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MEMORANDUM

Attachment 1

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SUBJECT: METHYL BROMIDE EMISSION RATIO GROUPINGS

This memorandum describes the procedures used to group the Methyl Bromide application types. Each application type is assigned the mean emission ratio from the appropriate group. The group mean emission ratio, together with the size of the application, determines the buffer zone length for a particular permitted application.

Materials and Methods

Physical characteristics of the application methods were initially used to assign each application method to a group. The initial groupings were as follows: 1) broadcast/tarp/deep, 2) broadcast/tarp/shallow, 3) broadcast/non-tarp/deep, 4) broadcast/non-tarp/shallow, 5) bed/tarp/shallow, 6) hot-gas. This initial grouping resulted in several empty cells for all possible combinations of factors. For example, there are no bed/tarp/deep applications. Therefore, the initial analysis to investigate the effect of tarping and/or depth of injection on the emission ratio value was conducted only on broadcast application types. All analysis was conducted on both the unadjusted and the adjusted for 50% recovery emission ratios.

Further grouping was based upon both physical characteristics of the application methods and the results from the statistical analysis of the broadcast application types. The application types represented in the monitoring data set were grouped into four types: 1) broadcast/non-tarp, 2) broadcast/tarp, 3) bed/tarp, and 4) hot gas. Due to risk management concerns about high air concentrations associated with hot gas, the emission ratio for this method remains at 1.0 and this method was eliminated from further analysis.

MINITAB statistical software, Release 12, was used for all analysis and graphical presentations (Minitab Inc., 1997). One and two-way analysis of variance (ANOVA) were used to perform the data analysis. The Anderson-Darling test for normality and Levene's test for homogeneity of variance were used to screen for violations of the assumptions of ANOVA (Minitab Inc., 1997). When required, transformation techniques were employed. Mean separation was accomplished using Fisher's pairwise comparison procedure.

Results and Discussion

Broadcast Application Types. Results of analysis on the broadcast application types are shown in Tables 1 through 3 and Figures 1 and 2. Results from the statistical tests to detect violations of the assumptions of ANOVA are shown in Table 1. For both the unadjusted and the recovery adjusted emission ratios, the data met both the normality (A-squared=0.201, p=0.865, and A-squared=0.192, p=0.885, respectively) and the homogeneity of variance assumptions (Levene's Test Statistic=1.017, p=0.381, and Levene's Test Statistic=1.031, p=0.377, respectively). The two-way ANOVA for both the unadjusted emission ratios and the recovery adjusted emission ratios (Tables 2 and 3, respectively) show no interaction between the factors tarp and depth of injection ($F_{1,18}$=0.30, p=0.590, and $F_{1,18}$=0.30, p=0.590, respectively). Therefore, the effects of tarping and depth of injection may be interpreted separately. For both unadjusted and recovery adjusted emission ratios, there is a significant effect due to tarp ($F_{1,18}$=6.32, p=0.022, and $F_{1,18}$=6.31, p=0.022, respectively) but no significant effect due to depth of injection ($F_{1,18}$=2.55, p=0.128, and $F_{1,18}$=2.57, p=0.126, respectively). Figures 1 and 2 clearly show the significant effect due to tarp and the non-significant effect due to depth of injection for both unadjusted and recovery adjusted emission ratios. For the unadjusted emission ratios, the mean for non-tarped applications is 0.19, while the mean for tarped applications is 0.12. The mean for shallow injections is 0.143, while the mean for deep injections is 0.145. For the recovery adjusted emission ratios, the mean for non-tarped applications is 0.37, while the mean for tarped applications is 0.24. The mean for shallow injections is 0.287, while the mean for deep injections is 0.290. These results indicate that for both the unadjusted and the recovery adjusted emission ratios, for the broadcast applications, there are only two distinguishable groups: non-tarp and tarp.

Broadcast and Bed Application Types. One-way ANOVA was conducted on the single factor of application type. The application types included were: 1) broadcast/non-tarp, 2) broadcast/ tarp, and 3) bed/tarp. Before the one-way ANOVA was conducted, the data was examined for violations of the assumptions of ANOVA. The results of that analysis are shown in Table 4. The Anderson-Darling Test indicates that, for both the unadjusted and the recovery adjusted emission ratios, the raw data violate the assumption of normality (A-squared=1.304, p=0.002, and A-squared=1.164, p=0.004, respectively). However, for both the unadjusted and the recovery adjusted emission ratios, Levene's Test indicates that the data do not violate the assumption of homogeneity of variance between groups (Levene's Test Statistic=1.553, p=0.229, and Levene's Test Statistic=0.648, p=0.531, respectively). The results in Table 5 show that for both the unadjusted and the recovery adjusted emission ratios, a $\log_{10}$ transformation corrected the violation of the normality assumption (A-squared=0.381, p=0.379, and A-squared=0.485, p=0.211, respectively) and maintained homogeneous variances between groups (Levene's Test Statistic=0.070, p=0.933, and Levene's Test Statistic=0.105, p=0.900, respectively).

The one-way ANOVA was conducted on both the raw emission ratios and the $\log_{10}$ transformed data. For both the unadjusted and the recovery adjusted emission ratios, the results obtained from both analysis were consistent. For simplicity, only results from analysis of the raw emission ratios are presented. Results from the one-way ANOVA on the raw emission ratios are shown in Tables 6 and 7. For both the unadjusted and the recovery adjusted emission ratios there is a significant difference between application types ($F_{2,28}=21.81$, $p=0.000$, and $F_{2,28}=21.26$, $p=0.000$, respectively). Further, the Fisher's pairwise comparison ($p=0.05$) indicates that bed/tarp application type is significantly different from both the broadcast/non-tarp and the broadcast/tarp. Figures 3 and 4 show the main effects means for application type. These figures clearly show the difference between the bed/tarp and the two broadcast application types. For the unadjusted emission ratios, the mean for broadcast/non-tarp is 0.19, the mean for broadcast/tarp is 0.12, while the mean for bed/tarp is 0.43. For the recovery adjusted emission ratios, the mean for broadcast/non-tarp is 0.24, the mean for broadcast/tarp is 0.37, while the mean for bed/tarp is 0.81.

Conclusions

Based upon the analysis discussed above, and the risk management decision to separate the hot gas method, the application types separate into four distinguishable groups. These groups are: 1) broadcast/non-tarp, 2) broadcast/tarp, 3) bed/tarp, and 4) hot gas. The mean unadjusted emission ratios and recovery adjusted emission ratios and their respective standard deviations and coefficients of variation (CV), for the four groups are shown in Table 8. Box-plots of the final groupings are shown in Figures 5 and 6.

References

Minitab Inc. 1997. User's Guide 2: Data analysis and quality tools. Release 12. Minitab statistical software

Table 1. Results of tests for the violation of assumptions of ANOVA, broadcast application types only.

	Normality Anderson-Darling Test		**Homogeneity of Variance Levene's Test**	
	Test Statistic	p-value	Test Statistic	p-value
unadjusted emission ratio	0.201	0.865	1.017	0.381
adjusted emission ratio	0.192	0.885	1.031	0.377

Table 2. ANOVA results for unadjusted emission ratios broadcast application types only.

Source	**DF**	**Seq. SS**	**Adj. SS**	**Adj. MS**	**F-ratio**	**p-value**
tarp	1	0.0230	0.0331	0.0331	6.32	0.022
depth	1	0.0118	0.0133	0.0133	2.55	0.128
tarp*depth	1	0.0016	0.0016	0.0016	0.30	0.590
error	18	0.0941	0.0941	0.0052		
total	21	0.1305				

Table 3. ANOVA results for recovery adjusted emission ratios, broadcast application types only.

Source	**DF**	**Seq. SS**	**Adj. SS**	**Adj. MS**	**F-ratio**	**p-value**
tarp	1	0.0909	0.1318	0.1318	6.31	0.022
depth	1	0.0473	0.0537	0.0537	2.57	0.126
tarp*depth	1	0.0063	0.0063	0.0063	0.30	0.590
error	18	0.3762	0.3762	0.0209		
total	21	0.5208				

Table 4. Results of tests for the violation of assumptions of ANOVA, broadcast and bed application types only.

	Normality Anderson-Darling Test		**Homogeneity of Variance Levene's Test**	
	Test Statistic	p-value	Test Statistic	p-value
unadjusted emission ratio	1.304	0.002	1.553	0.229
adjusted emission ratio	1.164	0.004	0.648	0.531

Table 5. Results of tests for the violation of assumptions of ANOVA on $\log_{10}$ transformed data, broadcast and bed application types only.

	Normality Anderson-Darling Test		**Homogeneity of Variance Levene's Test**	
	Test Statistic	p-value	Test Statistic	p-value
unadjusted emission ratio	0.381	0.379	0.070	0.933
adjusted emission ratio	0.485	0.211	0.105	0.900

Table 6. ANOVA results for unadjusted emission ratios, broadcast and bed application types only.

Source	DF	SS	MS	F-ratio	p-value
app. type	2	0.5509	0.2755	21.81	0.000
error	28	0.3536	0.0126		
total	30	0.9045			

Table 7. ANOVA results for recovery adjusted emission ratios, broadcast and bed application types only.

Source	DF	SS	MS	F-ratio	p-value
app. type	2	1.8102	0.9051	21.26	0.000
error	28	1.1920	0.0426		
total	30	3.0022			

Table 8. Summary table of unadjusted emission ratios and recovery adjusted emission ratios for broadcast and bed application types only.

		Unadjusted emission ratio			**recovery adjusted emission ratio**		
	n	em. ratio	st. dev.	CV	em. ratio	st. dev.	CV
broadcast/ non-tarp	8	0.19	0.087	46%	0.37	0.174	47%
broadcast/ tarp	14	0.12	0.065	54%	0.24	0.129	52%
bed/tarp	9	0.43	0.175	41%	0.81	0.309	38%

Figure 1. Main effects plots for the unadjusted emission ratios. Data shown are treatment means. For tarp code, non-tarp = 0, tarp = 1. For depth code, shallow = 0, deep = 1.

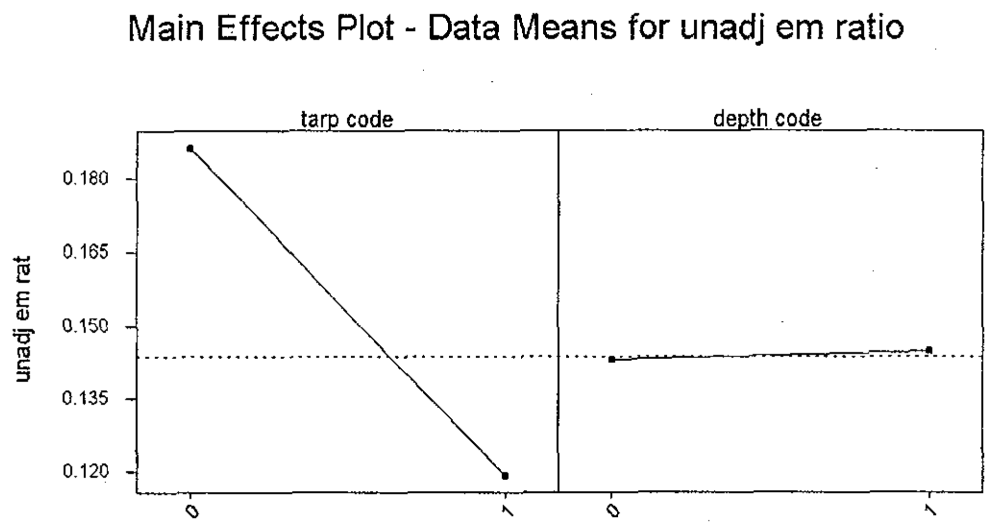

Figure 2. Main effects plots for the recovery adjusted emission ratios. Data shown are treatment means. For tarp code, non-tarp = 0, tarp = 1. For depth code, shallow = 0, deep = 1.

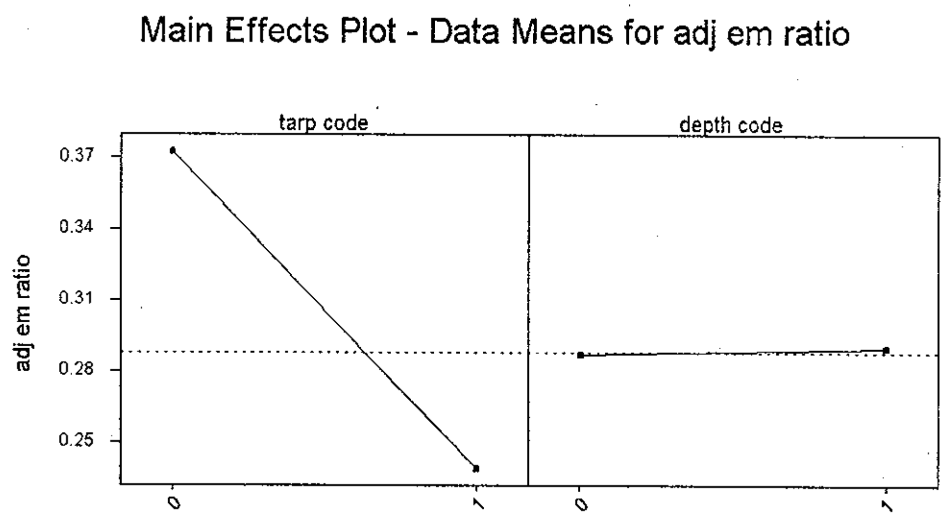

Figure 3. Main effects plots for the unadjusted emission ratios. Data shown are treatment means. For app. code, broadcast/non-tarp = 0, broadcast/tarp = 1, bed/tarp = 2.

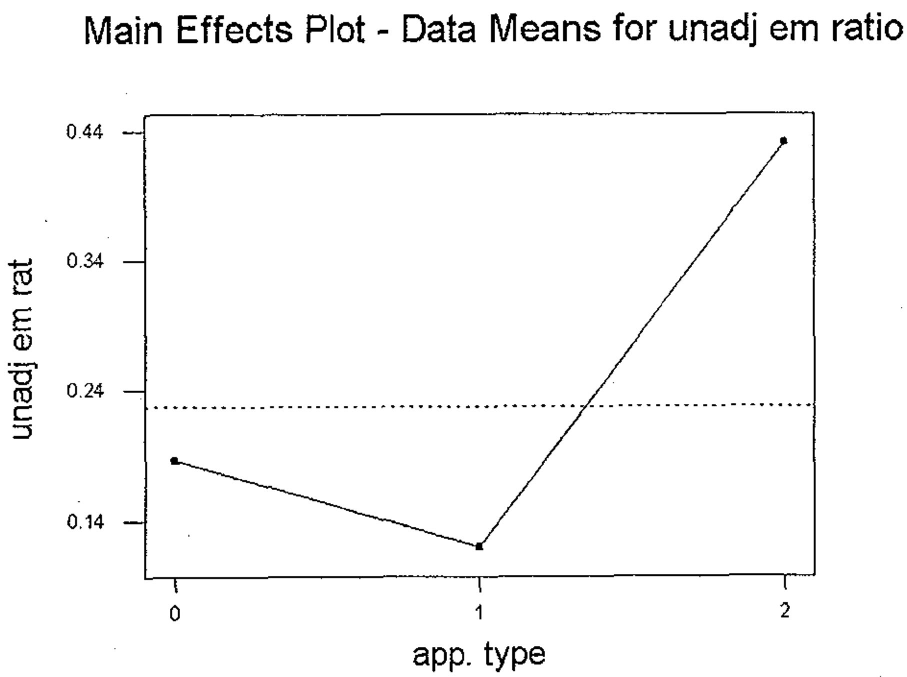

Figure 4. Main effects plots for the adjusted emission ratios. Data shown are treatment means. For app. code, broadcast/non-tarp = 0, broadcast/tarp = 1, bed/tarp = 2.

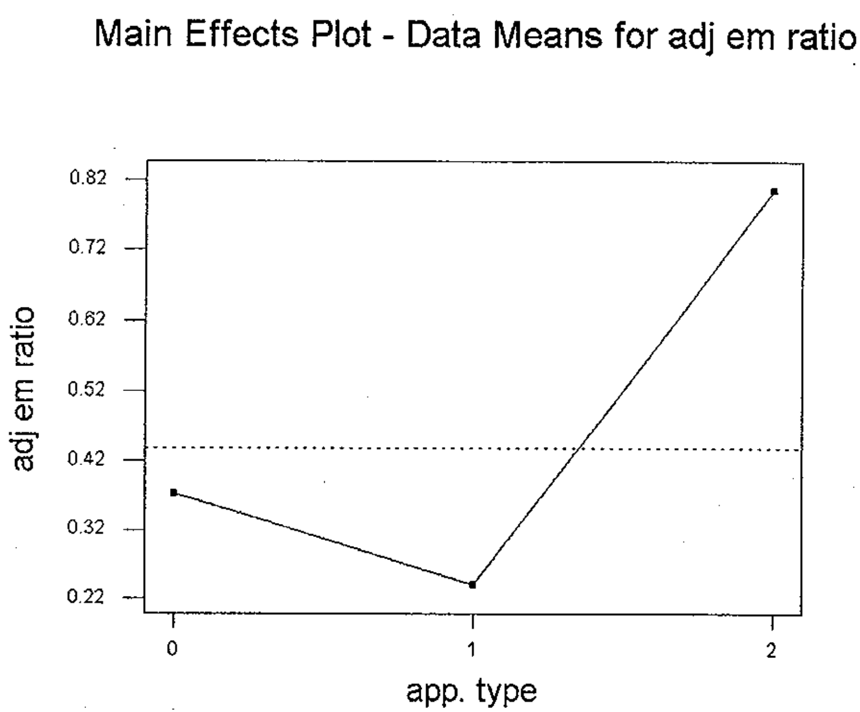

Figure 5. Box-plot of the final groupings of application types for unadjusted emission ratios. For app. code, broadcast/non-tarp = 0, broadcast/tarp = 1, bed/tarp = 2, hot gas = 3.

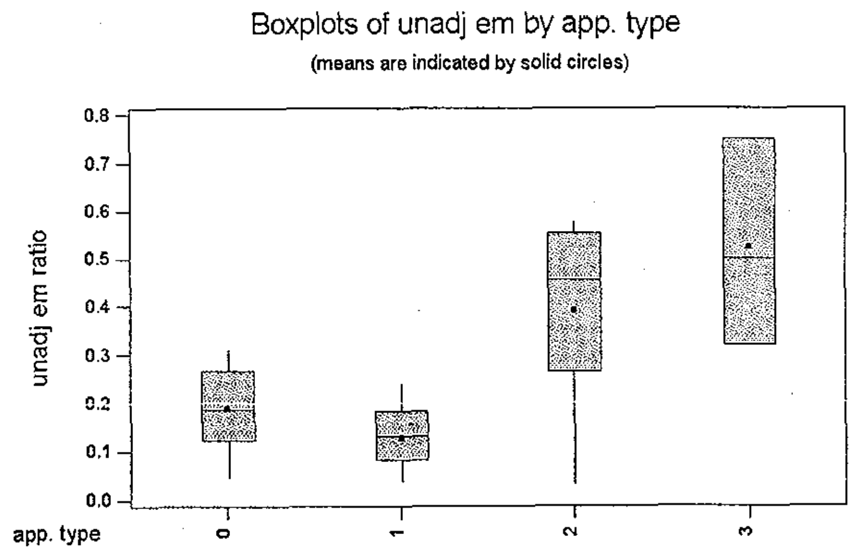

Figure 6. Box-plot of the final groupings of application types for recovery adjusted emission ratios. For app. code, broadcast/non-tarp = 0, broadcast/tarp = 1, bed/tarp = 2, hot gas = 3.