Magnuss VIRCAVS[1]

CHEMICAL COMPOSITION AND ASSESSMENT OF DRINKING WATER QUALITY: LATVIA CASE STUDY

SKŁAD CHEMICZNY I OCENA JAKOŚĆ WODY PITNEJ. STUDIUM PRZYPADKU: ŁOTWA

Abstract: Assessment of drinking water quality in seven largest Latvia drinking water supply systems (Riga, Daugavpils, Liepaja, Ventspils, Jelgava, Jurmala, and Rezekne) in 2008 using mathematical statistical processing of chemical composition data is carried out. In all analyzed drinking water the concentrations of Hg, Cd, Pb, Cu, Ni, Cr (total), BrO_3^- and trihalomethanes (total) were observed in the level of their quantification or less than it or concentration changes were observed only in some cases that are significantly less than their maximum permissible values (MPV). The processed data show that higher concentrations of sulphate in Jelgava and Jurmala drinking water were observed. In Jelgava drinking water sulphate concentration exceed the accepted MPV for 97 mg/dm^3 and in Jurmala - for 26 mg/dm^3. Besides, high values of total iron (1.15±0.54 mg/dm^3) and turbidity (14.2±7.2 nephelometric turbidity units) were obtained also in Jelgava drinking water. Relative high concentration of aluminium in Liepaja drinking water (0.2 mg/dm^3) takes place that achieves the MPV. Confidence intervals of mean values were calculated using Chebyshev's inequality. The processed data testify well even very well quality of the analyzed largest Latvia drinking water supply systems.

Keywords: drinking water quality, chemical composition, mathematical statistics, Latvia

Introduction

Provision of a qualitative drinking water is an important precondition for improvement of the life quality. Drinking water quality directly affects human health. The impacts reflect the level of contamination of whole drinking water supply system (raw water, treatment facilities and distribution network to consumers). The primary goals of environmental especially drinking water management are to provide safe drinking water supply in international and national scale. The international organizations, eg World Health Organization (WHO) have major functions to propose regulations, guidelines, and recommendations in order to realize human right to have access to an adequate of safe drinking water independently of their stage of development and their social and economic conditions.

Latvia has rich water resources, especially freshwater, which well exceeds current and planned consumption. In general chemical structure of raw water resources ensure to meet adequacy requirements of drinking water quality determined by Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption and Republic of Latvia Cabinet Regulation No. 235 "Mandatory harmlessness and quality requirements for drinking water, and the procedures for monitoring and control thereof" (adopted 29 April 2003).

Management of drinking water quality is a matter of great importance in Latvia. Implementation of the State Investment Program 800+, drinking water regular and audit monitoring as well as other environmental projects are integral part of public health and environmental protection.

[1] Faculty of Geography & Earth Sciences, University of Latvia, Alberta str. 10, Rīga, LV-1010, Latvia

The present study is devoted to assessment of drinking water quality in seven largest Latvia drinking water supply systems in 2008 using mathematical statistical processing of chemical composition data.

Materials and methods

Quality assessment of Latvia drinking water is carried out using chemical composition data of drinking water obtained from the Public Health Agency of the Ministry of Health. Drinking water was analyzed in 2008 in seven largest Latvia drinking water systems - Riga, Daugavpils, Liepaja, Ventspils, Jelgava, Jurmala, and Rezekne (Fig. 1).

Fig. 1. Latvia administrative map. The largest drinking water systems: Riga, Daugavpils, Liepaja, Ventspils, Jelgava, Jurmala, and Rezekne

Drinking water was sampled from the site of consumers and analyses were carried out considering the requirements (testing methods, sampling frequency, the necessary precision and accuracy, maximum permissible values (MPV) of the variables) in Republic of Latvia Cabinet Regulations No. 235 "Mandatory harmlessness and quality requirements for drinking water, and the procedures for monitoring and control thereof" (adopted 29 April 2003) and in Cabinet Regulations No. 118 adopted on March 12, 2002 "Regulations regarding the Quality of Surface Waters and Groundwaters" (with amendments). Drinking water quality was evaluated by the following variables: color, turbidity, pH, conductivity, aluminium, iron (total), fluorides, sulphates, ammonium, nitrates(V), nitrites(III), mercury, cadmium, lead, copper, nickel, chromium, bromates, trihalomethanes (total).

Data processing of drinking water chemical composition includes mathematical statistical calculations. The Q-test was applied for suitability estimation of drinking water data set. The mean and the confidence interval of chemical composition variables of drinking water was expressed using Chebyshev's inequality (confidence level $\alpha = 0.06$): $\bar{x} - 4s/\sqrt{n} \leq \mu \leq \bar{x} + 4s/\sqrt{n}$, where μ - mathematical expectation, $\bar{x}$ - mean, and s - standard deviation, and $4s/\sqrt{n}$ - standard error of mean [1]. Rezekne drinking water supply system was characterized only by two measurements of the variables. Availability of the data for further their processing was evaluated using also Chebyshev's inequality: $|x_1 - x_2| < 4s$ (where x_1 and x_2 - results of measurements). It was used for estimation of Al, Fe, F^-, pH, turbidity, and conductivity values. Assessment of differences between sample means was carried out using Bartlett's test criterion.

Characteristic of Latvia drinking water supply

Latvia has rich water resources, especially freshwater, which well exceeds current and planned consumption. Water resources allow providing high quality drinking water for all population - 70% is composed from artesian and 30% from surface water sources (rivers and lakes). Total amount of surface waters comprises 13,300 m^3 per capita but in European Union (EU) it comprises at an average 7,250 m^3 per capita [2]. In most water supply systems hydrogen-carbonate calcium water with mineralization 0.3÷0.4 g/dm^3 is used. Chemical structure of rock and infiltration water is caused by hydrogen-carbonate calcium water.

Mostly artesian waters are used for the centralized water supply in Latvia towns. They are better protected than groundwater table. Drinking water sources for the capital of Latvia Riga comprise a mixture of surface, natural groundwater, and artificially recharged groundwater from Lake Mazais Baltezers that is the main source for artificial recharge plant supplying up to 25% of Riga drinking water [3]. Reservoir of Riga hydro-power plant on the Daugava River is used as a surface water source. The Daugava Waterworks is the largest surface water treatment plant in Latvia that purifies more than 100 000 m^3 per day using alum as a coagulant [4]. However, quality of water taken from the reservoir of Riga hydro-power plant depends on transboundary pollution that enters into the Daugava River from Russia and Belarus. In the period from 1990 to 2007 three large accidents happened in the river Daugava basin. In November 1990 during filling a railroad tank in a chemical plant "Polimir", Novopolock (Belarus) spill of acetone cyanohydrin (ACH operates on respiratory centers) occurred. Significant amount of ACH leaked into the Daugava River. Due to the pollution mass fish deaths were observed in the river. Therefore during one week water supply from the Daugava River was interrupted in Riga. The second accident involved sanitation leakage from Belarus in the middle of 1990s. The last accident, disruption of oil pipe line Unecha - Ventspils (enterprise „Zapad-Transnefteprodukt", Russia), caused the Daugava River ecosystem contamination with diesel fuel that happened 23 March 2007. Diesel fuel of 4,171 Mg entered into the territory of Latvia, but ~ 90% was collected from the Daugava River waters. The noted accidents can originate and affect Riga drinking water quality [5].

Statistical description of drinking water chemical composition

The analyzed drinking water data of seven largest Latvia drinking water supply systems are conditionally divided into two groups. The first group involves the variables whose values do not change. They are the concentrations of Hg, Cd, Pb, Cu, Ni, Cr (total), BrO_3^- and trihalomethanes (total). These variables were observed in the level of their determination or less than it or concentration changes were observed only in some cases. The lowest observed concentrations are the following (in $\mu g/dm^3$): Hg - 0.1, Cd - 0.5, Pb -

1.0, Cu - 0.2, Ni - 2.0, Cr (total) - 1.0, BrO_3^- - 1.0, and trihalomethanes (total) - 10.0. Besides, the exceptions comprised total Cr concentration in Daugavpils drinking water - 20.0 µg/dm^3 and Ni concentration in Jelgava drinking water - 5.4 µg/dm^3 (1 measurement). Total concentrations of trihalomethanes of Riga drinking water varied in the wide range of 0.1÷50.1 µg/dm^3 (mean and standard error of mean 23.8±0.35 µg/dm^3). The same statistics for total concentrations of trihalomethanes of Liepaja drinking water are the following: range of 0.10÷1.14 µg/dm^3, mean and standard error of mean - 0.54±0.21 µg/dm^3. All noted concentrations are less than their MPV. Drinking water color modified in the range of 5÷10 units of Pt/Co scale with the exception of 20 units of Pt/Co scale in Daugavpils and Jurmala drinking water (1 measurement).

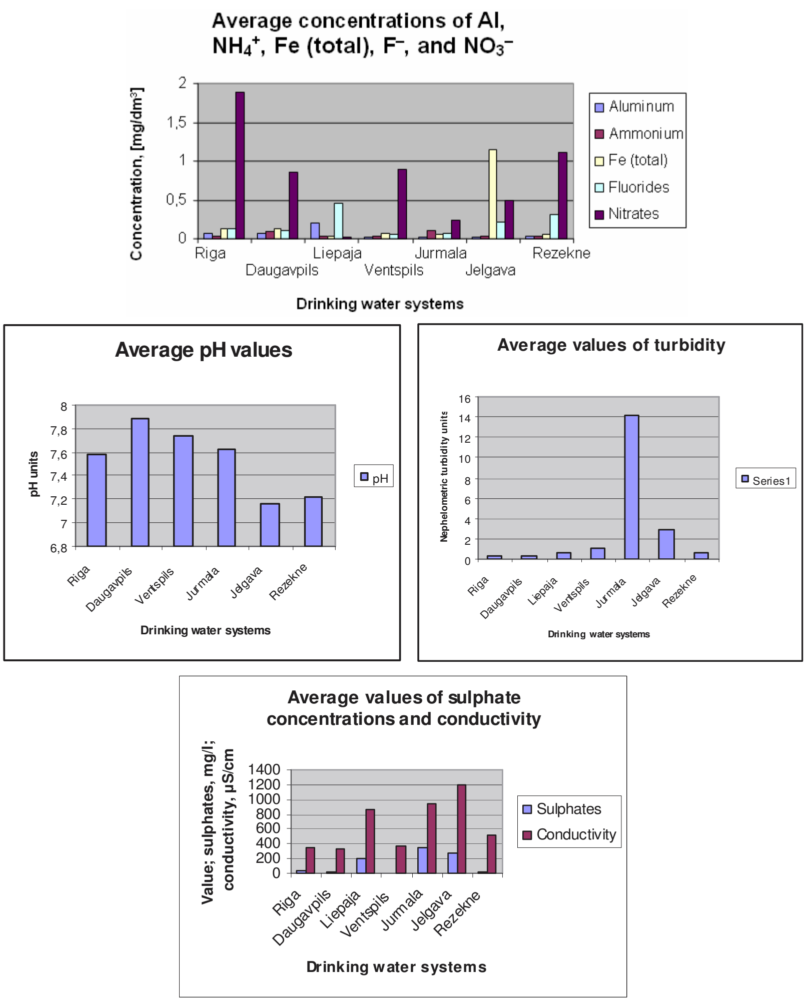

Fig. 2. Average values of Al, NH_4^+, Fe (total), F^-, NO_3^-, SO_4^{2-}, conductivity, turbidity, and pH in the largest Latvia drinking water systems

The second group includes the variables whose value changes were observed - turbidity, pH, and conductivity, concentrations of Al, Fe (total), F^-, SO_4^{2-}, NH_4^+, NO_3^- and NO_2^-. The obtained data of processing are summarized in Figure 2. Data set distribution character was estimated only for Riga drinking water variables (sample size n = 18) and its inadequacy to normal distribution was obtained. Therefore Chebyshev's inequality was applied to calculate confidence intervals of variable means because Chebyshev's theorem could be used to random variables of any distribution.

Comparison of variable mean and median shows that these statistics are not equal for all variables. Median is a statistic that is sensitive to data set symmetric or asymmetric distribution. Data symmetric distribution is observed if the mean and median are equal but in the opposite case - asymmetric distribution. Considering the diversity of sample sizes from n = 2 to n = 18 evaluation of data distribution character was not carried out. Comparison of differences between sample means at confidence level $\alpha = 0.05$ using Bartlett's test criterion testifies on the following assurance.

In all analyzed drinking water systems nitrate(III) and fluoride concentrations do not significantly differ. Mean concentration of aluminium in Liepaja drinking water system (0.2 mg/dm^3) significantly differs from its concentration in other drinking water systems that have statistically equal value 0.02 mg/dm^3. Concentration of aluminium in Liepaja drinking water is equal with MPV.

Total iron concentration (1.15±0.54 mg/dm^3) in Jelgava drinking water system significantly differs from total iron concentration of other systems but it exceed the MPV. High iron concentration is an important problem of drinking water quality in Latvia that is caused by high content of iron in groundwater tables. Therefore drinking water de-ironing is included in Latvia drinking water processing.

In Riga drinking water nitrate concentration has a wide dispersion that is specified by high standard deviation (±1.6 mg/dm^3). Mean concentration of nitrate (1.9 mg/dm^3) is significantly higher than in other drinking water systems that are in the range from 0.013 to 1.1 mg/dm^3.

Sulphate concentrations in Jelgava (347±41 mg/dm^3) and Jurmala (276±32 mg/dm^3) drinking water systems are significantly higher than in drinking water of Riga, Daugavpils, Liepaja, Ventspils, and Rezekne. Leakage from gypsum formations causes high sulphate concentrations in the noted drinking water systems. Comparison of sulphate concentrations with the MPV shows that in Jelgava drinking water average linear deviation is 97 mg/dm^3 and in Jurmala - 26 mg/dm^3.

In all drinking water systems conductivity mean values have a great dispersion with significantly high values of 1189±315 and 944±172 μS/cm in drinking water of Jelgava and Jurmala. It could be explained by high concentrations of sulphates.

Signinficantly high value of turbidity (14.2±7.4 nephelometric turbidity units, NTV) was observed in Jelgava drinking water. The Regulations No. 235 testifies turbidity values as acceptable to consumers and no substantial changes. In the case of surface water treatment, it should be striven to reach that turbidity caused by treatment plants does not exceed 1.0 (NTV).

Mean of drinking water pH falls in the range from 7.16 (Jurmala) to 7.88 (Daugavpils). pH of Riga and Jurmala drinking water significantly differs from pH of Daugavpils, Ventspils, Rezekne, and Jelgava drinking water owing their data great dispersion. Mean values pH stands in the pH range 6.5÷9.5 that satisfy the requirements of the Regulations No 235.

Conclusions

Assessment of chemical composition of the analyzed seven largest drinking water systems shows that drinking water quality satisfies to the harmlessness and quality requirements testified in the Regulations No. 235 with exception of higher concentrations of sulphate than the MPV in Jelgava and Jurmala drinking water as well as high values of turbidity and total iron in Jelgava drinking water. In all analyzed drinking water systems content of Hg, Cd, Pb, Cu, Ni, Cr (total), BrO_3^- and trihalomethanes (total) are in the level of their determination or less than it or some concentration changes were observed only in some cases that are significantly less than their MPV.

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SKŁAD CHEMICZNY I OCENA JAKOŚĆ WODY PITNEJ. STUDIUM PRZYPADKU: ŁOTWA

Abstrakt: W 2008 r. wykonano statystyczną ocenę jakości wody pitnej pobranej z siedmiu największych systemów wodociągowych Łotwy (Ryga, Daugavpils, Liepaja, Ventspils, Jelgava, Jurmala i Rezekne) na podstawie ich składu chemicznego. We wszystkich analizowanych wodach pitnych stężenia Hg, Cd, Pb, Cu, Ni, Cr (stężenie całkowite), BrO_3^- i trihalogenometanów (stężenie całkowite) były na granicy oznaczalności lub poniżej. Tylko w niektórych przypadkach obserwowano zmiany stężeń, ale były one znacznie mniejsze od dopuszczalnej wartości maksymalnej (MPV). Na podstawie analizy danych stwierdzono zwiększone stężenie siarczanów w wodzie pitnej z Jelgavy i Jurmaly. W wodzie pitnej Jelgavy stężenie siarczanów przekraczało maksymalne wartości dopuszczalne (MPV) o 97 mg/dm^3, a w Jurmale - 26 mg/dm^3. W wodzie pitnej z Jelgavy stwierdzono też duże całkowite stężenie żelaza (1,15 ± 0,54 mg/dm^3) i znaczne zmętnienie (14,2 ± 7,2 NTU). Stwierdzono stosunkowo duże stężenie glinu w wodzie pitnej z rzeki Liepaja (0,2 mg/dm^3), sięgające MPV. Przedziały ufności wartości średniej zostały obliczone z wykorzystaniem nierówności Czebyszewa. Analizowane dane świadczą o bardzo dobrej jakości wody pitnej z badanych sieci wodociągowych Łotwy.

Słowa kluczowe: jakości wody pitnej, skład chemiczny, statystyka matematyczna, Łotwa