An Analysis of the Relationship between Water Quality Indicators and Public Health in Vilnius

Vilniečių sergamumo ir geriamojo vandens kokybės rodiklių ryšio analizė

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Abstract/Reziume:

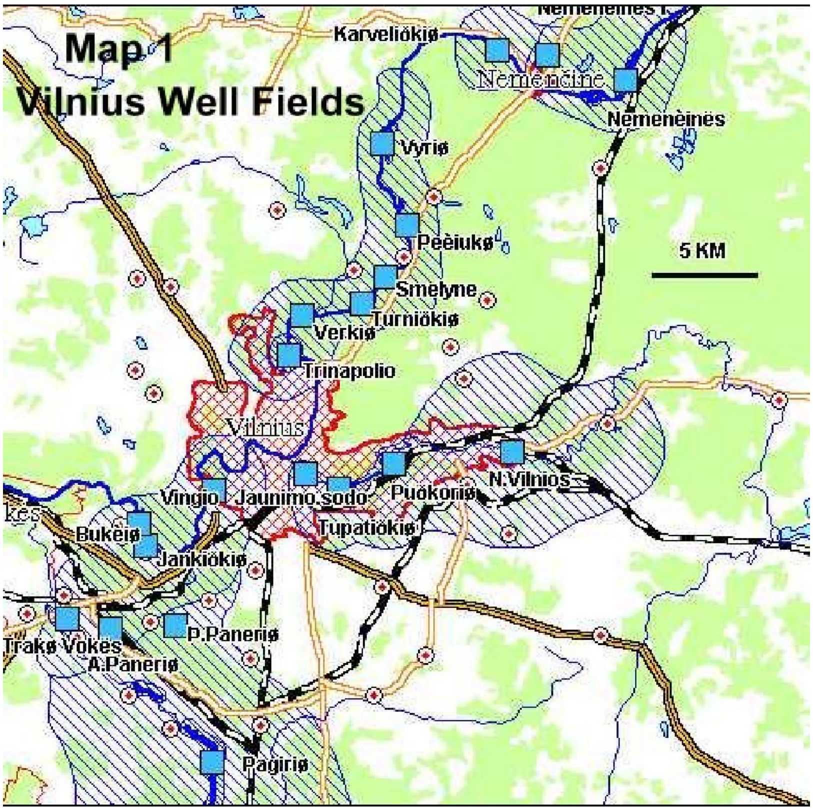
Tirdami geriamojo vandens kokybės įtaką gyventojų sergamumui, Vilniaus miesto teritoriją suskirstėme į 9 rajonus ir palyginome vandens kokybinius rodiklius 1992-1995m. bei 0 – 19m. amžiaus gyventojų sergamumo lygius 1991-1995 m. ir visų gyventojų 1991-1992 m. Ieškojome statistiškai patikimo ryšio tarp geriamojo vandens drumstumo, kietumo, geležies, nikelio ir švino koncentracijų, bendrosios organinės anglies kiekio ir sergamumo skrandžio, odos, inkstų ligomis, žarnyno infekcijomis, apsigimimais. Nustatėme, kad drumstumas tiesiogiai įtakoja sergamumą gastritu, funkciniais skrandžio sutrikimais bei žarnyno infekcijomis vaikų ir suaugusių tarpe. Ryšio tarp geriamojo vandens kietumo ir sergamumo inkstų akmenlige nenustatėme. Bendrosios organinės anglies kiekis neįtakojo sergamumo žarnyno infekcijomis.

Nustatyta koreliacija tarp geležies koncentracijos vandenyje ir sergamumo odos ligomis, švino ir apsigimimų vaikų (iki 19m.) tarpe, nikelio ir sergamumo odos ligomis visų gyventojų tarpe.

Vilniaus centralizuotai tiekiamo vandens drumstumas koreliuoja su geležies koncentracija.

Introduction:

Via the many ways that we contact the natural environment, perhaps no relationship is greater than that between humans and water. We use it for the preparation of foods, personal hygiene, and often consume directly 2-3 liters per day, much stemming directly from our taps. Further increasing its importance and necessitating its protection is the vulnerability of groundwater to contamination from anthropogenic land-use practices and the high cost of remediation in such an event. Given this strong dependency on water, it is important to understand how water affects our health and ensure that it is properly protected and managed.



Nineteen well fields in Vilnius supply approximately 155,000 cubic meters per day to the citizens of Vilnius, comprising the bulk of drinking water consumed as shown in **Map 1**.

These 19 well fields supply the municipal water supply system and can be broken down into 9 sections, see **Table 1**. Since people drink water from these 9 water supply systems and not directly from the well field, any study looking at public health should look at water quality and public health by the geographic location of these water supply systems.

In this brief and preliminary study, we examined public health data in Vilnius from years 1991 to 1995 in conjunction with sets of water quality data spanning 1992-1995. Our first goal was to look at the public health data geographically to see how disease rates vary throughout the city. The second goal was to examine the water quality data and see if any of the variability in the disease rates could be explained by the available water quality data based on documented relationships from epidemiological studies.

Most importantly, this study should demonstrate the integrated nature of issues such as drinking water quality and the need for continuous information exchange among agencies that work in this field in Vilnius. With effective and timely information exchange, agencies can hopefully make better informed and therefore more effective decisions regarding the management of drinking water in the city.

Table 1 showing which well fields supply water to various districts in Vilnius

System # &Well Field	Water extraction 1998, thous. m^3/d	Predicted extraction in 2010, thous. m^3/d	District(s) supplied
1 Peciukai, Viriai, Karveliškes, Nemencine	50	60	Pašilaiciai, Fabijoniškes, Šeškine, Viršuliškes, Justiniškes, Santariškes, Antakalnis
2 Verkiai, Turniškes, Smelyne, Trinapolis	31	37	Kalvariju g. raj., Zverynas, Zirmunai, Antakalnis
3 Vingio Parkas, Z. Paneriai	18	22	Naujamiestis, Savanoriu pr., Kauno g., Vaduvos g. raj.
4 Bukciai, Jankiškes	15	18	Lazdynai, Karoliniškes, Pilaite
5 Tupatiškes, Puškoriai, Pavilnis	14	17	Antakalnis, Uzupis, Pavilnis
6 Pagiriai	10	12	Kirtimai, Dilgyne, Naujininkai, Liepkalnis
7 Traku Voke, A. Paneriai	6	8	A. Paneriu raj.
8 N. Vilnia	6	8	N. Vilnios raj.
9 Sereikiškiu	5	6	Gedimino pr., Senamiestis
Vilniaus m.	**155**	**188**	

Source: Vilniaus Miesto Vandenvieciu Eksploatacijos ir Vandens Tiekmo Sistemos Optimizacija. SPUAB "Vilniaus Vandenys" ir UAB Vilniaus Hidrogeologija. Vilnius, 1998.

Data and Methods:

Public Health Data

Public health data were obtained from the public health database maintained by the Vilnius Public Health Center or *Vilniaus Visuomenes Sveikatos Centras* (VSC). Each time a patient visits a polyclinic in Vilnius, a record is sent to the VSC 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 years 1991 and 1992 for all ages. After 1992, only records for those under age 20 were kept. The data set contains over 1 million records and diseases are recorded utilizing the *International Classification of Diseases, 9th Revision* (ICD) codes (Министерство здравоохранения СССР).

Water Quality Data

The water quality data came primarily from the VSC that performs water quality testing in the municipal water supply system throughout Vilnius for basic indicators of water quality such as total hardness, turbidity, iron, and others. This database spanned the years 1992 to 1995 and contained approximately 400 geographically classified records per water quality indicator. We favored the use of this data set over others because this data set takes measurements from the tap, i.e. the end consumption point, and thus should be the most representative of the quality of water people are actually consuming.

We also utilized the local water company's, *Vilniaus Vandenys's*, water quality data for nickel, lead, and turbidity levels as measured at the water supply system reservoirs. The reservoirs are typically located at a point where water from separate well fields combines and is treated before entering the distribution system to consumers.

Twenty-six Total Organic Carbon (TOC) samples were also taken throughout the city as part of a pilot project in March 1999 and analyzed at labs in Siauliai and in Chicago.

Analysis

Raw data from the VSC was collected in a DB4 database format. In order to analyze the information, a Microsoft Access database was designed and the information imported. Also developed in the database was a feature to analyze the data geographically by water supply system. To accomplish this, each street in both the public health and water quality databases 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; i.e. one could then calculate the number of diagnoses of a particular illness or the average level of a water quality indicator by water supply system. All streets where also classified by the 20 city districts.

Utilizing a data table that also included the population living on each street in Vilnius, annual disease rates were calculated per 100,000 residents. In total we composed two public health data sets; one contained all ages for years 1991 to 1992 and the second contained ages 0-19 but spanned from 1991 to 1995. (This is again because health data after 1992 was only collected for children). Since to analyze the data for years 1991 to 1995 we only are looking at patients aged 0-19, we had to multiply by the portion of the population represented by the age-group 0-19. This was roughly calculated as 0.261 (Vilnius Statistical Office).

After calculating disease rates and the average of water quality results in each of the nine distribution systems, we began to look for relationships between the levels of water quality indicators and the levels of various diseases. Our searches were aided through documented relationships in medical and scientific journals on the relationships between water quality and public health. For more detailed statistical analyses, discrete data sets were exported from the Microsoft Access database to Microsoft Excel and to Systat 7.0 for Windows.

With a data set of water quality data and public health data, we performed a linear regression analysis holding the water quality indicator as independent and the disease rate as the dependent. We also regressed certain sets of water quality data to other sets of water quality data, such as the relationship between turbidity measured at water supply reservoirs and turbidity measured at taps. The details and results of each analysis can be seen in **Table 5**.

Results:

Description of Water Quality Results

The water quality indicators utilized in this study include turbidity, total hardness, TOC, nickel, lead, and total iron. **Table 2** contains the water quality data set and detailed information about how, when, and where sampling took place. **Table 3** contains descriptive statistics for the water quality data.

Table 2 Water Quality Figures

Water Supply System	Total Hardness[1] mg-ekv/L	Total Hardness[2] mg-ekv/L	Turbidity[1] mg/L	Turbidity[4] mg/L	TOC[6] mg/L	TOC[5] mg/L	Iron[2] mg/L	Iron[1] mg/L	Pb[3] mg/L	Ni[3] mg/L
1-Antaviliai	5.05	5.05	2.326	0.600	1.11	1.04	1.24	1.24	0.018	0.021
2-Trinapolis	5.19	5.19	1.877	0.950	1.01	0.89	0.64	0.73	0.020	0.020
3-Vingis and Z Paneriai	5.22	5.22	1.589	0.150	0.93	1.31	2.17	0.75	0.025	0.038
4-Bukciai	5.94	5.94	1.000	0.150	1.10	1.00	0.56	0.34	0.017	0.023
5-Tupatiskes	5.89	5.88	3.083	1.450	0.77	0.73	1.02	1.14	0.016	0.019
6-Kirtimai	3.90	3.89	1.821	0.750	1.21	1.28	0.51	0.60	0.010	0.014
7-A Paneriai	4.99	4.99	4.000	1.300	0.46	0.46	2.57	1.87	0.015	0.019
8-N Vilnia	4.73	4.73	1.000	0.700	0.77	0.73	0.70	0.70	0.009	0.020
9-Sereikises	5.05	5.05	1.056	0.750	0.87	0.98	0.56	0.61	0.016	0.022

Key to Water Quality Measurements
1 VSC water quality data average of 1992-1995, only measurements made in the municipal water supply system
2 VSC water quality data average of 1992-1995, all measurements (e.g. also in private water supply systems)
3 Vilnius Vandenys water quality data as measured at reservoirs, average 1995-1999
4 Vilnius Vandenys water quality data as measured at reservoirs, average 1995
5 Total Organic Carbon test results from April 1999, Siauliai Laboratory, test results from water supply system reservoir only
6 Total Organic Carbon test results from April 1999, Siauliai Laboratory, average level as calculated from 1-4 samples per water system

Description of Diagnosis Rate Results

The ICD codes that we reviewed include 001-009 (Intestinal Infections), 535 (Gastritis), 536 (Disorder of Stomach Functions), 592 (Kidney Stones), 690 (Erythematosquamous dermatosis), and 740-759 (Growth-related disorders). **Table 4** contains the disease rates calculated for each water supply system for each selected ICD codes.

Table 3 Descriptive Statistics for Water Quality Data

	Total Hardness[1]	Total Hardness[2]	Turbidity[1] mg/L	Turbidity[4] mg/L	TOC[6] mg/L	TOC[5] mg/L	Iron[2] mg/L	Iron[1] mg/L	Pb[3] mg/L	Ni[3] mg/L
Mean	5.103888889	5.104444444	1.972444444	0.755555556	0.914444	0.9355556	1.107667	0.886222	0.016222	0.021778
Median	5.048	5.05	1.821	0.75	0.93	0.98	0.702	0.73	0.016	0.02
Standard Deviation	0.607766905	0.60770287	1.023447496	0.444018893	0.229026	0.2712522	0.761043	0.459977	0.004842	0.006591
Range	2.046	2.05	3	1.3	0.75	0.85	2.06	1.53	0.016	0.024
Minimum	3.895	3.89	1	0.15	0.46	0.46	0.514	0.337	0.009	0.014
Maximum	5.941	5.94	4	1.45	1.21	1.31	2.574	1.867	0.025	0.038
Count	9	9	9	9	9	9	9	9	9	9
Confidence Level(95.0%)	0.467171301	0.467122079	0.786691895	0.341303356	0.176045	0.2085031	0.58499	0.35357	0.003722	0.005066

Key to Water Quality Measurements
1 VSC water quality data average of 1992-1995, only measurements made in the municipal water supply system
2 VSC water quality data average of 1992-1995, all measurements (e.g. also in private water supply systems)
3 Vilnius Vandenys water quality data as measured at reservoirs, average 1995-1999
4 Vilnius Vandenys water quality data as measured at reservoirs, average 1995
5 Total Organic Carbon test results from April 1999, Siauliai Laboratory, test results from water supply system reservoir only
6 Total Organic Carbon test results from April 1999, Siauliai Laboratory, average level as calculated from 1-4 samples per water system

Description of the Relationships between
Water Quality Indicators and Diagnosis Rate Results

Based on the results for water quality indicators and public health diagnosis rates calculated in each of the nine water supply systems, we performed regression analysis to look for relationships. The results of these linear regression analyses are presented in **Table 5**. The regression analysis is a unique tool because it tells us how much of the variability in our dependent variable is explained by our independent variable. This is enumerated in the R-squared (R^2) value presented in Table 5. The R^2 value is equal to 1.0 minus the ratio of the residual variability of the Y variable to the original variance (StatSoft, Inc.). If X and Y are perfectly related the residual variance will be equal to 0.0 and thus the R^2 value equal to 1.0. For example, if we have an R^2 value of 0.55, then we know that the relationship explains 55% of the variability in the data, and we have 45% residual variability. In short, the closer the R^2

value is to 1.0, the more of the variability we have explained. The closer R^2 value is to 0.0, the less we have explained.

Table 4 Diagnosis Figures for Selected Diseases

All ages, 1991-1992, Average annual diagnosis rate per 100,000					
Water Supply System	Gastritis (535)	Disorders of Stomatch Function (536)	KidneyStones (592)	Erythematosquamous dermatosis (690)	Intestinal Infections (001-009)
1-Antaviliai	408.75	256.29	32.26	5.04	4.76
2-Trinapolis	486.87	212.74	98.15	5.62	12.347
3-Vingis and Z_ Paneriai	496.15	366.68	76.66	17.36	6.188
4-Bukciai	315.63	109.67	33.43	6.69	0.149
5-Tupatiskes	547.86	189.84	109.9	8.33	16.652
6-Kirtimai	276.61	243.01	20.68	2.59	5.745
7-A_ Paneriai	578.35	674.75	27.54	0	9.18
8-N_ Vilnia	51.09	19.65	0	0	0.655
9-Sereikises	515.7	170.64	62.57	5.69	5.688

Ages 0-19, 1991-1995, Average annual diagnosis rate per 100,000					
Water Supply System	Gastritis (535)	Disorders of Stomatch Function (536)	KidneyStones (592)	Erythematosquamous dermatosis (690)	Growth-related (740-759)
1-Antaviliai	1052.43	959.74	3.48	24.72	9.11
2-Trinapolis	1153.71	1059.61	2.65	49.04	17.06
3-Vingis and Z_ Paneriai	649.53	1330.1	4.43	83.13	14.19
4-Bukciai	569.53	920.29	2.05	18.45	3.69
5-Tupatiskes	1401.08	913.64	7.66	61.25	13.02
6-Kirtimai	637.88	423.93	0	23.77	8.72
7-A_ Paneriai	1118.51	2827.93	0	105.52	12.66
8-N_ Vilnia	78.29	30.11	0	0	0.15
9-Sereikises	572.42	514.3	11.62	58.11	12.78

Also included in Table 5 is the p-value of the relationship. The p-value is a measure of the significance of the relationship in the sense that the samples we have taken are representative of the total population. The p-value is essentially based on the sample size, a larger sample size being more representative of the whole population. A p-value of 0.093 means that there is a 9.3% chance that the relationship that we have found between the variables is a complete "fluke." For the purpose of this study we have chosen a p-value < 0.10 for values that we will accept, which corresponds to an $\alpha > 90\%$. Although the R^2 value and the p-value are related, one often refers to the R^2 value as a measure of strength or magnitude and the p-value as a measure of significance.

It can be noticed that we did find several statistically significant and strong relationships as displayed in Table 5. For the age group 0+ years and the 1991-1992 data set, we noticed a few interesting findings. The relationship between turbidity levels and gastritis (ICD 535) had an R^2 value of 0.351 and a p-value of 0.093, again meaning that the relationship between the variables explains 35.1% of the variance in the variables. Other strong relationships included the relationship between nickel levels and erythematosquamous dermatosis (ICD 690) with an R^2 value of 0.719.

We also examined total hardness to kidney stones (ICD 592) and TOC to intestinal infections (ICD 001-009) but the relationships showed below acceptable p-values. As a further note on the TOC measurements, this was the first time the samples were taken in Vilnius and we

Table 5 Water Quality Indicator to Disease Rate Analyses

Age group 0+, years 1991-1992[8]				
R^2	**P Value**	**Water Quality Indicator**	**Disease (ICD Code)**	Accept/ Reject(§)
0.351	0.093	Turbidity[1]	Gastritis (535)	Accept
0.607	0.013	Turbidity[1]	Disorders of Stomach Function (536)	Accept
0.432	0.054	Turbidity[1]	Intestinal Infections (001-009)	Accept
0.284	0.140	Total Hardness[1]	Kidney Stones (592)	Reject
0.285	0.138	Total Hardness[2]	Kidney Stones (592)	Reject
0.090	0.433	TOC[5]	Intestinal Infections (001-009)	Reject
0.096	0.417	TOC[6]	Intestinal Infections (001-009)	Reject
0.719	0.004	Ni[3]	Erythematosquamous dermatosis (690)	Accept
Age group 0-19, years 1991-1995[7]				
R^2	**P Value**	**Water Quality Indicator**	**Disease (ICD Code)**	Accept/ Reject(§)
0.602	0.014	Turbidity[1]	Gastritis (535)	Accept
0.603	0.014	Turbidity[1]	Disorders of Stomach Function (536)	Accept
0.400	0.067	Pb[3]	Growth-related disorders (740-759)	Accept
0.370	0.082	Fe[1]	Erythematosquamous dermatosis (690)	Accept
0.617	0.012	Fe[2]	Erythematosquamous dermatosis (690)	Accept
Water Quality Indicator to Water Quality Indicator Analyses				
R^2	**P Value**	**Water Quality Indicator**	**Water Quality Indicator**	Accept/ Reject(§)
0.544	0.023	Turbidity[4]	Turbidity[1]	Accept
0.854	0.000	Fe[1]	Turbidity[1]	Accept
Key to Measurements				
1 VSC water quality data average of 1992-1995, only measurements made in the municipal water supply system				
2 VSC water quality data average of 1992-1995, all measurements (e.g. also in private water supply systems)				
3 Vilnius Vandenys water quality data as measured at reservoirs, average 1995-1999				
4 Vilnius Vandenys water quality data as measured at reservoirs, average 1995				
5 Total Organic Carbon test results from April 1999, Siauliai Laboratory, test results from water supply system reservoir only				
6 Total Organic Carbon test results from April 1999, Siauliai Laboratory, average level as calculated from 1-4 samples per water system				
7 VSC Public Health Data, age group 0-19 years, data span 1991-1995				
8 VSC Public Health Data, age group 0+ years, data span 1991-1992				
§ Based on p-values less than 0.100 we "accept" results, corresponds to α > 90%				

believe that further samples should be taken before extensively comparing this indicator to public health. There were very few TOC samples taken and the analyses of identical samples at two labs did not coincide. Further, both microbiological activity and organic chemicals can contribute to TOC levels, and in the absence of data pertaining to the percentage breakdown of each contaminant, it is very difficult to say how TOC levels would be manifest in public health data (Greenburg).

In the age group of 0-19 years for 1991-1995, we also found some interesting relationships. Turbidity related to gastritis (ICD 535) and disorders of stomach function (ICD 536) with R^2 values of 0.602 and 0.603. Average total iron measurements taken in both municipal and private water systems related to erythematosquamous dermatosis (ICD 690) with an R^2 value of 0.617. Average lead levels taken at water supply reservoirs yielded an R^2 value of .400 in relation to growth-related disorders (ICD 740-759).

We also looked at turbidity levels recorded at reservoirs versus those at taps, yielding an R^2 value of 0.544 and total iron to turbidity, yielding an R^2 value of 0.854.

Discussion:
The relationship between turbidity and gastrointestinal illness is well-documented in epidemiological studies (Schwartz). Although turbidity alone may not represent a health threat, increased turbidity levels create a medium for microbiological activity and can compromise disinfection treatments. Turbidity may also act in other ways affecting public health, but the influence is not clear. Microbiological activity should specifically be manifest in a relationship to intestinal infections (ICD 001-009), but may also turn up other gastrointestinal disorders such as gastritis (ICD 535) and disorder of stomach function (ICD 536). As noted in Table 5, we confirmed many of relationships in the drinking water situation in Vilnius.

Increased nickel levels have also been proven to increase incidence of disease affecting the skin, stomach, blood, liver, kidneys, immune system, and reproduction and development in rats and mice (Agency for Toxic Substances and Disease Registry). Given this research our findings of increase incidence of erythematosquamous dermatosis (ICD 690) coinciding with increased nickel levels could be quite notable.

Developmental and growth-related disorders in children have also been associated with increased levels of lead intake (Agency for Toxic Substances and Disease Registry). Our study also found a relationship between lead levels and growth-related disorders in children (ICD 740-759).

Although a scientific study has yet to prove that increased iron levels in water can contribute to skin-related disease, our results did show a strong connection to erythematosquamous dermatosis (ICD 690). Further research should attempt to see if this is true. Also in association with iron levels, we noticed a very strong correlation between iron levels and turbidity levels. If iron contributes to turbidity and turbidity leads to increases in gastrointestinal illness, then negative health effects are stemming indirectly from iron.

The relationship between turbidity as measured in reservoirs and turbidity as measured from taps seems quite logical. However, we should note that turbidity levels were substantially higher as measured from the tap. This situation highlights the need for coordination between source and terminus water quality measurements. Water quality monitoring at the source is necessary, but to the consumers the most important location for monitoring is of course at the tap.

Lithuanian Hygienic Norm 1998 Drinking Water has set new standards for water quality and the law will be phased in, beginning in the year 2000. It should be noted that maximum contaminant levels (MCL) for nickel as set in this new law are frequently exceeded in Vilnius water supply systems. Lead levels, turbidity levels, and iron levels are also found quite often in above MCL quantities based on this new law. **Table 6** outlines some of the potential compliance problems. Given the known health impacts of these contaminants in drinking water Vilnius should consider ways bringing water quality into compliance with national laws.

It is important to mention some of the potential sources of error in this experiment. In an analysis of a water quality indicator such as nickel, levels may increase in series with other contaminants in water. Although levels of heavy metals will vary little over a short time period, turbidity levels fluctuate regularly and using a 4-year average might not be the most effective method for measuring short-term fluctuations in turbidity. Unlike heavy metals, which typically will have a cumulative effect on health, turbidity will likely be manifest in short-term health effects. Given that we were performing an analysis over 9 discrete populations, the 9 water supply districts, other environmental or social factors could also be at work influencing our results.

Table 6 Selected Potential HN 1998 Compliance Issues

Water Quality Indicator and HN 1998 Standard	Water supply systems whose mean value exceeded norm	Measurement Note
Turbidity 1.74 mg/L (satisfactory)	1-Antaviliai, 2-Trinapolis, 3-Vingio, 4-Bukciai, 5-Tupatiskes, 6-Kirtimai, 7-A. Paneriai	1
Total Iron 1.0 mg/L (satisfactory)	1-Antaviliai, 5-Tupatiskes, 7-A. Paneriai	1
Pb 0.025 mg/L	3-Vingio	2
Ni 0.020 mg/L	1-Antaviliai, 2-Trinapolis, 3-Vingio, 4-Bukciai, 8-N. Vilnia, 9-Sereikiskes	2
Key to Water Quality Measurements		
1 VSC water quality data average of 1992-1995, only measurements made in the municipal water supply system		
2 Vilnius Vandenys water quality data as measured at reservoirs, average 1995-1999		

Conclusion:
The first goal of the study was to look for differences in disease rates in Vilnius geographically by water supply district and see if any of the differences could be explained based on available water quality data. We did find substantially divergent disease rates across a wide variety of disease groupings. This definitely indicates that there is a strong environmental or social influence at work.

The second goal was to identify the cause of the variance. Although preliminary studies such as this cannot be the final, definitive word, we think the findings here suggest that water quality is having an impact on health. The importance research is further stressed by the published health effects of these contaminants and the nonsuccess of Vilnius to obtain national hygienic norms set for these contaminants as outlined in Table 6.

To summarize our major findings:

- Turbidity positively related to gastrointestinal illnesses (ICD 535 & 536) in the young 0-19 year group and in the 0+ year group.
- Lead levels positively related to growth-related disorders (ICD 740-759) in the 0-19 year age group.
- Nickel levels positively related to erythematosquamous dermatosis (ICD 690) in the 0+ year age group.
- Total iron levels positively related to erythematosquamous dermatosis (ICD 690) in the 0-19 year age group.

In the near future we would recommend a time-series analysis of turbidity and microbiological data in conjunction with public health data for gastrointestinal illness. By performing a time-series analysis on one study group, many social and other environmental factors will diminish in influence and allow the study to focus more specifically on the effects of a given water quality indicator such as turbidity.

Studies such as these will also be aided with more liberal agency policies regarding data sharing. Although the public health data for Vilnius are maintained in a single location, several groups, such as the VSC, Vilniaus Vandenys, and consulting firms, maintain separate databases for water quality data. This diminishes the value of the data and makes comprehensive analyses difficult. Further the Municipality should look to see what other indicators need to be monitored given the natural and anthropogenic load on Vilnius well fields. Monitoring of organic chemicals and other microbiological conditions would seem appropriate in a city the size of Vilnius. Most important, there is substantial variance in disease rates among water supply and city districts, and a geographic approach has proved successful in examining public health data by water supply systems can be very helpful in identifying health problems stemming from water quality.

References:

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for lead. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1993.

Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for nickel (update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, 1996.

Greenberg, Arnold E. and others. Standard Methods for the Examination of Water and Wastewater. 18th Edition. 1992.

Klimas, Algirdas and others. Vilniaus Miesto Vandenviečių Eksploatacijos ir Vandens Tiekmo Sistemos Optimizacija. SPUAB "Vilniaus Vandenys" ir UAB Vilniaus Hidrogeologija. Vilnius: Vilniaus Hidrogeologija, 1998.

Schwartz, Joel and others. Drinking Water Turbidity and Pediatric Hospital Use for Gastrointestinal Illness in Philadelphia. Epidemiology. November 1997, Volume 8 Number 6. Baltimore: 1997.

Statistical Office of Vilnius. Vilnius in Figures, 1996. Vilnius: Vilniaus Apskrities Statistikos Valdyba, 1998.

StatSoft, Inc. Electronic Textbook. Internet: StatSoft, Inc., 1998.

Министерство здравоохранения СССР. Статистическая классификация болезней, травм и причин смерти. Москва: Министерство здравоохранения СССР, 1986.