AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

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Project: WX-04010

Centra Gas Manitoba Inc.
444 St. Mary Avenue
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C-0463

Attention: **Mr. Andrew Galarnyk**

Dear Sir:

RE: MONITORING REPORT #3
IN-SITU BIOREMEDIATION PILOT STUDY
CENTRA GAS SUTHERLAND AVENUE OPERATIONS SITE
WINNIPEG, MANITOBA

INTRODUCTION

AEE is pleased to provide this third monitoring report, summarizing monitoring of the in-situ bio-remediation pilot study currently being conducted at the Centra Gas Sutherland Avenue operations site in Winnipeg, Manitoba. This report includes the results of monitoring completed during May and June 1997. The two wells (IP1 and IP2), containing Oxygen Release Compounds (ORC), are approximately 3 m upgradient from the two monitoring wells, MW5 and MW 14, respectively.

MONITORING PROGRAM

Site monitoring was conducted by AEE between May 12 and 22, 1997 (Monitoring Round 3) and on June 26, 1997 (Monitoring Round 4). The monitoring included in-situ testing for dissolved oxygen, carbon dioxide and temperature as well as laboratory analysis to determine general groundwater chemistry and concentrations of polyaromatic hydrocarbons (PAH's) and benzene, toluene, ethylbenzene and xylenes (BTEX). This report also summarizes the results of some additional analyses completed on samples obtained in March 1997, namely:

- During Monitoring Round 2 (March 97), samples were obtained and submitted to AEE's laboratory to determine concentrations of ammonia-nitrogen and numbers of PAH degrading microbes.

- All wells on site, both within and outside of the pilot program area, were field tested in June 1997 for carbon dioxide and dissolved oxygen concentrations.

The monitoring results for the wells within the pilot study area (MW5, MW14, IP1 and IP2) are summarized in Tables I to VI. The results of previous monitoring are also shown for comparative purposes. The results of the additional testing are summarized in Tables VII and VIII.

ASSESSMENT OF RESULTS

Based on the monitoring results, the following comments are offered:

PAH's and BTEX

1. The reduction in total dissolved PAH concentrations previously noted at MW 5 did not continue through Monitoring Rounds 3 and 4. However, the increases noted during May and June appear to be limited to a sharp increase in the naphthalene concentration. The remaining PAH compounds appear to be present at concentrations similar to March 1997, and significantly lower than the initial monitoring conducted in December 1996. At present the reason for the increase in naphthalene in the groundwater is not readily apparent, however it is speculated that it could be attributable either to the higher groundwater flows during the spring months or to the elevated water table, either of which may have intercepted a source of naphthalene located at shallower depths.

2. Although the total PAH reduction at MW 5 did not continue through May and June, there was a continued reduction in BTEX concentrations, with the concentrations much lower than in December 1996 and slightly lower than in March 1997.

3. The trend in PAH and BTEX concentrations at MW 14 was similar to that of MW5, with a sharp increase in the naphthalene concentration and a slight increase in the remaining PAH compounds. There was a slight to moderate reduction in BTEX concentrations since March 1997. At present, AEE has been unable to determine why the naphthalene jump at MW 14 occurred one month earlier than at MW5.

General Water Chemistry

4. The general water chemistry at MW 5 has changed little since the onset of the pilot study; with the only apparent trends being a steady reduction in sulphate and a general increase in calcium, magnesium, chlorides and carbon dioxide. At MW 14, there was an increase in chlorides, magnesium and sulphate and an apparent increase in dissolved organic carbon. The magnesium increase is likely due to the ORC's, which are largely composed of magnesium peroxide and magnesium hydroxide.

5. The pH at IP 1 remains elevated, however it has dropped from that noted in March 1997. The reduction in pH is encouraging with regards to the possible long term implementation of the program. The pH at IP2, MW 5 and MW 14 has remained fairly consistent during the pilot program (7 to 7.75).

Dissolved Oxygen

6. The dissolved oxygen (DO) concentrations at MW 5 and MW14 have increased since March 1997, at which time they were lower than preferred. However, the DO concentrations which were measured at the remaining wells on site (outside of the study area) were comparable to those at MW5 and MW14 and therefore the DO at MW 5 and MW 14 may not be attributable to the ORC socks. Regardless, the DO concentrations at the site are at levels which are beneficial to biological degradation of organic compounds. It can be inferred that the DO increase at the site is due to the increased groundwater flow rate.

7. At the injection wells, the DO concentrations are much lower than in March 1997 and are now consistent with the concentrations measured throughout the remainder of the site. On this basis, it can be concluded that the ORC socks are no longer delivering significant DO to the groundwater in the study area.

Additional Testing

8. The numbers of PAH degrading microbes were found to be fair to good; 1600 CFU/ml at MW 5 and >11,000 CFU/ml at MW 14. These results are encouraging with regards to the possible long term implementation of the remediation program.

9. The ammonia nitrogen concentrations appear to be high enough to sustain microbial activity.

SUMMARY

In summary, it appears that the ORC socks installed in January and February 1997 are no longer delivering significant dissolved oxygen to the groundwater in the study area. The duration (4 to 6 months) is in keeping with the expectations of the supplier and it may be possible that the life span was reduced as a result of the high groundwater flows during the 1997 flood event. In order to obtain additional information for this pilot study, a new sock has been installed in MW 5.

While there is a limited amount of data (4 monitoring events) , it is AEE's opinion that the results of the field trial continue to indicate that biodegradation of PAH and MAH's can be enhanced through the addition of dissolved oxygen into the subsurface environment. The data

suggests that a significant reduction in BTEX concentrations and a moderate reduction in PAH concentrations can likely be achieved at the site if full scale implementation of the program is undertaken. At present, the main item of concern is the elevated naphthalene concentrations which have recently been identified. It is possible that the increased naphthalene concentrations may be attributable to hydrogeologic effects, rather than an inability to degrade these compounds (i.e. a large increase in the naphthalene concentrations in the site groundwater, which have only been partially reduced in the study area). In this regard, the naphthalene concentration at MW 22 will be determined during the next monitoring round. MW 22 is outside of the test area and it is hoped that the relative change in naphthalene concentrations from December 1996 to August 1997 at MW 22 can be compared to the relative change in naphthalene concentration within the study area. This will aid in identifying the effectiveness of the ORC treatment in reducing the naphthalene concentrations.

In order to further refine the PAH degrading ability of the proposed program, AEE has initiated a laboratory treatability study at AEE's Portland, Oregon office. The primary focus of the evaluation will be to determine, in a controlled condition, the ability to reduce PAH concentrations in the groundwater utilizing three conditions; a) an abiotic condition, b) a native ground water condition and c) a nutrient enhanced groundwater condition. Each test will be run with the aid of ORC. The treatability test program will be performed on groundwater from MW14, due its higher PAH concentrations and the higher PAH degrading bacteria numbers.

The last site monitoring event will be completed at the end of August 1997, once the re-installed ORC sock in MW 5 has had sufficient time to release dissolved oxygen into the groundwater.

If you have any questions in the mean time, please do not hesitate to contact this office.

Yours truly,
AGRA Earth & Environmental Limited

Harley Pankratz, P. Eng.
Manager; Winnipeg Operations

Reviewed By:
Jack Spadaro, PhD

Dist: (2) Addressee
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TABLE I
COMPARATIVE RESULTS - MONITORING WELL 5
GENERAL WATER CHEMISTRY

Parameter	MONITORING WELL NO. 5				
	Dec 96	Feb 97	Mar 97	May 97	June 97
Dissolved Oxygen (ppm)	4.2	3.2	1.6	9.5	8.8
Temperature (Degrees C)	8.5	6.5	6.7	6.5	7.4
Redox Potential (mV)	+125	-13	+131.5	+143	+124
Dissolved Iron	21.1	33.7	34.0	17.7	22.6
Calcium	235	358	315	371	380
Magnesium	148	210	186	212	219
Potassium	16.6	7.8	5.0	6.3	8.1
Sodium	102	115	94	103	106
Bicarbonate	1190	1560	956	1120	1170
Carbonate	<1	<1	<1	<1	<1
Chloride	207	434	602	619	656
Hydroxide (as CaCO3)	<0.1	<0.1	<0.1	<1	<1
Nitrate as N	0.27	0.36	0.71	0.46	0.21
Sulphate	229	181	179	176	152
Conductivity (mS/cm)	2.40	3.52	3.45	3.31	3.32
pH (unitless)	7.26	7.19	7.34	7.53	7.37
Dissolved Inorganic Carbon	234	124	188	258	115
Dissolved Organic Carbon	19	19	18	26	25
Total Alkalinity (as CaCO3)	1090	1030	784	922	961
CO2 (ppm)	NM	NM	775	4200	>5000

Notes: All results in mg/l (parts per million) unless otherwise noted.

TABLE II
COMPARATIVE RESULTS -MONITORING WELL 14
GENERAL WATER CHEMISTRY

Parameter	MONITORING WELL NO. 14				
	Dec 96	Feb 97	Mar 97	May 97	June 97
Dissolved Oxygen (ppm)	5.4	2.8	0.2	11.5	8.5
Temperature (Degrees C)	7.9	7.7	7.1	6.5	8.5
Redox Potential (mV)	+65	+124	+147.8	+148	+137
Dissolved Iron	23.2	26.6	18.0	16.8	20.4
Calcium	236	240	239	208	253
Magnesium	137	137	149	222	209
Potassium	14.3	10.4	8.8	14.5	15.9
Sodium	102	113	104	89	104
Bicarbonate	1050	1040	1050	1244	1370
Carbonate	<1	<1	<1	<1	<1
Chloride	191	166	225	238	258
Hydroxide (as CaCO3)	<0.1	<0.1	<0.1	<1	<1
Nitrate as N	0.29	0.34	0.26	1.74	0.07
Sulphate	232	257	282	329	394
Conductivity (mS/cm)	2.31	2.42	2.67	2.67	2.59
pH (unitless)	7.26	7.28	7.60	7.43	7.49
Dissolved Inorganic Carbon	207	102	207	245	134
Dissolved Organic Carbon	21	18	25	34	33
Total Alkalinity (as CaCO3)	1050	852	860	1020	1120
CO2 (ppm)	NM	NM	>5000	>5000	>5000

Notes: All results in mg/l (parts per million) unless otherwise noted.

TABLE III
COMPARATIVE RESULTS - MONITORING WELL NO. 5
ORGANIC CHEMISTRY

Parameter	MONITORING WELL NO. 5			
	Dec 96	Mar 97	May 97	June 97
POLYCYCLIC AROMATIC HYDROCARBONS (PAH's)				
Naphthalene	0.13	0.039	3.1	2.7
Acenaphthylene	0.14	0.011	0.13	0.063
Acenaphthene	0.027	0.10	0.059	0.032
Fluorene	0.022	0.0015	0.0044	0.0029
Phenanthrene	0.024	0.0004	0.0049	0.0026
Anthracene	0.0055	0.0004	0.0012	0.0006
Fluoranthene	0.0057	0.0002	0.0006	0.0003
Pyrene	0.0064	0.0008	0.0019	0.0006
Benzo(a)anthracene	0.0015	0.0001	<0.0001	<0.0001
Chrysene	0.0006	0.0001	0.0001	<0.0001
Benzo(b)fluoranthene	0.0002	<0.0005	<0.0005	<0.0005
Benzo(k)fluoranthene	0.0005	<0.0005	<0.0005	<0.0005
Benzo(a)pyrene	0.0015	<0.0005	<0.0005	<0.0005
Indeno(1,2,3-cd)pyrene	0.0007	<0.0005	<0.0005	<0.0005
Dibenzo(a,h)anthracene	0.0001	<0.0005	<0.0005	<0.0005
Benzo(g,h,i)perylene	0.0008	<0.0005	<0.0005	<0.0005
TOTAL PAH's	**0.3665**	**0.1535**	**3.3021**	**2.8020**
MONOCYCLIC AROMATIC HYDROCARBONS (MAH'S)				
Benzene	47	2.0	1.2	1.3
Toluene	4.0	0.027	0.011	0.011
Ethylbenzene	3.8	1.3	0.56	0.003
Xylenes	3.2	1.0	0.61	0.54
TOTAL BTEX	**58.0**	**4.327**	**2.381**	**1.854**

Note: All results in mg/l (parts per million).

TABLE IV
COMPARATIVE RESULTS - MONITORING WELL NO. 14
ORGANIC CHEMISTRY

Parameter	MONITORING WELL NO. 14			
	Dec 96	Mar 97	May 97	June 97
POLYCYCLIC AROMATIC HYDROCARBONS (PAH's)				
Naphthalene	0.20	1.2	3.2	6.3
Acenaphthylene	0.10	0.081	0.16	0.23
Acenaphthene	0.017	0.013	0.020	0.025
Fluorene	0.014	0.0014	0.018	0.027
Phenanthrene	0.015	0.0078	0.018	0.041
Anthracene	0.0035	0.0022	0.0044	0.0089
Fluoranthene	0.0036	0.0022	0.0057	0.0089
Pyrene	0.0043	0.0066	0.0095	0.034
Benzo(a)anthracene	0.0012	0.0014	0.0028	0.0032
Chrysene	0.0013	0.0013	0.0025	0.0029
Benzo(b)fluoranthene	0.0013	0.0017	0.0030	0.0033
Benzo(k)fluoranthene	0.0004	0.0007	0.0014	0.0020
Benzo(a)pyrene	0.0013	0.0021	0.0034	0.0037
Indeno(1,2,3-cd)pyrene	0.0007	0.0014	0.0016	0.0012
Dibenzo(a,h)anthracene	0.0001	<0.0005	0.0034	<0.0005
Benzo(g,h,i)perylene	0.0009	0.0017	0.0012	0.0010
TOTAL PAH's	**0.3646**	**1.3245**	**3.4549**	**6.6921**
MONOCYCLIC AROMATIC HYDROCARBONS (MAH'S)				
Benzene	60	75	48	13
Toluene	5.5	8.9	4.0	4.0
Ethylbenzene	5.6	8.8	3.3	2.5
Xylenes	4.4	7.7	3.5	4.2
TOTAL BTEX	**75.5**	**100.4**	**58.8**	**23.7**

Note: All results in mg/l (parts per million).

TABLE V
COMPARATIVE RESULTS - INJECTION WELLS
GENERAL WATER CHEMISTRY

Parameter	INJECTION WELL NO. IP1			
	Feb 97	Mar 97	May 97	June 97
Dissolved Oxygen (ppm)	6.3	19.7	NM	9.2
pH (unitless)	9.02	9.82	NM	8.9
Temperature (degrees Celsius)	NT	6.1	NM	7.0
CO2 (ppm)	NT	>5000	400	400

TABLE VI
COMPARATIVE RESULTS - INJECTION WELLS
GENERAL WATER CHEMISTRY

Parameter	INJECTION WELL NO. IP2			
	Feb 97	Mar 97	May 97	June 97
Dissolved Oxygen (ppm)	4.6	24.1	9.1	9.7
pH (unitless)	7.54	7.73	7.75	7.38
Temperature (degrees Celsius)	6.3	6.5	4.5	7.0
CO2 (ppm)	NT	>5000	>5000	1075

TABLE VII
SITE GROUNDWATER CONDITIONS

Monitoring Well No.	Dissolved Oxygen	CO_2
MW01	8.9	>5000
MW12	7.4	>5000
MW18	8.8	>5000
MW21	5.5	>5000
MW22	13.3	3600
MW23A	22.1	>5000
MW23B	14.1	>5000
MW24A	NM	375
MW24B	7.5	1100
MW24C	7.2	1200

Note: All results in mg/l (parts per million).

TABLE VIII
ADDITIONAL TESTING

Monitoring Well No.	PAH Degrading Bacteria	Ammonia-Nitrogen	Phosphorous
MW05	1600 CFU	2.27 ppm	
MW14	>11000 CFU	3.55 ppm	