# An Analysis Of Turbidity, Nickel, & Lead Concentrations In Drinking Water And Selected Public Health Statistics In Vilnius Municipality

**R. Flay**

*University of California, Berkeley*

**1. Abstract:**

Drinking water quality plays an important role in public health, meriting its protection. In analyzing nine districts in Vilnius Municipality for relationships between water quality and health, rates of gastrointestinal disease were found to be 34%-151% higher in districts with higher turbidity concentrations and rates of congenital anomalies 59% higher in districts with higher lead concentrations. While this was a preliminary study, it will hopefully demonstrate the need to make the protection drinking water quality a priority for Vilnius city.

**2. Introduction:**

The legacy of the Soviet Union, a nascent economy, and recently restructured environmental and health protection regime pose a great challenge to drinking water quality in the Republic of Lithuania (Feshbach 1995) (Kadunas 1997). In the capital city of Vilnius, 19 well fields supply approximately 155,000 cubic meters per day to the residents, comprising the bulk of drinking water consumed (Klimas 1998). These 19 well fields feed nine distinct municipal water supply districts as shown in **Map 1**. Many of these well fields are located in urbanized areas where the threat of anthropogenic contamination is high, raising questions about water quality and the influence on public health. Additionally, it is known that turbidity can compromise disinfection and serve as a medium for microbiological growth, which can lead to gastrointestinal illness (Schwartz 1997). The influence of nickel and lead on kidney disorders and birth defects is also documented in epidemiological work (ATSDR. 1993; ATSDR. 1996). In this study, I examined public health data from years 1991 to 1995 in conjunction with sets of water quality data from these districts to see if perhaps any relationships exist in Vilnius. Of interest is the indirect influence that turbidity might have on rates of intestinal infectious diseases (International Classification of Diseases-9$^{th}$ Revision (ICD-9) codes 001-009), gastritis and duodenitis (535), disorders of stomach function (536), and diseases of the esophagus, stomach, and duodenum (530-537). Also of interest is the influence of nickel levels on kidney infections (590), and the influence of lead on congenital anomalies (740-759).

**3. Hypotheses:**

**$H_{O(1)}$:** Water supply districts with high turbidity as measured at the tap do not have higher instances of ICD-9 diseases 001-009 (grouped), 530-537 (grouped), 535, and 536. (Each hypothesis was tested individually).

**$H_{A(1)}$:** Water supply districts with high turbidity as measured at the tap do have higher instances of ICD-9 diseases 001-009 (grouped), 530-537 (grouped), 535, and 536.

**$H_{O(2)}$:** Water supply districts with high turbidity as measured at the treatment facility, i.e. the source, do not have higher instances of ICD-9 diseases 001-009 (grouped), 530-537 (grouped), 535, and 536. (Each hypothesis was tested individually).

**$H_{A(2)}$:** Water supply districts with high turbidity as measured at the treatment facility do have higher instances of ICD-9 diseases 001-009 (grouped), 530-537 (grouped), 535, and 536.

**$H_{O(3)}$:** Water supply districts with higher nickel concentrations as measured at the treatment facility do not have higher instances of ICD-9 590.

**$H_{A(3)}$:** Water supply districts with higher nickel concentrations at the treatment facility do have higher instances of ICD-9 590.

**$H_{O(4)}$:** Water supply districts with higher lead concentrations as measured at the treatment facility do not have higher instances of ICD-9 740-759 (grouped).

**$H_{A(4)}$:** Water supply districts with higher lead concentrations as measured at the treatment facility do have higher instances of ICD-9 740-759 (grouped).

**$H_{O(5)}$:** Vilnius Municipality complies with Lithuanian Hygienic Norm 24:1998 for levels of turbidity, nickel, and lead in drinking water.

**$H_{A(5)}$:** Vilnius Municipality does not comply with Lithuanian Hygienic Norm 24:1998 for levels of turbidity, nickel, and lead in drinking water.

**4. Data, Methods, & Analysis:**

Public health data were obtained from the database maintained by the Vilnius Public Health Center or Vilniaus Visuomenes Sveikatos Centras (VVSC). Each time a patient up to age 19 visits a polyclinic in Vilnius, a record is sent to the VVSC recording the diagnosis, the patient's age, residence, the date, and other useful information. The data spanned the years 1991 to 1995 for ages 0-19 and comprised over 1 million records, classified by the International Classification of Diseases, 9th Revision (ICD-9) codes. Each street in the public health database was assigned to the water supply district in which it is located. This allowed for the creation of queries based on the water supply systems. Utilizing a data table that also included the population living on each street in Vilnius, monthly disease rates were calculated per 100,000 residents. Water quality data were obtained from the local water company, Vilniaus Vandenys, for nickel, lead, and turbidity concentrations as measured at the nine separate water supply district reservoirs.

Table 1: Water Supply District Classifications of High and Low Based on Water Quality Indicators

| District | Turbidity (mg/L) at Tap | Turbidity (mg/L) at Source | Ni (mg/L) | Pb (mg/L) |
|---|---|---|---|---|
| 1-Antaviliai | Low | High | High | Low |
| 2-Trinapolis | Low | High | High | High |
| 3-Vingis Parkas | High | Low | High | High |
| 4-Bukciai | High | Low | High | High |
| 5-Tupatiskes | High | High | Low | High |
| 6-Kirtimai | Low | Low | Low | Low |
| 7-A.Paneriai | High | High | Low | Low |
| 8-N.Vilnia | Low | Low | Low | Low |
| 9-Sereikises | Low | Low | Low | Low |
| Threshhold Median Value (mg/L) | >1.4 | >0.75 | >0.018 | >0.0165 |

Water quality data also came from the VVSC that performs turbidity testing in the municipal water supply system at the tap.

The first step in analysis involved the coding of each district as high or low based on median values of turbidity at the tap, turbidity at the treatment facility, nickel, and lead. I arbitrarily selected these threshold values for turbidity as measured at the tap at 1.4 mg/L, turbidity measured at the treatment facility at 0.75 mg/L, nickel at 0.018 mg/L, and lead at 0.0165 mg/L. Coding the data allowed me to overcome the problems I had with very non-normal distributions of water quality measurements and a very large amount of variability.

Table 2: Descriptive Statistics for Turbidity, Ni, & Pb

| | Turbidity (mg/L) at Tap | Turbidity (mg/L) at Source | Ni (mg/L) | Pb (mg/L) |
|---|---|---|---|---|
| 75th Quartile | 2.175 | 1.425 | 0.03 | 0.02 |
| Median | 1.45 | 0.9 | 0.0185 | 0.016 |
| 25th Quartile | 1 | 0.3 | 0.014 | 0.012 |
| Shapiro-Wilk W Test | 0.0001 | 0.0001 | 0.0001 | 0.0246 |
| N | 28 | 78 | 70 | 70 |
| Mean | 1.825 | 0.919 | 0.0218 | 0.0169 |
| Standard Error of Mean | 0.275 | 0.073 | 0.00147 | 0.0008 |
| Upper 95% CI | 2.388 | 1.065 | 0.0248 | 0.0185 |
| Lower 95% CI | 1.262 | 0.077 | 0.0189 | 0.0153 |

Table 3: Descriptive Statistics for Disease Rates

| Monthly Diagnosis Rates for Age Group 0-19 Years per 100,000 Residents of the Cohort Aged 0-19 years for the Years 1991-1995 | | | | | | |
|---|---|---|---|---|---|---|
| Disease ICD-9 Code | 001-009 | 530-537 | 535 | 536 | 590 | 740-759 |
| 75th Quartile | 3.31 | 90.44 | 98.48 | 105.48 | 9.87 | 0 |
| Median | 0 | 43.59 | 55.42 | 61.23 | 0 | 0 |
| 25th Quartile | 0 | 0 | 19.81 | 19.81 | 0 | 0 |
| Shapiro-Wilk W Test | 0.001 | 0 | 0 | 0 | 0 | 0.001 |
| N | 2358 | 1314 | 540 | 540 | 540 | 4824 |
| Mean | 7.436 | 61.816 | 66.974 | 83.136 | 7.295 | 1.894 |
| Standard Error of Mean | 0.443 | 2.279 | 2.742 | 4.402 | 0.939 | 0.106 |
| Upper 95% CI | 8.305 | 66.287 | 72.361 | 91.782 | 9.14 | 2.103 |
| Lower 95% CI | 6.567 | 57.345 | 61.588 | 74.49 | 5.45 | 1.686 |

The coding is shown in **Table 1**. Descriptive statistics for the water quality data and public health data can be seen in **Table 2** and **Table 3**, respectively.

Second, based on districts grouped high and low for each water quality indicator, an ANOVA Test was performed to determine if there was a significant difference between the disease rates of the high group and disease rates of the low group. Additionally, a Wilcoxon/Kruskal-Wallis Rank-Sum Test was performed to test for differences between the high and low groups. This test was chosen given that the public health data are not normally distributed based on the Shapiro-Wilk Test and also possess significantly unequal variances. The results of these analyses are shown in **Table 4**.

Lastly, to test for compliance with Lithuanian water quality standards in Hygienic Norm 24:1998 (HN 24:1998), a Wilcoxon Signed-Rank Test was performed comparing the means of water quality samples to the standard. The results are displayed in **Table 5**.

**5. Sources of Error, Discussion & Conclusions:**

For this analysis, age distribution was assumed to be equal among districts, variances in diagnosis rates were assumed to be reasonably equal, and the distributions of diagnosis rates were assumed to be relatively normal. The confounding effects of socioeconomic status, temperature, and other factors that influence public health were assumed to be negligible (Anderson 1997).

In order to reject the null hypothesis, the districts with high levels of a given water quality indicator had to test significantly higher for a given disease rate at an α-level of 0.05 and a Power level of 0.90 in the ANOVA Test. The Power of the analysis in **Table 4** is the probability of not rejecting the null hypothesis when it should have been rejected. These districts also had to test higher and be significant in the Wilcoxon/Kruskal-Wallis Rank-Sum Test at an α-level of 0.05. This was an extra built-in measure of security to hopefully reduce the risk of coming to an incorrect conclusion, given the non-normal nature of the distributions.

Based on these standards, I rejected **$H_{O(1)}$** and accepted **$H_{A(1)}$** that districts with high turbidity as measured at the tap do have higher instances of gastritis and duodenitis (535), disorders of stomach function (536), and diseases of the esophagus, stomach, and duodenum (530-537). I further rejected **$H_{O(2)}$**, and accepted **$H_{A(2)}$** that districts with high turbidity as measured at the treatment facility do have higher instances of ICD-9 diseases 001-009 (grouped), 530-537 (grouped), 535, and 536. The ANOVA test showed a sizable difference in the means of the high and low group in several instances, for example diseases of the esophagus, stomach, and duodenum (530-537) where on average 83 diagnoses per 100,000 per month occurred in the high turbidity districts, versus 47 per month in the low.

With respect to nickel, I found no significant difference in both the ANOVA test and the Wilcoxon/Kruskal-Wallis Test, thereby not refuting **$H_{O(3)}$**. For lead, I did find variability among the groups that was more than one would expect to find by chance. Rejecting **$H_{O(4)}$**, I accepted **$H_{A(4)}$** that districts with higher lead concentrations as measured at the treatment facility do have higher instances of congenital anomalies (740-759 grouped).

Table 4: Comparison of Disease Rates in Districts with Higher Contaminant Concentrations to Districts with Lower Concentrations

| 0-19 Year Age Group | | ANOVA Test | | | | | | | | | Wilcoxon/Kruskal-Wallis Rank-Sum Test*** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indicator** | **ICD-9 Code** | **Mean of High** | **Mean of Low** | **Difference** | **Upper 95%** | **Lower 95%** | **Std Error** | **DF** | **Prob>t** | **Power** | **of High from mean** | **Probability>ChiSq** |
| Turbidity at Tap | 001-009 | 8.385 | 6.676 | 1.71 | 3.457 | 0 | 0.891 | 2356 | 0.0552 | 0.4831 | -5.005 | <.0001 |
| Turbidity at Tap | 530-537 | 83.346 | 44.653 | 38.693 | 47.452 | 29.935 | 4.465 | 1311 | <.0001 | 1 | 6.826 | <.0001 |
| Turbidity at Tap | 535 | 77.885 | 58.245 | 19.64 | 30.361 | 8.918 | 5.458 | 538 | 0.0003 | 0.9487 | 2.803 | 0.0051 |
| Turbidity at Tap | 536 | 124.812 | 49.795 | 75.017 | 91.233 | 58.801 | 8.255 | 538 | <.0001 | 1 | 9.018 | <.0001 |
| Turbidity at Source | 001-009 | 9.615 | 5.692 | 3.923 | 5.665 | 2.181 | 0.888 | 2356 | <.0001 | 0.993 | 11.561 | <.0001 |
| Turbidity at Source | 530-537 | 89.869 | 39.428 | 50.441 | 59.022 | 41.859 | 4.374 | 1311 | <.0001 | 1 | 11.094 | <.0001 |
| Turbidity at Source | 535 | 98.444 | 41.798 | 56.65 | 66.377 | 46.915 | 4.954 | 538 | <.0001 | 1 | 10.418 | <.0001 |
| Turbidity at Source | 536 | 120 | 53.645 | 66.3542 | 82.839 | 49.869 | 8.392 | 538 | <.0001 | 1 | 8.392 | <.0001 |
| Nickel | 590 | 7.715 | 6.96 | 0.756 | 4.472 | 0 | 1.892 | 538 | <.69 | 0.068 | 9.848 | <.0001 |
| Lead | 740-759 | 2.266 | 1.429 | 0.838 | 1.257 | 0.418 | 0.214 | 4821 | <.0001 | 0.975 | 8.223 | <.0001 |

| 0-19 Year Age Group | | Accept or Reject Null Hypothesis based on an alpha-level of 0.05 and a beta-level of 0.10 in the ANOVA Test, and an alpha-level of 0.05 in the Wilcoxon/Kruskal-Wallis Rank-Sum Test | | Percentage Difference in Diagnosis Rates in Districts with Higher Concentrations of Contaminants* | | |
|---|---|---|---|---|---|---|
| **Indicator** | **ICD-9 Code** | **Accept/Reject Null Hypothesis (that diagnosis rates are not higher)** | **Hypothesis Number**** | **Percentage Higher** | **Upper 95% CI of %** | **Lower 95% CI for %** |
| Turbidity at Tap | 001-009 | Accept | 1 | **NA** | | |
| Turbidity at Tap | 530-537 | Reject | 1 | **87%** | **106%** | **67%** |
| Turbidity at Tap | 535 | Reject | 1 | **34%** | **52%** | **15%** |
| Turbidity at Tap | 536 | Reject | 1 | **151%** | **183%** | **118%** |
| Turbidity at Source | 001-009 | Reject | 2 | **69%** | **100%** | **38%** |
| Turbidity at Source | 530-537 | Reject | 2 | **128%** | **150%** | **106%** |
| Turbidity at Source | 535 | Reject | 2 | **136%** | **159%** | **112%** |
| Turbidity at Source | 536 | Reject | 2 | **124%** | **154%** | **93%** |
| Nickel | 590 | Accept | 3 | **NA** | | |
| Lead | 740-759 | Reject | 4 | **59%** | **88%** | **29%** |

*Most interesting in this table is the percentage difference in diagnosis rates (plus 95% confidence intervals) between the districts with lower concentrations of contaminants and the districts with higher concentrations of contaminants.

**Specifics of the hypotheses are described in the text.

***As mentioned in the text, the Wilcoxon/Kruskal-Wallis Rank-Sum Test was an extra measure of security to avoid coming to an incorrect decision about rejecting the null hypothesis, given the potential of violating assumptions of normality in the distributions and equal variances. The null hypothesis had to be rejected for both tests in order for me to accept the alternative hypothesis.

For **$H_{(5)}$**, the Wilcoxon Signed Rank Test did not show at an α-level of 0.05 that the water measurements did not comply with water standards and **$H_{O(5)}$** was not rejected (Ministry of Health Protection 1998). Although beyond the scope of this study, while measurements throughout the city did not seem out of compliance with Lithuanian standards, measurements in individual districts were in some cases substantially higher and suggest compliance problems.

Table 5:Test for HN 24:1998 Compliance

| Wilcoxon Signed Rank Test Comparing Samples to Water Quality Standard | | | | Accept or Reject Null Hypothesis of Compliance based on an a-level of 0.05 | Hypothesis Number |
|---|---|---|---|---|---|
| **Indicator** | **Mean** | **HN 24:1998 Standard** | **P>t** | | |
| Turbidity from Tap | 1.825 | 1.5 | 0.252 | Accept | 5 |
| Turbidity from Source | 0.919 | 1.5 | 1 | Accept | 5 |
| Ni | 0.022 | 0.02 | 0.27 | Accept | 5 |
| Pb | 0.017 | 0.02 | 1 | Accept | 5 |

In summary, districts with higher turbidity concentrations seemed to have 34%-151% higher instances of gastrointestinal disorders and districts with higher lead concentrations seemed to have 59% higher instances of congenital anomalies for the 0-19 year age-group. It is hoped that these preliminary findings will encourage Vilnius Municipality to seek ways to protect drinking water quality and educate its citizens about the influence of water quality on public health.

## 6. References:


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