Temperature-dependence in sewer blockage frequency

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Contents

1 Methods

1.a Data

Albuquerque Bernalillo County Water Utility Authority (ABCWUA) responds to SSB events after discovery by maintenance workers or reports of blockages from the public. This study used an anonymised dataset of SSB dates, along with engineers' estimates of blockage cause. SSB reports from the period January 2009 - January 2013 (inclusive) were used in this study. Since most days had no SSB, the total number of SSB per week was computed and used in subsequent analysis. Sanitary sewer blockages per week (SSB/W) is the primary focus of this work.

Sewer grab sample temperature (SGST) measurements were collected by ABCWUA personnel during routine maintenance, using XXX probes XXXX etc. (??mark) SGST measurements were available from 15 manholes, leading to 3 interceptors within Albuquerque. ??(How many total samples) ??(Mark - explain interceptors / structure of this data) SGST from the period December 2005 - December 2010 (inclusive) were used in this study.

Mean daily air temperature (MDAT) was obtained from the Albuquerque International airport's (KABQ) automated METAR data collection system (available from `http://www.wunderground.com/history/airport/KABQ`) for the period of record for which either SSB and SGST or measurements were available (December 2005 - January 2013, inclusive).

1.b Analysis

All analysis was conducted with the R statistical programming environment (R Core Team 2013). For final selection of linear model specifications, both Bayes'information criterion (BIC) and parsimony considerations were employed.

For comparison with SSB data, MDAT measurements were averaged by week to yield mean weekly MDAT (MW-MDAT). In addition, SGST measurements were averaged by week (all interceptors were combined), yielding mean weekly SGST (MW-SGST). Weeks without SGST measurements were excluded from analyses that included SGST.

First, we used ordinary linear models to estimate the response of MW-SGST to MW-MDAT, interceptor identity, and manhole identity. In favor of parsimony, and due to the small effect sizes and/or statistical non-significance, interceptor and manhole identity were excluded from subsequent models. Next, we used generalized linear models (GLM) to estimate the response of SSB/W to either MW-SGST or MW-MDAT. We also used a GLM to estimate the response of SSB/W to both MW-MDAT and blockage cause. Due to low sample numbers, the response of SSB/W to both MW-SGST and blockage cause was not estimated.

2 Results

2.a Air temperature (MDAT) and sewage temperature (SGST)

Candidate models were ranked using BIC ($\Delta = 10$; Table 1). The best model included air temperature, interceptor identity and an interaction between the two. This indicates that there was small but significant variation between interceptors and manholes responses to temperature. This model explained the majority of variation in sewage temperature ($R^2 = 0.78$).

	Model	BIC
1	null	8160.33
2	b.by.interceptor	8105.16
3	b.by.manhole	8176.95
4	m.by.interceptor	8147.29
5	m.by.manhole	8229.28
6	mb.by.interceptor	8094.78
7	mb.by.manhole	8242.55

Table 1: Candidate models for predicting sewage temperature using mean air temperature, ranked using Bayes Information Criterion

Sewage temperature increases with air temperature ($p < 0.001$; Table 2), but scales sub-linearly: sewers remain above freezing when air temperature falls below 0°C, but do not reach the same peaks as air temperature (Figure 1).

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	17.2139	0.1632	105.51	0.0000
MeanTempC	0.4103	0.0094	43.66	0.0000
InterceptorValley	-1.0761	0.2168	-4.96	0.0000
InterceptorWestside	0.5294	0.2111	2.51	0.0122
MeanTempC:InterceptorValley	0.0165	0.0125	1.32	0.1864
MeanTempC:InterceptorWestside	-0.0406	0.0124	-3.27	0.0011

Table 2: Sewage temperature increases with mean air temperature, but interceptors differed slightly in their responses to air temperature

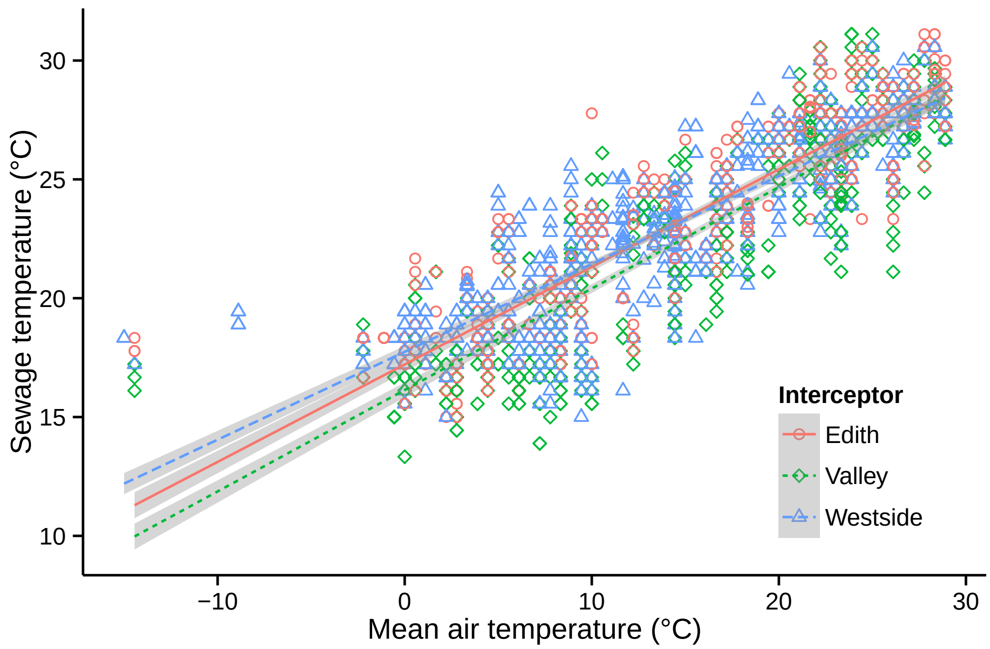

Figure 1: Sewage temperature increases with mean air temperature, but interceptors differed slightly in their responses to air temperature. As air temperature drops below freezing, no further decreases in sewage temperature are observed.

2.b Sewage temperature and sewer blockages

The final model specification employed a negative binomial GLM with a log link function Venables and Ripley 2002, with SBW responding to mean weekly MDAT. The SBW data followed an overdispersed Poisson distribution, with forty-one weeks (23.8%) showing one or zero incidents. Consequently, the final negative binomial specification provided a significant improvement over a Poisson GLM (likelihood ratio tests, $p < 0.001$).

We find that sewers blockages are more frequently observed at lower sewage temperatures (Figure 2A). This relationship was highly statistically significant ($p < 0.001$; Table 3), but explained little deviance in blockage frequency (6% deviance explained). ??deviance code - knitr, see pr2 below ??explain deviance signif.

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.9713	0.6547	4.54	0.0000
Temp	-0.0900	0.0283	-3.18	0.0015

Table 3: Weekly mean sewage temperature predicts the number of blocked sewers that week ($n = 153$ weeks)

2.c Air temperature and sewer blockages

As noted above, we found that sewer blockages were more frequent during colder weeks. Air temperature was a highly significant predictor of sewer blockage frequency (Table 4; Figure 2B), but had limited explanatory power (4% deviance explained). ??more

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.0313	0.1728	5.97	0.0000
Mean.TemperatureF	-0.0274	0.0102	-2.68	0.0074

Table 4: Weekly mean air temperature predicts the number of blocked sewers that week ($n = 471$ weeks)

This dataset includes 491 blockages where grease was the estimated blockage cause, representing 54% of incidents during the study period. When these grease-caused SBW were modeled separately, a statistically significant

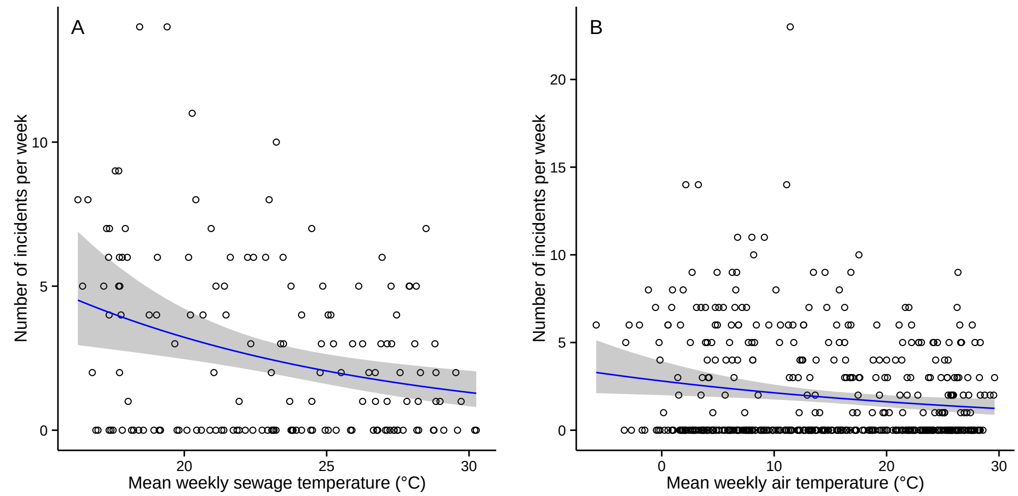

Figure 2: Both sewage temperature (A; $n = 153$ weeks) and air temperature (B; $n = 471$ weeks) can be used to predict sanitary sewer blockages

increase of these SBW with decreasing temperature was also observed (Table 5). Again, this explains a small amount deviance?? ??Fig3 – see greaseplot and nongreaseplot ??Model to test by cause

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.5586	0.1616	3.46	0.0005
Mean.TemperatureF	-0.0393	0.0099	-3.99	0.0001

Table 5: Negative binomial GLM predicting blockages caused by grease ($n = 471$ weeks)

However, there was no relationship between temperature and other blockages (Table 6; Figure 3). The model predicting grease blockages explained 4% of deviance, compared with 0.5% for the model predicting other blockages.

3 Discussion

??both sewer temp and air temp are signif predictors, sewer temp is better ??likely that the reponse of sewer temp to air temp is dependent on local local climate and sewer configuration (mark?), warrants testing in different

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.0812	0.1673	0.49	0.6276
Mean.TemperatureF	-0.0140	0.0099	-1.41	0.1573

Table 6: Negative binomial GLM predicting blockages not caused by grease ($n = 471$ weeks)

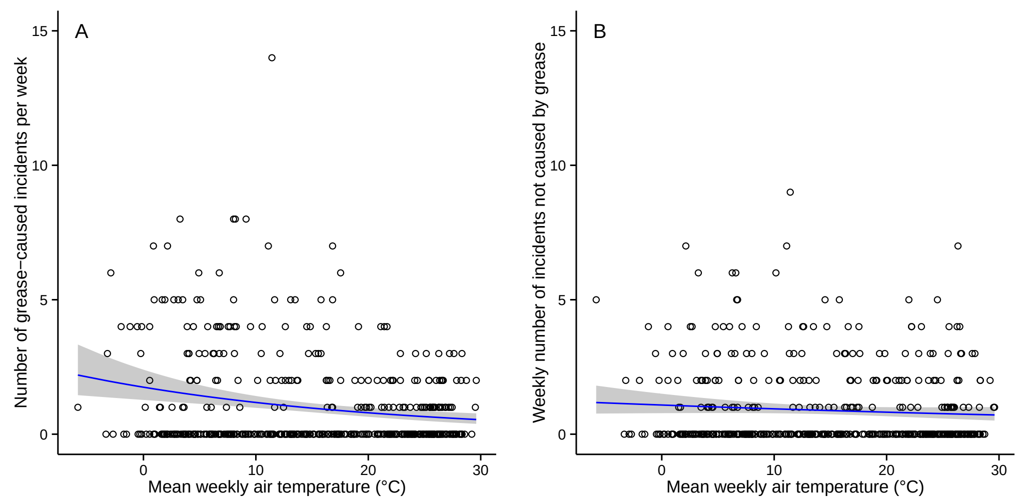

Figure 3: Mean weekly air temperature predicts blockages caused by grease (A; $n = 471$ weeks) but not other blockages (B; $n = 471$ weeks)

locales. ABQ diurnal temp, elevation gradient and cold air drainage. ??if municipalities are already collecting SGST, it would be an appropriate addition to system maintainance planning

Temperature data, which are widely and freely available, have modest utility in predicting sewer blockages over weekly timescales. These results suggest that areas experiencing increasing average temperatures may find that this trend alleviates the pressure placed on sewage systems by FOG deposits. Similarly, weather forecasts and real-time weather observations may prove useful for predicting and responding rapidly to blockages, reducing the threat to property and public health.

Data from sewer measurements are a slightly more accurate predictor of blocking frequency. Where these data are regularly collected and rapidly analysed, they could be used in place of air temperature to anticipate problems in sanitation infrastructure.

The relationship between air and sewage temperature is likely to be mediated by ground temperature, and therefore by groundwater levels. The difference in predictive ability between sewage and air temperature may reflect the variable groundwater levels during the seasonal cycle in Albuquerque. Similarly, differences between interceptors and manholes may reflect elevation and land use, via their effects on groundwater temperature. Models including precipitation patterns and/or local physical characteristics (e.g. water table height, land use, soil type, geology) could test this hypothesis.

With continuing population rise and urbanisation, efficient operation of urban waste-water infrastructure is an increasingly important issue for global public health. Sato et al. 2013 recently highlighted the importance of more research into efficacy of waste-water treatment techniques, particularly in the developing world. The data in this study were not collected specially for research purposes. Rather, this study used data already collected by industry as part of standard operations, married with publicly accessible weather data available online. This demonstrates the potential usefulness of historic industry datasets for addressing future challenges.

References

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