Wolverine Clean Energy Venture (WCEV) Permit Application # 317-07:
Evaluation of Mercury Deposition Impacts Via the MMREM Model
4/11/08
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This paper documents the review of the applicant's mercury impact assessment via the MPCA (2006) MMREM model. In Part (I), the applicant's model assumptions are noted and the model is operated to verify the applicant's reported results. In Part (II), this reviewer presents some alternative model assumptions and the affects that they have on the model results. This is not to say that the alternatives explored are necessarily more appropriate than those of the applicant. This exercise was intended to learn about the sensitivity of the model to various alternative model inputs which could be considered to be potentially reasonable.

I. Applicant's key assumptions, model inputs and key outputs

Applicant's key assumptions:
Mercury emission rate = 43 lb/yr
Mercury speciation = 100% RGM (per applicant's Appendix 30, p. 14)
Fraction of terrestrial deposited Hg reaching water body = 10% (MMREM default)

Table 1. Applicant's key model inputs and assumptions.

	Water body (w.b.) name	**w.b. size (acres)**	**w.s. size (acres)**	**w.s. minus w.b. size (acres)**	**Existing fish Hg (mg/kg)[1]**	**Incremental air impact (ug/m^3)[5]**		**Bkgd. dep. Rate to w.b.[2]**	**Bkgd. dep. rate to w.s.[2]**
						Over w.b.	**Over w.s.**		
A	Swan L.	109[4]	28027	27918	0.24	1.19E-6	1.92E-6	19.2	51.6
B	Swan L.	109[4]	28027	27918	0.24	1.19E-6	1.92E-6	**12.5**	**33.6**
C	Trout L.[3]	357	16244	15887	0.24	9.86E-7	1.04E-6	19.2	51.6
D	Trout L.[3]	357	16244	15887	0.24	9.86E-7	1.04E-6	**12.5**	**33.6**
E	L.Augusta	532	3574	3042	0.24	9.14E-7	6.59E-7	19.2	51.6
F	L.Augusta	532	3574	3042	0.24	9.14E-7	6.59E-7	**12.5**	**33.6**

[1] The existing fish Hg level of 0.24 mg/kg is a surrogate value based on the data for smallmouth bass from Lake Esau. This is reported to be the highest of the two 95% UCL levels derived from the two lake-specific sets of fish Hg data from the most representative lakes (Grand Lake and Lake Esau; applicant's App. 30: App. 4, Table 2).
[2] Background deposition rates. w.b. = water body. w.s. = watershed. Model runs A, C, and E utilized the applicant's estimated total background deposition rate of 19.2 ug/m^2-yr to water bodies. This value was based on the available wet deposition monitoring data for the nearest monitoring station (Pellston, MI) and an assumed equivalent dry deposition rate. The accompanying background deposition rate to terrestrial watershed areas was assumed to be greater than the rate to water bodies by a factor of 2.69 (the quotient of 33.6/12.5). This is the MMREM default relationship. This is intended to

account for greater deposition to terrestrial areas than directly to water bodies (MPCA, 2006). For model runs B, D, and F, the applicant evaluated impacts utilizing the MMREM model default values for background deposition rate (flux): 12.5 ug/m^2-yr to water bodies and 33.6 ug/m^2-yr to terrestrial watershed areas.

[3] Big Trout Lake and Little Trout Lake are interconnected, and therefore were evaluated together as "Trout Lake". Water body areas were reported as 103 acres (Little Trout Lake), 242 acres (Big Trout Lake, and 12 acres (Little Trout River), for a total of 357 acres.

[4] The Swan Lake area was reported as 84 acres, and the Swan River as 25 acres, for a total of 109 acres.

[5] Appendix 30, Table 3, presented ambient air impacts for a nominal (1 g/s) emission rate. Actual impacts were not provided in App. 30. It was not indicated if the applicant derived the Hg impacts from modeling all the facility sources, or only the CFB boilers. The reviewer converted those nominal impacts to actual impacts for a combined emission rate of 6.05E-4 g/s (4.80E-3 lb/hr) for CFB1 and CFB2, per Table 6-17, because the CFB boilers represent 98.2% of the total facility Hg emissions (from applicant's Table 6-17). The applicant verbally confirmed this approach.

Table 2. Applicant's key modeling results for deposition rates associated with facility mercury emissions.

Model run	Water body	Facility's mercury deposition rate (flux) (ug/m^2-yr)	
		Water body	watershed
A	Swan L.	**0.4**	**0.7**
B	Swan L.	**0.4**	**0.7**
C	Trout L.	**0.3**	**0.4**
D	Trout L.	**0.3**	**0.4**
E	L. Augusta	**0.3**	**0.2**
F	L. Augusta	**0.3**	**0.2**

Table 3. Applicant's key MMREM modeling results for mass loading, fish mercury levels, and hazard quotients.

	Water body	Mass loading to w.b. (g/yr)		Fish Hg (mg/kg)[1]			Hazard Quotient (HQ)[1]		
		Ambient	Project	Bkgd.	Incr.	Total	Bkgd.	Incr.	Total
A	Swan L.	591.45	7.71	0.24	0.003	0.243	0.55	0.01	0.56
B	Swan L.	385.13	7.71	0.24	0.005	0.245	0.55	0.01	0.56
C	Trout L.	359.49	2.81	0.24	0.002	0.242	0.55	0.00	0.55
D	Trout L.	234.08	2.81	0.24	0.003	0.243	0.55	0.01	0.56
E	L. Augusta	104.86	0.96	0.24	0.002	0.242	0.55	0.01	0.56
F	L. Augusta	68.28	0.96	0.24	0.003	0.243	0.55	0.01	0.56

[1] The fish mercury level and HQ are reported here as the background (ambient) level, the modeled incremental impact from the project, and the total. The HQ is calculated based on an assumed recreational fish consumption rate of 15 g/d, consisting entirely of trophic level 4 fish as assumed for the existing fish mercury levels in Table 1.

II. Alternative model assumptions

The reviewer tested the affect on the modeling results of some key alternative assumptions (Table 4). This is not to say that the alternative assumptions are necessarily more appropriate than those utilized by the applicant.

Table 4. Alternative model assumptions.

Parameter	Applicant's assumption	Reviewer's alternative	Comments
Mercury speciation profile	100% reactive gaseous mercury (RGM) (this is a worst-case assumption, based on the MMREM relative deposition velocities)	50/30/20: 50% Hg^0 (elemental mercury); 30% RGM; 20% Hg(P) (particulate mercury)	Lacking facility-specific speciation data, the 50/30/20 profile approximation is based on a recommendation of the USEPA (Mercury Study Report to Congress) for all sizes of coal-fired power plants. With Hg emission controls as proposed for WCEV, the RGM may be less than 30% but is unknown.
Fraction of mercury deposited in the terrestrial watershed which reaches the water body	10% (MMREM default assumption)	20%	EPA (2001) indicates that there is a range of values based on empirical observations, but that, "…a delivery ratio of 20% is a reasonable estimate of the central tendency of this value, an appropriate estimate for the purposes of this study."
Surrogate value for the existing ambient fish concentration (mg/kg)	0.24 mg/kg (values were considered for different lake- and species-specific or combined datasets)	0.30 mg/kg	For the two most representative lakes (Grand Lake and Lake Esau), 0.30 mg/kg is the highest lake- and species-specific 95% UCL for trophic level 4 fish (based on 1995 Grand Lake legal-size smallmouth bass (n=10)).
Background mercury deposition rate	19.2 ug/m^2-yr to water bodies; 51.6 ug/m^2-yr to terrestrial watershed; OR, MMREM model defaults of 12.5 and 33.6 ug/m^2-yr.	17.2 ug/m^2-yr to water bodies; either 17.2 or 46.3 ug/m^2-yr to terrestrial watrershed	MDEQ (2008) presents a summary of the deposition rate estimates for Pellston. For the 10-year period 1995-2006, the arithmetic average total deposition rate estimate = 17.2 ug/m^2-yr. For consistency with the MMREM assumptions, the deposition rate to terrestrial areas may be assumed to be greater by a factor of 2.69. Or, it could be treated consistently as 17.2 ug/m^2-yr for background deposition at all locations, although the MMREM model would still treat facility deposition to water and land differently.

The MMREM model was run utilizing the alternative assumptions. This was applied to Swan Lake only, for expediency (Tables 5-7). In comparison to the other lakes modeled, Swan Lake was found by the applicant to have the project's highest mass loading to a water body, highest incremental fish impact, and (tied for) highest HQ impact. The alternative assumptions were run separately (runs G-N) and in combinations (runs O-Q). As with the initial model runs (Tables 1-3), both of the applicant's approaches for estimating the background deposition rate were utilized. Other model inputs, e.g., acreage and incremental air impacts (total), were the same as in the initial model runs. The speciation profile of 50/30/20 results in MMREM model inputs as shown in Table 5.

Table 5. Modeled incremental air impacts and deposition to Swan Lake based on a 50/30/20 mercury speciation profile.

Hg species	**Incremental air impact over water body (ug/m^3)**	**Incremental air impact over watershed (excluding water body) (ug/m^3)**	**%**	**Facility deposition (ug/m^2-yr)**	
				w.b.	**w.s.**
Hg(II) (RGM)	3.57E-7	5.76E-7	30%	0.1	0.2
Hg^0	5.95E-7	9.6E-7	50%	0	0
Hg(P)	2.38E-7	3.84E-7	20%	0	0
Total	**1.19E-6**	**1.92E-6**	**100%**	**0.1**	**0.2**

Table 6. Model inputs utilizing alternative model assumptions for Swan Lake (values different that applicant's assumptions are in BOLD).

	Hg speciation	**Fraction reaching water body**	**Existing fish Hg (mg/kg)**	**Deposition rate to w.b. (ug/m^2-yr)**	**Deposition rate to w.s. (ug/m^2-yr)**
G	**50/30/20**	10%	0.24	19.2	51.6
H	**50/30/20**	10%	0.24	12.5	33.6
I	100% RGM	**20%**	0.24	19.2	51.6
J	100% RGM	**20%**	0.24	12.5	33.6
K	100% RGM	10%	**0.30**	19.2	51.6
L	100% RGM	10%	**0.30**	12.5	33.6
M	100% RGM	10%	0.24	**17.2**	**46.3**
N	100% RGM	10%	0.24	**17.2**	**17.2**
O	**50/30/20**	**20%**	**0.30**	12.5	33.6
P	**50/30/20**	**20%**	**0.30**	**17.2**	**17.2**
Q	**50/30/20**	**20%**	**0.30**	**17.2**	**46.3**

Table 7. Swan Lake MMREM modeling results utilizing alternative assumptions.

	Mass loading to w.b. (g/yr)		Fish Hg (mg/kg)			Hazard Quotient (HQ)		
	Ambient	**Project**	**Bkgd.**	**Incr.**	**Total**	**Bkgd.**	**Incr.**	**Total**
G	591.45	2.62	0.24	0.001	0.241	0.55	0.00	0.55
H	385.13	2.62	0.24	0.002	0.242	0.55	0.00	0.55
I	1174.44	15.23	0.24	0.003	0.243	0.55	0.01	0.56
J	764.75	15.23	0.24	0.005	0.245	0.55	0.01	0.56
K	591.45	7.71	0.30	0.004	0.304	0.69	0.01	0.70
L	385.13	7.71	0.30	0.006	0.306	0.69	0.01	0.70
M	530.69	7.71	0.24	0.003	0.243	0.55	0.01	0.56
N	201.92	7.71	0.24	0.009	0.249	0.55	0.02	0.57
O	764.75	5.19	0.30	0.002	0.302	0.69	0.00	0.69
P	396.24	5.19	0.30	0.004	0.304	0.69	0.01	0.70
Q	1053.79	5.19	0.30	0.001	0.301	0.69	0.00	0.69

III. Discussion

The applicant's modeling assumption of 100% reactive gaseous mercury (RGM) is a conservative (worst-case) assumption for modeling deposition impacts to the nearby water bodies, based on the relative MMREM deposition velocities. Other conservative assumptions in the modeling include: modeling long-term impacts based on the maximum proposed permitted emission rate; utilizing a surrogate fish mercury level which is set at the 95% upper confidence limit (UCL) for the similar nearby lakes; and, assuming that the 15 g/day sport fish consumption rate consists entirely of top predator species (trophic level 4) such as the surrogate species (smallmouth bass) rather than a mixture of trophic level 4 and 3 (which would presumably have lower mercury levels than trophic level 4). Depending on future actual fishery use, it may also be conservative to assume that anglers will utilize the lakes evaluated as recreational fisheries at a fish consumption rate of 15 g/day (about one ½ lb meal every 2 weeks).

The results of the alternative model inputs (Table 7) can be compared to those of the applicant's model runs A and B of Table 3 (Swan Lake).

The application of the alternative value for the existing fish concentration (0.30 mg/kg, vs. the applicant's value of 0.24 mg/kg) is shown in model runs K and L. The alternative value for background fish mercury results in an increase in the incremental fish impact from 0.003 to 0.004 mg/kg, and from 0.005 to 0.006 mg/kg, depending on the set of background deposition rate estimates utilized. There was no change in the model's HQ increment (0.01).

The alternative mercury speciation profile (50/30/20, vs. the applicant's assumption of 100% RGM) is modeled in runs G and H. The alternative assumption results in a large reduction in the project's mass loading to the water body (2.62 g/yr, vs. 7.71 g/yr). The resulting incremental fish mercury impact (mg/kg) is reduced from 0.003 to 0.001, and from 0.005 to 0.002, depending on the set of background deposition rate estimates utilized. The HQ increment is reduced from 0.01 to 0.00.

The alternative assumption for the fraction of mercury deposited in the terrestrial watershed which reaches the water body (20%, vs. the applicant's value of 10%) is

modeled in runs I and J. The alternative assumption of doubling the fraction of terrestrial deposition reaching the water body doubles the total mass loading rate to the water body, because this source is predominant over the deposition directly to the water. The modeled incremental impacts to fish mercury levels and HQ due to the project were not affected by the alternative assumptions.

Model runs M and N evaluated the impacts of assuming a background deposition rate of 17.2 ug/m^2-yr, with a proportionally higher rate to terrestrial areas (46.3 ug/m2-yr; run M) or no difference (run N). These gave results that were very similar to the applicant's, except run N gave a higher fish incremental impact (0.009 mg/kg).

Some combinations of alternative assumptions were utilized in runs O-Q. These gave fairly similar results to the applicant's assumptions, with regard to the incremental fish impact (0.001 to 0.004 mg/kg) and the incremental HQ (0.00 or 0.001).

It may also be noted that the applicant's assessment accounted for all of the local water bodies suggested for inclusion by the AQD. This did not include Nettie Lake, although it is know to have elevated fish mercury levels, because it is located approximately 19 km SW of the facility. It was not included because the distance from the facility, and the direction being not in the direction of the prevailing wind, suggested that it would be less impacted than the selected lakes. Subsequent dispersion modeling by AQD confirmed that the modeled ambient air impact over Nettie Lake was relatively lower than the lakes evaluated: 8.70 E-07 ug/m^3.

References:

Michigan Department of Environmental Quality (MDEQ). 2008. Mercury Strategy Staff Report. MDEQ's Current Status and Recommended Future Activities Toward the Goal of Eliminating Anthropogenic Mercury Use and Releases in Michigan.

Minnesota Pollution Control Agency (MPCA). 2006. MPCA Mercury Risk Estimation Method (MMREM) for the Fish Consumption Pathway (Local Impacts Assessment). December 2006. Version 1.0.

EPA. 2001. Mercury Maps. A Quantitative spatial Link Between Air Deposition and Fish Tissue. Peer Reviewed Final Report. EPA-823-R-01-009.