

**HYGIENIC EVALUATION OF SOURCES OF DRINKING WATER USED
IN PRIMARY MILK PRODUCTION**

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Abstract

*The aim of the study was to examine the quality of drinking water from sources for mass supply and individual supply used on agricultural farms intended for primary milk production in industrially contaminated area. Water was investigated in accordance with the requirements for drinking water. Chemical investigation showed that limits for nitrates and chlorides were exceeded in samples from sources for individual supply. Coliform bacteria as an indicator of faecal contamination were present only in sources for individual supply and the limits were exceeded particularly in spring, summer and fall. Limits for bacteria cultivated at 37°C were exceeded only in source 4 in autumn. The samples from individual supply were the most contaminated from the bacteriological point of view. The maximum acceptable limits for *E. coli* in sources for mass supply were not exceeded. The maximum acceptable limits for EC were exceeded throughout investigations in samples from sources for individual supply.*

Keywords: *drinking water, quality of sources, coliform bacteria, *E. coli**

1. INTRODUCTION

The most important problems to which humans have to face in this century are global climate changes and lack of high quality drinking water. Due to anthropogenic activities we commonly find territories where the drinking water sources are contaminated to such degree that the water from them is neither suitable for drinking and watering of animals nor for food processing and other purposes related to our everyday life (Sasáková 2009).

The Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (in short, the EU Water Framework Directive) adopted in 2000, establishes legislative frame for introduction of uniform water policy in EU countries. It is based on integrated control of water sources within drainage basins that consists in coordination of strategic targets in sectors such as agriculture, forestry, industry and similar. It is expected that the EU member states ensure good quality of surface and ground water by the year 2015 (Lanz, K & Scheuer 2000).

In the Slovak Republic, the EU Water Framework Directive is implemented through the Act. No. 364/2004 Coll. on water which takes into consideration also the requirements set by Council Directive 91/676/EEC of 12th December, 1991, on protection of water against contamination with nitrates from agricultural sources. The quality of ground water is frequently reduced by intensive agriculture and the use of nitrogen fertilizers and pesticides. In order to ensure sufficient quantity of safe drinking water we must prevent penetration of nitrates originating from agriculture into water sources and

eliminate all interventions and operations that could affect negatively the quality of water supplies (Howd & Fan 2008).

Additional components that contaminate ground water are heavy metals, crude oil and its products, carbohydrates and chlorine, particularly from point sources of contamination, such as waste dumping grounds (Klinda 2010; Council Directive 91/676/EEC 1991).

The Regulation No. 199/2008 Coll. establishes Programme of agricultural activities in declared vulnerable areas. These are agricultural areas where the level of nitrates in surface and ground water or in lakes exceeds 50 mg.l⁻¹ due to agricultural activities.

The quality of water is currently a priority with regard to general and economical point of view but also because the quantity and quality of water is the basic factor of environmental management and protection. The aim of protection is to prevent and eliminate such intervention and activities that can affect adversely the quantity and quality of available water (Šimková 2004).

The plans for ensuring safety of drinking water are based on HACCP (Hazard Analyse and Critical Control Points 2004), i.e. analysis of risk and critical control points in production premises, particularly in food production. The plans for drinking water safety will be integrated also in water directive which presently undergoes revision (Munka 2010). This directive will be obligatory and will have to be implemented in the Slovak legislation before predetermined date (Cortvriend 2010). It is a general rule that water from every source used for public supply must be treated. Water from some ground water sources must be disinfected if intended for drinking.

Wells as sources of drinking water for individual and mass supply must comply with hygiene rules. It is necessary to check the surroundings of wells so there are not present any sources of potential contamination, such as septic tanks, sewage pipelines, liquid fuel tanks, animal houses, manure heaps and similar (Klinda 2010).

Ground water is the type of water located in rock environment (Younger 2007). It is a priceless, well available and quantitatively, qualitatively and economically most suitable source of drinking water. It has constant temperature and usually does not require special treatment, only removal of some minerals or ensuring the health safety, for example by chlorination. However, the number of substances that may contaminate ground water increases which poses a risk of their penetration into food chain (Macler & Mercle 2000).

On the basis of report of the State Geological Institute of D. Štúr (SGIDS 2006) in Bratislava, Slovakia, about the influence of geological environment on public health according to environmental regions up to one third of Slovak population lives in disturbed or strongly disturbed environment. This is conditional upon high contamination of soil, natural waters, rocks and river sediments and increased natural radioactivity in more than 10% of Slovak territory.

From the microbiological point of view, the analyses in 2010 showed that the hygiene limits most frequently exceeded in drinking water and distribution pipelines involved *Escherichia coli*, coliform bacteria, enterococci, bacteria cultivated at 22 °C and 37 °C and live organisms.

The Slovak Office of Public Health (OPH) reported in 2010 that 85.29 % of population is connector to public water supply. However, recently many families disconnect from public supply and use their own wells as sources of drinking water. Due to this considerable decrease in consumption of drinking water from public distribution was recorded (Bohus & Dugasova 2010).

All activities in primary milk production affect essentially the safety of milk and milk products (cleaning and disinfection, rinsing). Drinking water becomes a part of products and thus its quality and

safety must be monitored. Water is important also for personal hygiene and hygiene of the working environment.

Intake of contaminated water by cattle can cause diarrhoea, loss of appetite and hepatotoxic disorders with fatal consequences (Beede 2006). Insufficient intake of water decreases productivity and has adverse health consequences. High-yield cows drink daily approx. 75 l of water. Water in drinkers should be adequate quality and not contaminated with feed residues or excrements. The drinking system should be frequently cleaned (Brestenský 2008).

Combination of higher level of sulphates and magnesium can cause diarrhoea, hydrogen sulphide results in anaemia, high levels of sulphates, iron and manganese increase demands on copper. Acidic water (pH below 5.1) may increase problems associated with chronic or slight acidosis, decrease milk yield and feed intake or result in a number of infectious and metabolic problems. Alkaline water (pH above 9.0) may cause chronic or slight alkalosis and in some cases also symptoms resembling slight acidosis. Nitrate levels exceeding 100 mg/l may affect adversely fertility of cattle (Olkowski 2010).

2. MATERIAL AND METHODS

Analysis of quality of drinking water from sources intended for individual and mass supply on agricultural farms for primary milk production located in vulnerable areas and evaluation of results was carried out according to Governmental Order of SR No. 496/2010 Coll. on requirements for drinking water and control of quality of drinking water.

Investigations were carried out on 5 farms, three supplied with water from sources intended for individual supply and two connected to mass public supply source. Water samples were collected from February to December in all four seasons.

Relevant parameters were examined at sampling and after their transfer to laboratory. Visual examination (colour, turbidity and odour) was done within 24 hours. Temperature was measured at sampling.

Physical and chemical examination focused on parameters that indicate contamination of water with faeces of humans or people and affect adversely the primary milk production.

Bacteriological examination included parameters that indicate general contamination of water (BC22 and BC37), possibility of contamination of water with faeces of animals and people or with sewage (coliform bacteria), and presence of micro-organisms that are part of digestive tract of man and animals (*E. coli*). Colonies (CFU) were counted after inoculation of samples onto relevant nutrient agars and cultivation for prescribed time at optimum temperatures.

3. RESULTS

In all samples we determined pH, COD, saturation with O₂ and the content of Ca + Mg. Moreover we checked them qualitatively for the indicators of faecal contamination: ammonium ions, nitrites, nitrates, chlorides, iron, phosphates and free chlorine. Only the samples which proved positive at qualitative testing of indicators of faecal contamination were investigated quantitatively (Tab. 1).

Ammonium ions (NH₄⁺) were detected only in samples collected from source 2 and reached the highest concentration in spring which could be related to melting of snow or extensive rainfall. Nitrites (NO₂⁻) were present in this source in samples collected in autumn. Nitrates (NO₃⁻) were found in all sources at every sampling in spring and only in traces in the remaining seasons. Chlorides (Cl⁻) were

detected particularly in winter in samples from sources 2 and 3 and in other sources only in trace levels.

The results obtained indicate that limit values for nitrates and chlorides were exceeded in samples from sources 3 and 4 (sources for individual supply).

Samples collected in autumn showed that the limit value for nitrates was exceeded in source 4 (78.3 mg/l) and the limit for chlorides in source 3 (475.03 mg/l).

Results of microbiological examination are shown in Table 2 and Figure 1-3. Maximum limit value (MLV) for plate counts of *E. coli* (EC) in 100 ml sample volume (mass supply) were not exceeded. In sources for individual supply the MLV for EC was exceeded in sources 3 and 4 throughout the sampling. In the source 3 the MLV for EC was exceeded in winter (1 CFU/10 ml), summer (6 CFU/10 ml) and autumn (13 CFU/10 ml) and in source 4 also in winter (8 CFU/10 ml), summer (66 CFU/10 ml) and autumn (130 CFU/10 ml).

Coliform bacteria (CB) as an indicator of potential faecal contamination were present only in individual sources (2, 3 and 4). In all sources for individual supply coliform bacteria were present in 10 ml of water in all seasons (source 2: 8 CFU in winter, 220 CFU in spring, 60 in summer and 48 in autumn; source 3: 26 CFU in winter, 240 in spring, 138 in summer and 35 in autumn; source 4: 80 CFU in winter, 260 in spring, 288 in summer and 240 in autumn) (Figure 1-3). BC22 were exceeded (>300 CFU) only in source 3 in spring and in source 4 in summer.

Seasons	Source	Parameters and limit values					
		pH	Nitrate (NO ₃ ⁻)	Chlorides (Cl ⁻)	COD	Ca ²⁺ + Mg ²⁺	Saturation O ₂
		6.5 – 9.5 LV	50 mg/l LV	250 mg/l LV	3 mg/l LV	1.1 – 5.0 mmol/l RV	>50 % RV
Winter	1	6.71	3.1	1.7	2.32	1.05	67.44
	2	6.81	4.4	23.7	1.04	4.0	57.92
	3	6.62	50.26	90.3	2.0	0.72	67.95
	4	7.24	0	11.34	0.68	3.45	63.56
	5	6.91	0	3.54	0.32	3.35	67.67
Spring	1	7.61	8.13	0.35	0.84	1.00	69.85
	2	7.10	4.32	36.51	0.36	3.75	51.66
	3	7.27	18.43	123.36	0.6	2.15	61.25
	4	6.95	26.87	45.37	1.12	2.55	59.43
	5	7.40	10.02	6.38	0.24	3.45	68.04
Summer	1	8.25	9.6	7.09	2.32	1.04	79.1
	2	6.99	4.1	31.90	1.04	3.5	55.4

	3	6.88	15.3	131.16	0.72	2.1	74.1
	4	6.63	27.0	38.99	3.4	2.5	71.3
	5	7.31	9.9	3.54	0.2	2.45	78.7
Autumn	1	7.01	8.5	2.5	0.88	0.75	62.3
	2	6.63	4.1	28.56	0.52	3.3	50.3
	3	6.85	15.3	475.03	0.16	1.85	60.8
	4	6.58	78.3	124.07	0.32	1.9	69.2
	5	6.69	9.9	4.5	1.16	2.4	69.8

Table 1 Results of quantitative determinations in samples of drinking water from investigated sources

Legend

Limit value - LV

Maximum limit value - MLV

Recommended value - RV

Individual supply - IS

Mass supply- MS

Maximum plate counts of BC37 were exceeded only in source 4 in summer (290 CFU/1 ml) and autumn (150 CFU/1 ml).

The content of free chlorine showed that this way of disinfection was carried only in sources for mass supply (1 and 5) as the samples from these sources showed presence of residual chlorine. In sources for individual supply we detected residual chlorine only in source 2 (0.1 mg/l in summer and autumn).

Source	Seasons	EC MLV	CB LV	BC22 LV	BC37 LV	Cl ₂ LV
		0 CFU/100 ml MS 0 CFU/10 ml IS	0 CFU/100 ml MS 0 CFU/10 ml IS	200 CFU/ 1 ml MS 500 CFU/1 ml IS	50 CFU/ 1 ml MS 100 CFU/1 ml IS	LV 0.3 mg/l
1 MS	winter	0	0	0	0	0
	spring	0	0	0	0	0
	summer	0	0	140	0	0
	autumn	0		0	0	0.1
2	winter	0	8	0	0	0
	spring	0	220	170	160	0

IS	summer	0	60	148	80	0.1
	autumn	0	48	80	50	0.1
3 IS	winter	1	26	104	30	0
	spring	4	240	> 300	270	0
	summer	6	138	124	140	0
	autumn	13	35	90	103	0
4 IS	winter	8	80	120	90	0
	spring	6	260	180	165	0
	summer	66	288	> 300	290	0
	autumn	130	240	0	150	0
5 MS	winter	0	0	1	0	0.1
	spring	0	0	0	0	0
	summer	0	0	0	0	0.2
	autumn	0	0	0	0	0

Table 2 Results of microbiological examination of samples of drinking water from investigated sources

4. DISCUSSION

Good environmental status is one of the basic conditions for existence of human population. Environmental contamination is an acute problem of the present time. Consequences of global climate changes affect significantly the water reserves and their availability.

The mean consumption of water in Slovakia per head and day is approximately 120 litres. However, even today we have some regions that lack water of adequate quality and the number of such regions is expected to increase with time.

Individual components of the environment, air, water, soil and organisms affect each other and contaminants shift from one place to another and accumulate in certain locations. Considerable attention is paid to vulnerable regions that were in the past or are still endangered by human activities.

Of all our results we would like to stress the results of microbiological examination of the selected sources. Plate counts of *E. coli* indicating potential faecal contamination were found in sources intended for individual supply (3 and 4) at all samplings and in all seasons and thus these sources failed to comply with the Governmental Order No. 496/2010 Coll.

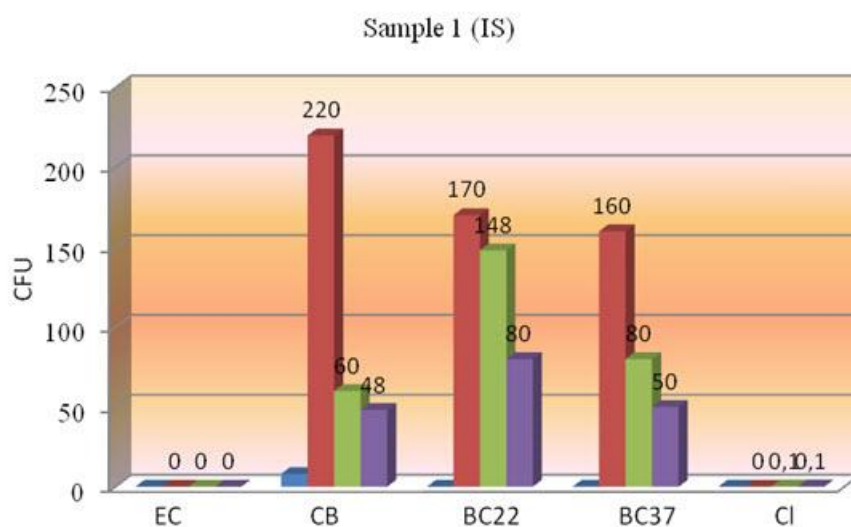


Figure 1 Plate counts of microbiological examination of sample 2

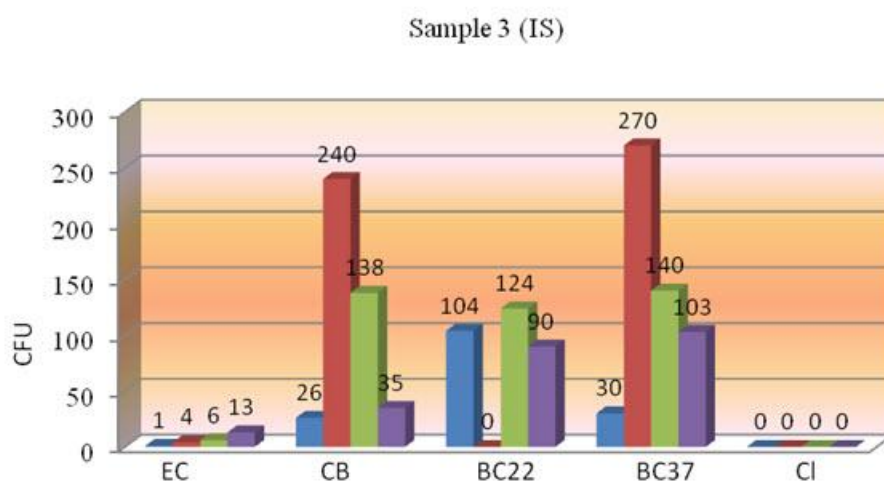


Figure 2 Plate counts of microbiological examination of sample 3

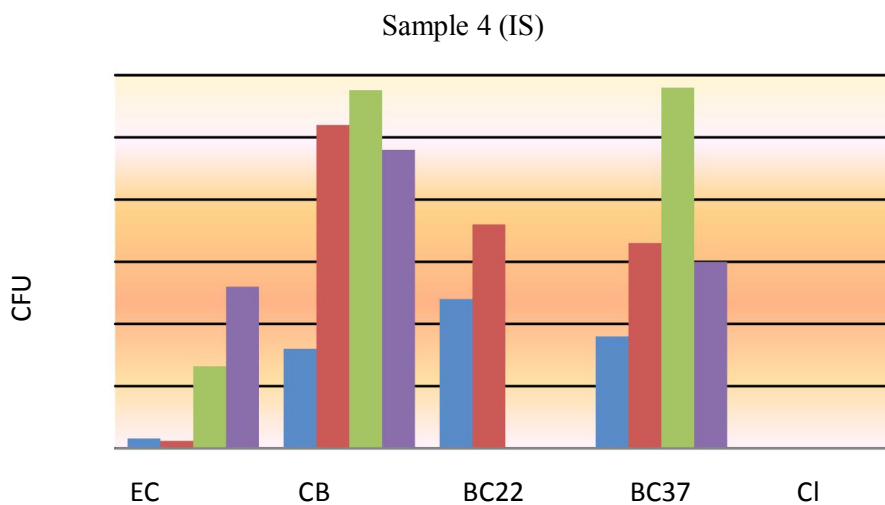


Figure 3 Plate counts of microbiological examination of sample 4

Legend

Blue-winter

Red-spring

Green-summer

Violet-autumn

Determination of free chlorine showed that in the effort to decrease the risk of waterborne diseases the sources for individual supply were disinfected only sporadically. On the other hand, free chlorine was present in sources for mass supply which are disinfected regularly.

Despite the fact that sources for individual supply 3 and 4 were fenced, their surroundings were not kept up and protected adequately. Contamination of these sources could be associated with keeping and grazing of farm animals or application of their excrements on soil. This may produce situation which results in contamination of ground water in the entire location.

Determination of contaminants in drinking water requires a complex system of evaluation of risks resulting from exposure to chemical substances and other contaminants. However the quality of data on toxicity is very variable which presents a problem for risk evaluation. Studies of toxicity in animals are the biggest source of data for risk evaluation (Howd & Fan 2008).

Polluted water can affect adversely the animals that have to consume it (exitus of calves, ketosis or acetonemia of cattle, chronic diarrhoea, liver damage, spreading of infections) (Bitton 1999).

Because all activities in primary milk production affect essentially the safety of milk products, one must eliminate or decrease potential microbial contamination from all sources already in this phase of food chain. The sources of microbial risk include farm environment, water sources for watering of animals, cleaning and rinsing of production equipment and the animals themselves. It is most important to comply with the rules of good practice in animal rearing and keep the animals healthy. Low level of hygiene during milking and the treatment of milk can result in introduction of contaminants already in the phase of primary production (Code 2004).

In dairy cows more than 95% of udder infections is caused by agents spread by alimentary way (*Streptococcus agalactiae*, *Staphylococcus aureus*, *Mycoplasma spp.*) or by environmental agents such as *Streptococcus dysgalactiae*, *Streptococcus uberis*, *Escherichia coli* and similar.

The present situation in primary milk production requires constant stressing of simple procedures and measures that can be implemented easily and support permanently good quality of milk and control of mastitis. These measures and procedures should be introduced and implemented in everyday operation of milking parlours, in animal houses, nutrition, manipulation with animals and similar (Tančin & Tančinová 2008).

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