

2. Data Compilation and Analysis

Consistent with the requirements of the GM, historical data for all RTRC compliance monitoring activities were provided for a period from January 1, 2010 through February 11, 2015. These data were analyzed for comparison to the USEPA Total Coliform Rule (TCR) database (37 states data for the year 2005) (US Data). A brief summary of these data is provided in the **Table 1**.

Table 1: Summary of the City of Winnipeg TCR Compliance Data and Comparison to US Data

	# Samples	TC+	% TC+	# EC+	% EC+
USEPA TCR database (2005)	1,642,162	38,773	2.36%	1353	0.082%
City of Winnipeg-Excluding January 26, 2015	11,096	42	0.38%	3	0.027%
City of Winnipeg-Including January 26, 2015	11,138	50	0.45%	8	0.072%
Louisville, KY(2005) (pop. 740,000)	3,606	5	0.14%	1	0.028%

These data indicate that excluding the event of January 26, 2015, the City compliance data compares favourably to results across the US and to a similarly sized US city. Prior to this event, the City had experienced only 3 compliance samples positive for EC in the past 5 years.

Compliance data collected during the October 7, 2013 event, the May 26, 2014 event and the January 26, 2015 event that were positive for TC are presented in **Table 2**. These data indicate that an unusually large number of samples were both TC and EC positive, despite the presence of a good chlorine residual, low turbidities, and, with the exception of one sample (SW12, May 26, 2014), low HPC counts. For all three events, samples collected the previous week and repeat samples on the two days following were all negative for TC and EC, with all other water quality parameters in normal ranges.

Table 2: Positive TC/EC Compliance Samples Collected 2010 - 2015

Sample Name	Date Sampled	Free Chlorine (mg/L)	Turb (NTU)	EC (MPNU/ 100 mL)	TC (MPNU/ 100 mL)	HPC (CFU/mL)
SW-07	26-Jan-15	0.74	0.17	1	1	<10
SE-04	26-Jan-15	0.78	0.31	1	3	<10
SE-03	26-Jan-15	0.76	0.25	1	4	<10
NE-01	26-Jan-15	0.49	0.26	1	5	<10
NE-07	26-Jan-15	0.96	0.19	9	53	<10
NE-06	26-Jan-15	0.95	0.31	<1	1	<10
SW-12	26-May-14	0.94	0.10	11	201	1390
SE-07	07-Oct-13	0.38	0.13	2	4	<10
SE-08	07-Oct-13	0.57	0.20	3	8	<10
SW-07	07-Oct-13	0.74	0.26	<1	3	<10
SE-05	07-Oct-13	0.67	0.26	<1	3	<10

Under the USEPA Revised Total Coliform Rule (RTRC) of 2014, violations of the rule occur when more than 5% of TC samples are positive in any given month, or when a given sample location is positive for TC

for two consecutive days, with one of these samples also being EC positive. By this definition, the data from January 26, 2015 would not trigger a RTCR violation, as the repeat samples were negative (no sample locations were positive on consecutive days). However, the number of TC/EC positive samples was highly irregular and warranted follow up from the ODW as regulator and the City as utility.

HPC, free chlorine residual, and turbidity data were further analyzed over the 5 year period and for the October 7, 2013, May 26, 2014 and January 26, 2015 events to provide insight into the events. Free chlorine residuals would be expected to decrease in the presence of any significant contamination event; this trend wasn't observed during the October 7, 2013, May 26, 2014 and January 26, 2015 events. To evaluate the possibility of artificial bias in the chlorine dataset, the frequency distribution for free chlorine residuals over the 5 year period was reviewed for abnormal truncation at lower levels of reported data (indicative of an artificially biased dataset). As shown in **Figure 1**, no abnormalities were observed, with the shape of the distribution fitting a normal distribution and indicative of a reliable dataset.

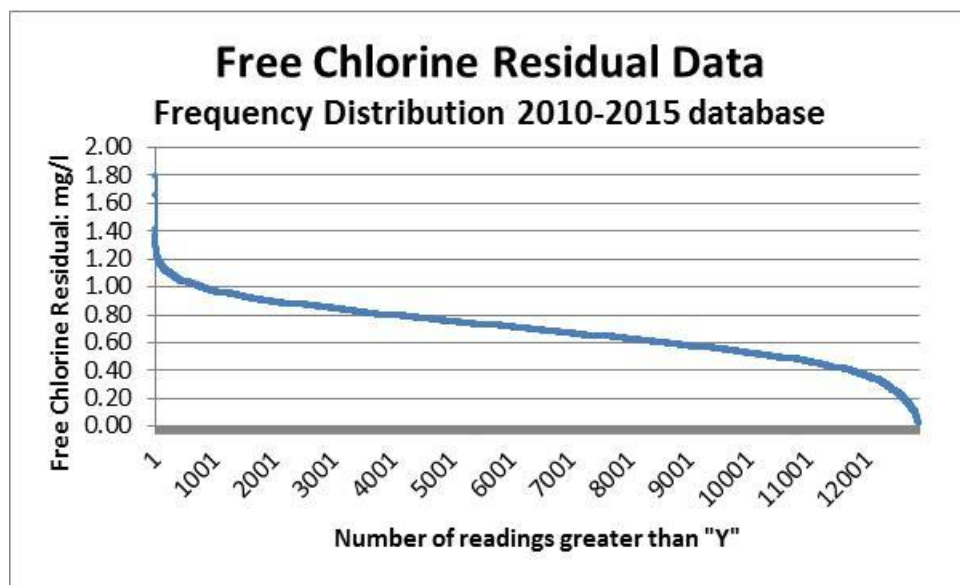


Figure 1: Frequency Distribution of Free Chlorine Residual Data, 2010-2015.

Chlorine residual data for the two-week period prior to and including the October 7, 2013 event were analyzed and found to be representative of very good water quality, with the average and minimum free chlorine levels at 0.69 mg/L and 0.24 mg/L respectively. HPC values for the same period represented very good water quality, with 114 of 132 samples below the detection limit of 10 CFU per mL, and a maximum HPC level of 260 CFU per mL on September 23, 2013.

Chlorine residual data for the two-week period prior to and including the May 26, 2014 event were analyzed and found to be representative of very good water quality, with the average and minimum free chlorine levels at 0.88 mg/L and 0.15 mg/L respectively. HPC values for the same period represented very good water quality, with 159 of 168 samples below the detection limit of 10 CFU per mL, and a maximum HPC level of 50 CFU per mL on May 20, 2014.

Chlorine residual data for the two-week period prior to and including the January 26, 2015 event were analyzed and found to be representative of very good water quality, with the average and minimum free chlorine levels at 0.77 mg/L and 0.16 mg/L respectively. HPC values for the same period represented

very good water quality, with 151 of 160 samples below the detection limit of 10 CFU per mL, and a maximum HPC level of 330 CFU per mL on January 19, 2015.

One possible explanation for the unusual pattern of TC/EC positives during the January 26, 2015 event was that sediment-imbedded TC/EC was re-suspended in pipes during some unobserved hydraulic event, resulting in a “pulse” of sediment and the observed spike in TC/EC detections. To evaluate this possibility, data on turbidity and chlorine residuals from the main flushing database were analyzed to determine if there was an association between suspended sediment (as indicated by turbidity levels) and decreased free chlorine levels (which might be associated with the possible presence of TC/EC). Data presented in **Figure 2** indicates no such correlation, with a correlation coefficient (R^2) near zero. Noting that chlorine residuals and turbidity levels were normal for the two weeks prior to the January 26, 2015 event, and that increases in sediment levels have no apparent impact on chlorine residuals, the available chlorine and turbidity data provided no support for a TC/EC contamination scenario involving re-suspension of sediment in the distribution system.

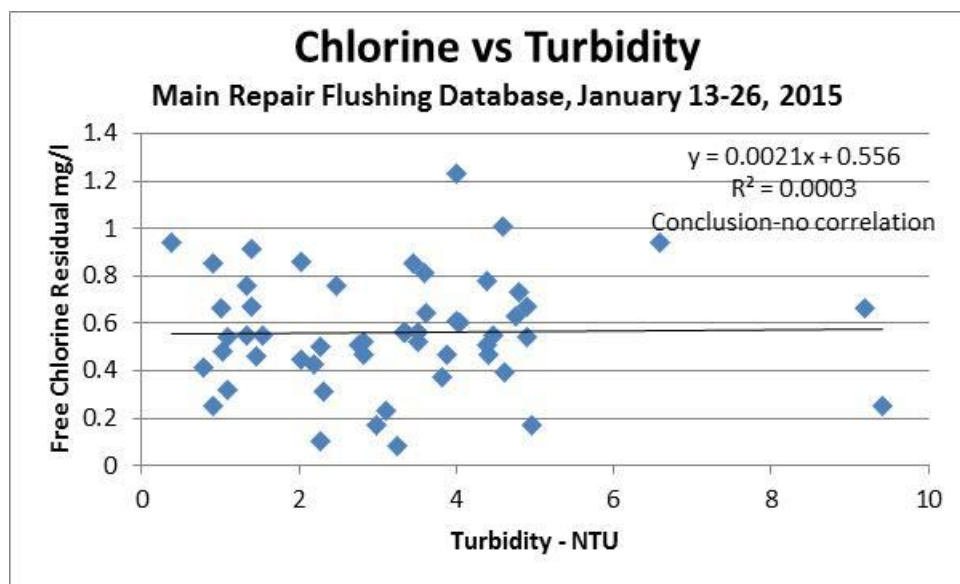


Figure 2: Free Chlorine Vs Turbidity from the Main Flushing Database

In addition to the TCR compliance database, the City database of non-compliance monitoring (additional samples taken beyond what is required by regulation from January 1, 2010 – February 11, 2015) was analyzed in detail for possible clues to the January 26, 2015 event. This database includes records from 5044 samples from 19 locations in the distribution system throughout the City. TC, EC, and HPC are measured at each location weekly. As of October 2013 chlorine residuals were measured at these locations as well. Data from the compliance database were combined with data from the non-compliance database for further analysis. This combined database provided 16,531 samples for analysis; a rich database for statistical analysis.

HPC values from the combined dataset are provided in **Figure 3**. Of the 16,088 analyses of HPC in the dataset, 89% were reported as <10 CFU/mL, indicating very good water quality. HPC values reported as <10 CFU/mL were arbitrarily assigned a value of 5 to allow graphing on the log-scale in **Figure 3**. Higher HPC levels tended to be reported in warmer weather months. HPC levels reported over the 5 year period provided no indication of problematic distribution system biofilm or sediment-attached microorganisms.

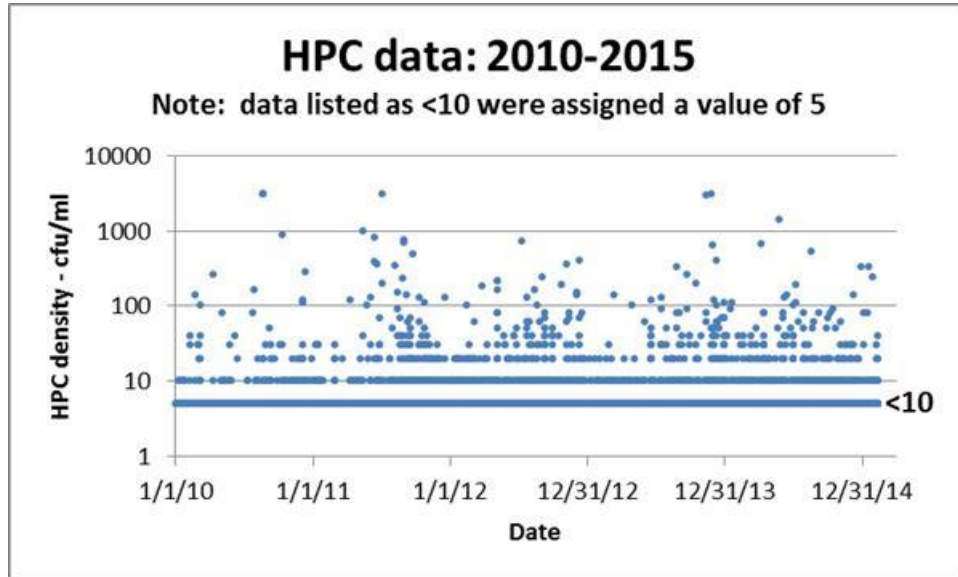


Figure 3: HPC Data from January 1, 2010 through February 11, 2015.

Data from the 2010-2015 combined dataset were sorted and parsed to a subset that contained matched pairs of quantified HPC data (reported above the detection limit) and free chlorine data. A total of 1350 matched pairs of data were graphed to determine if there was an association between increased HPC levels and decreased chlorine residuals (**Figure 4**). The correlation coefficient (R^2) of near zero indicates that there was no observed correlation between HPC and free chlorine residuals. Only two data points (the first two on the x-axis) represent an expected trend of higher HPC with lower chlorine residuals, with chlorine residuals of 0.02 and 0.05 mg/L, respectively. Chlorine residuals below 0.1 mg/L are considered to be near the detection limit for field analysis. This analysis indicates that if a short-term pulsed sanitary contamination of the distribution system had occurred, it would be possible to detect elevated HPC levels even in the presence of measurable chlorine residual. However, no HPC were detected and free chlorine residuals were normal from the samples which tested positive on January 26, 2015, which is counter-indicative of a contamination event in the distribution system. This same trend was observed for the October 2013 event. HPC levels were high in the May 2014 event, which more closely resembles expected trends from an environmental contaminant source that could have originated in the DS, the sampling process, or the lab process.

The review of over 16,000 samples in the 5 year period prior to and including the January 26, 2015 event provided no indication that the City distribution system was contaminated on January 26, 2015 other than the positive TC and EC samples. The January 26, 2015 finding of positive TC and EC in several samples coincident with normal free chlorine levels and low HPC levels, however, is consistent with a sanitary contamination in the sample collection and/or analysis processes. Data trends from the October 2013 event are very similar to those of January 2015 event, likewise indicating a contamination in the sample collection or lab analysis process. Data from the single positive sample during the May 2014 event contained high HPC levels along with elevated TC and a positive EC detection, but with low turbidity, a strong chlorine residual, negative repeat samples, and no indication of increased gastrointestinal (GI) disease. While the compilation of all data from the May 2014 event indicate that the likely source of contamination was either sample collection or lab analysis, it is impossible to definitely rule out the DS as a possible source of the contamination.

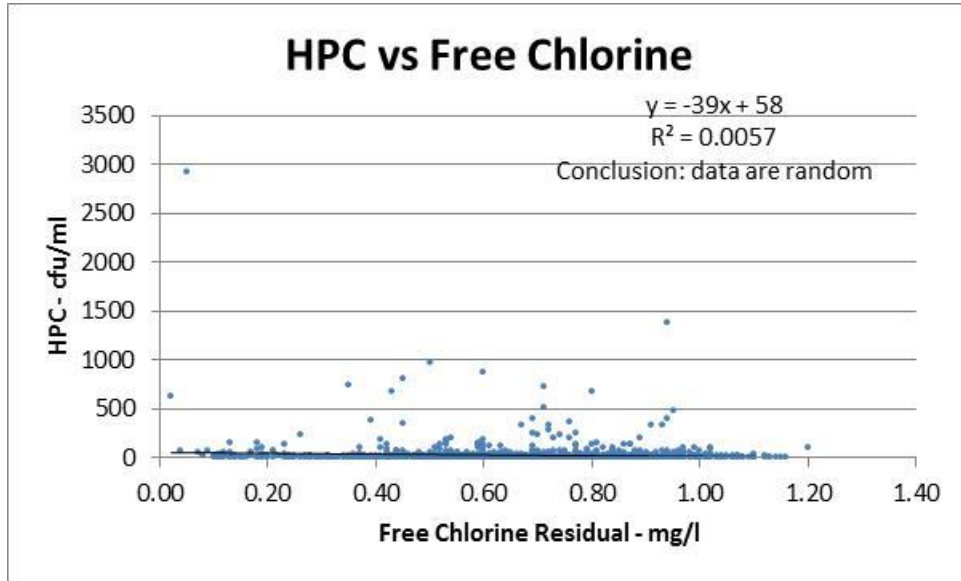


Figure 4: HPC vs Free Chlorine Residual of Matched-Pair Data from the Combined Database