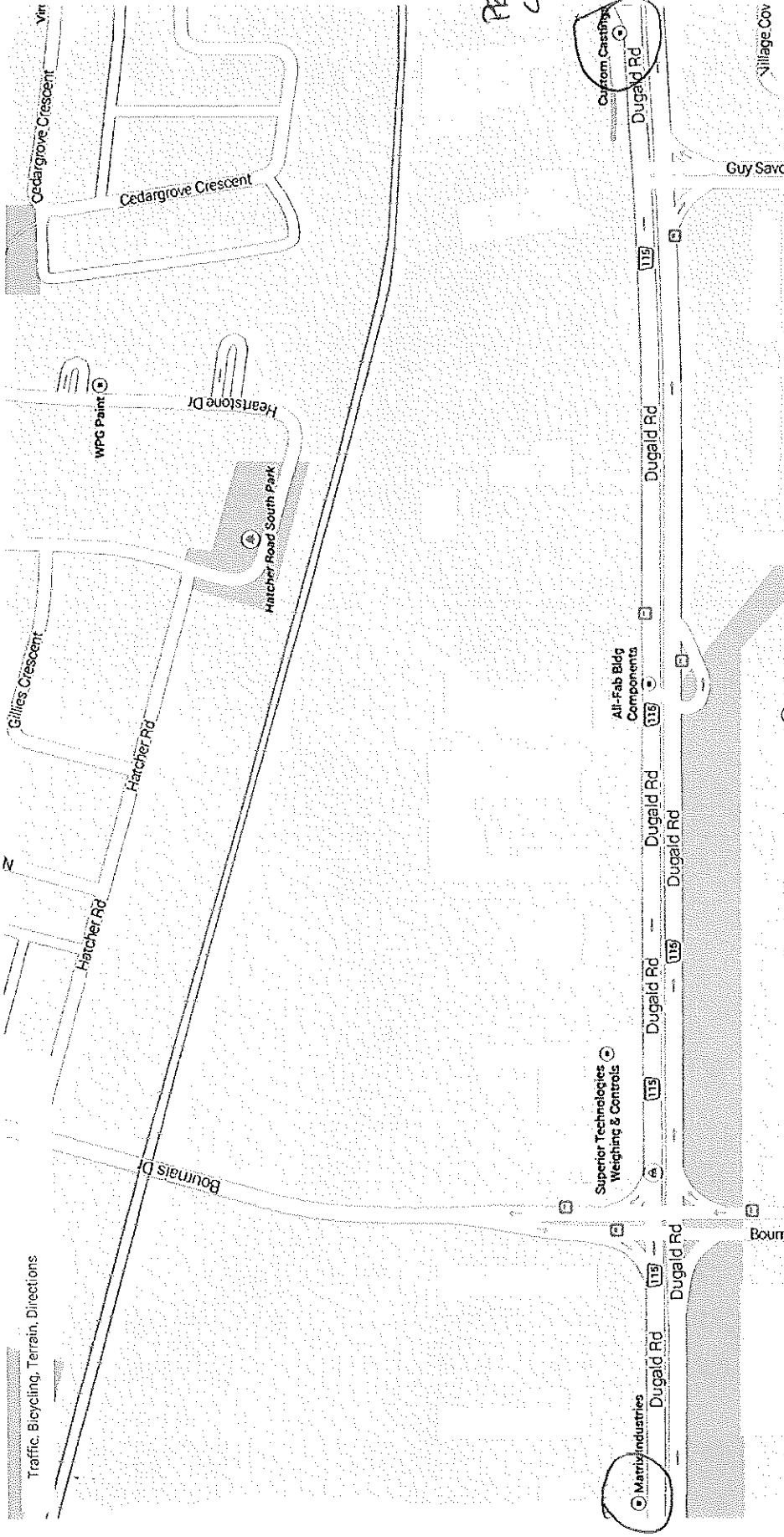
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