MICROBIOLOGICAL SAFETY OF WATER SUPPLIES

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INTRODUCTION

The safety of water supplies has several aspects and all of them are included in a coherent system of requirements enhancing each other in the USA. Hungary has never prescribed what treatment source water has to be submitted to, nor have performance requirements been formulated, like demanding a minimum of 6 log coliform kill from the disinfection process. In this region, a case by case authorization process that, although is much cheaper, is prone to be subjective and exposed to the possibility of mistaken decisions, has achieved acceptance. A very important yet rarely formed issue in this region is the strong representation of the consumer's interests that may assist in enforcing quality goals.

From those security facets, it is the system of MCLs that are traditionally used, although the standard limit values have not been embedded in the same legal institutional and official public environment that would render them as effective tools of quality enforcement as seen in the USA. The basic standard microbiological requirements in Hungary that may be similar to those of the neighboring countries are shown in Figure 1.

1. Water quality leaving the waterworks

Parameter	limit value
Total plate count/ml 37°C	20
Total plate count/ml 22 °C	100
Coliform in 100 ml	0

Fecal coliforms, P. aeruginosa and enterococci sulfite reducing clostridia must not be present in 100 ml each

2. Water quality in distribution system: general case

Parameter	good	tolerable
Total plate count/ml 37 °C	20	100
Total plate count/ml 22 °C	100	500
Coliform in 100 ml	0	2*

*in not more than 5 percent of the samples
fecal coliforms, P. aeruginosa and enterococci sulfite reducing clostridia must not be present in 100 ml each

R.A. Deininger et al. (eds.), Security of Public Water Supplies, 185–195.

3. Water quality in distribution system: deep well water*

Parameter	good	tolerable
Total plate count/ml 37 °C	20	100
Total plate count/ml 22 °C	100	500
Coliform in 100 ml	0	2*

*as defined by temperature >20°C and ammonium content > 0.5 and /or COD>5.0
Fecal coliforms, P aeruginosa, enterococci, and sulfite reducing clostridia must not be present in 100 ml each.

Figure 1. Drinking water microbiological requirements in Hungary

STANDARDS

The starting point in devising standards has been the Guidelines of WHO, but nowadays there is a more binding perspective, namely Hungary's joining of the European Union has the greatest influence on drinking water safety. The first time in the history of this country, drinking water quality has to be taken seriously and it has to appear in a formal, legally binding and accountable way; this was not the case before. As a result, assessing the water sources quality in a coherent manner and devising long term plans to adjust protective measures to their present status and future role is a compelling force. A national project of groundwater assessment with major governmental inputs, recent issuances of up-to-date water resources protection ordinances, and the ongoing redrafting of the ordinance on waterworks are proving that high officials are also committed to these tasks. This also indicates that they will not remain on the level of political statements.

On the first impression, one might be afraid of the lower microbiological requirements of the European Union (directive 80/778) of which the drinking water quality requirements will be adopted into Hungarian law. However, it is not necessary to loosen the requirements. It should also be possible to have the opportunity to redraft them with the commitment of making them more flexible and more obliging.

Another segment of the safety is the technical level of the waterworks and the skill and training of the operators. It is one of the most burning issues of this day that with a deepening gap between the greater, profitable systems and the smallest ones that it is impossible to run on clear economical grounds, even if the water rates already hit the tolerance limits of the population served and aggravated with the well known fact the poorest are living in the smallest communities supplied by these systems. The problems of microbiological safety in these small systems are serious, but for the time being, there is no perspective for their resolution, and since they are hardly represented in the statistics, this situation can stay for a long time.

The majority of the recently privatized systems are hopefully facing essential development and it seems that techniques and treatment procedures that have never been hoped for are increasingly finding their way in the Hungarian drinking water supply. However, caution must be stressed. The responsibility of officials involved in the authorization of novel technologies is great since this region is also a hunting field of wild, capitalistic, and irresponsible profit hunters who try and sell all the novelties of the western industries, as well as proven novel technologies. Unfortunately, their actions are being supported by corruption, incompetence and the unclear system of personal responsibilities.

WATER QUANTITY AND QUALITY

Hungary is in a rather favorable situation as far as the abundance of available water is concerned; however, the quality aspect is not that good. Even then, Hungary is lucky enough that it has other choices than using the rather polluted surface waters, which are represented among source of drinking water at only 7 percent. Even most of the surface waters abstracted are of rather good quality microbiologically. River water abstractions were reduced and increasingly substituted with better quality sources in the last decade with the gross decrease of water demand, to the extent that there are only four waterworks of this sort. Other significant surface sources are Lake Balaton with six waterworks and some double function reservoirs of the northern mountain area. The latter has eutrophication with frequent cyanobacterial blooms as the greatest problems that also have bacteriological quality aspects, because biomass of blue-green algae is the substrate of bacterial growth. It also competes for active chlorine, thus causing disinfection efficiency problems.

About one quarter of drinking water is abstracted from bank infiltration wells, once known to be the highest quality source, but now the gross pollution of rivers has made it necessary to treat even these sources. Well water abstracted downstream of Budapest is being treated with ozone and GAC before chlorination to remove iron and manganese because the majority of the sewage is dumped untreated into the Danube.

The chemical and microbiological safety of a group of the upstream wells was thoroughly studied in a WHO-UNDP project; it was found that the probability of virus passage, even through the shortest bank infiltration zones, is very low as assessed by virtue of indicator phages. The major danger being made to these wells, beyond the sewage pollution, is the bed dredging activity with challenging the filtration capacity.

About another 20 percent can be the proportion of unconfined groundwater from shallow wells and karstic aquifers as sources of drinking water. The former is limited to a few regions with abundant water reserve from adjacent riverbeds and territories with low level agricultural activities affecting the upper groundwater table. Karstic aquifers supply excellent quality water, but due to their vulnerability, they have been sources of waterborne outbreaks several times, stressing the necessity of extreme caution.

The rest of the sources (about 50 percent) is confined groundwater with generally excellent microbiological quality, but it does not mean that these systems are providing drinking water of excellent quality. The situation seems to be just the opposite with the greater number of these deep wells. The problems begin already with the wells', in particular, the drop in consumption, together with the formerly installed high output pumps, leads to the practice of a few hours of pumping, alternated with long periods (sometimes days) of stagnation. As a result, microbial growth frequently begins in the well itself.

The chemistry of the water obtained from deep aquifers in several counties of southern and southeastern Hungary makes it impossible to distribute it without any treatment. The treatment is the factor that renders these waters biologically unstable with deep effects on their microbiological quality.

Basic treatment steps include aeration from removal of methane that is present in quantities that frequently threaten explosions. Chlorination, and in many cases, sand filtration or other processes for arsenic, iron, and/or manganese removal are included. The supply systems distribute originally reductive water. However, with treatment, they become oxygen saturated, humic, nutrient rich, and have a high ammonium content. This becomes the stage of abundant biofilm formation and microbial aftergrowth that is accompanied by the growth of higher forms of life such as amoebae microscopic crustaceans, and visible mosquito larvae. It is clear that microbiological safety means a more or less lack of risk of outbreaks connected with unsafe source water, and a lot of these systems are examples of other sides of this question.

The main problem inherited from the former era is that microbiological problems of this nature have never been attempted to be solved. Waterworks administrators have been more committed to quantity and technical aspects. The microbiological safety has been infringed in several aspects. High total plate counts contain high numbers of opportunistic pathogens such as aeromonads, psueodomonads and acinetobacters, which are seldom isolated. An overwhelming majority of the suppliers' laboratories, and even water labs of the public health service, have no skill and training to isolate and identify these bacteria, the presence of which is absolutely undesirable in hospitals and other environments of highly susceptible populations. In some rare occasion when recognition of the composition of the bacterial flora was attempted, we could isolate as high numbers of aeromonads as thousands per mL. *P. aerouginosa* in the order of magnitude of 100/ml and isolated other opportunistic pathogens as *P. stutzeri*, *Stenotrophomons maltophilia*, *Serratia* spp. and *Acinetobacter calcoalceticus*.

In addition, there is only one laboratory in Hungary that takes care of Legionella occurrences in water distribution systems. It was recently learned that the systems, particularly the hot water distribution systems of some hospitals, are heavily contaminated with this bacterium, as are the hot water systems of some housing quarters with bad hydraulic design parameters. However, there is not the faintest idea about the presence and density of Legionella in the systems supplied from the aforementioned deep wells. This situation is further aggravated by the presumed ignorance of this issue by general practitioners and hospital physicians. It is a sensitive issue that may indicate a serious problem area of the Hungarian health care system that is in the deepest pit of its records; that's why there's the reluctance of clearing ambitions.

Another possible consequence of the high total plate count is its masking effect on the presence of coliforms that may happen here, too. However, to be objective, the contrary possibility has to also be mentioned: aeromonads may be mixed erroneously with coliforms and a false positive finding may lead to unjustified alert. In the course of interlaboratory trials for water labs, a rather low level of knowledge and training was found. Fortunately, with the repeated trials, the number of poorly performing labs has significantly decreased and the great majority of them is doing well, at least as far as the minimum daily routine is concerned. There is, however, a great lack in specialized microbiological water labs, including this laboratory which is a national reference laboratory for water microbiology, but is incapable of detecting and identifying a series of newly emerging pathogens that will be mentioned shortly.

A rather special problem of microbiological nature, but chemical in result is the frequently detected nitrite formation in the distribution systems of the above kind. As high as 4-5 ppm nitrite has been measured at sampling locations farthest from the input, but values above the standard limit (0.3 mg/l) are rather frequent. It was discovered that beyond the ammonium of the source water, higher water temperatures, enrichment in oxygen and long residence time with low flow rates all favor nitrification. It is quite difficult to repress them since biofilm nitrifiers tolerate high concentrations of chlorine, even those that often effectively decrease total plate count. An unclear aspect is the generally evident lack of the completion of nitrification in these utilities. The complete nitrification would be an ideal outcome resulting in accumulation of a few ppm nitrate in exchange for the ammonium, but the nitrite oxidizers are apparently not finding the necessary conditions to grow.

There are only a handful of waterworks that remove ammonium so that complete nitrification occurs in advance of discharging water into the distribution system. This is a solution that should be supported much more, since it makes disinfection more effective. Until then only frequent flushing helps, but operators are too often reluctant to apply effective flushing programs because of the water losses and resultant water rate increase.

Actually, disinfection is a hot issue with these systems, since in the presence of ammonium, bound chlorine is known to be much less effective against microbes and arousing much more consumers complaints. Although chloramination is used in a lot of systems, for instance in the USA, as a tool to extend the contact time, even bound active chlorine concentration drops quickly in these systems by the time the water gets to the farther stretches of the network. High organic content with COD values up to 10-15 mg/l (measured as oxygen) means a high chlorine demand and results in the quick disappearance of active chlorine. Also, stagnation often by drastic drop in water consumption, but sometimes also by bad hydraulic design, leads to the lack of protection in the side mains. Removal of organics, a highly desirable treatment option, is only exceptional because of its rather high cost. Solutions other than granulated activated carbon filtration would be necessary.

Attempts to resolve some of the problems of microbiological safety together with the controversial DPB formation in systems like that includes the use of alternative disinfectant such as chlorine dioxide and more commonly the combined application of chlorine dioxide and chlorine. Figure 2 shows what effect on microbial safety these problems have. Only statistics of some counties representing types of source waters together with Budapest and the average of that county are shown. The reliability of some of the data is questionable because of the rather low numbers; these are printed in italics. Only the percentage of unacceptable data divided into two classes is shown. According to the recent practice, samples with high TPC or the presence of P. aeruginosa are reported as objectionable. Those with coliform numbers exceeding the limit values, or any other fecal indicators (such as enterococci, clostridia, or E. coli) are referred to as unacceptable for drinking. The intended purpose of this distinction is to force urgent effective measures in the latter case, with keeping up the pressure for long term solutions, as well as repeated actions for the optimal maintenance of the distribution system in the former.

1. Untreated source groundwater

County	Dominant type of source water	No.	Percent objectionable	Percent unacceptable
Bekes	Confined ground	103	16.5	6.8
Bacs-Kiskun	Confined ground	193	7.3	0.5
Jasz-Nagykun	Confined ground	682	1.3	3.1
Somogy	Mixed ground/surf	137	15.3	3.6
Vezprem	*Unconfined ground*	*33*	*18.2*	*36.4*
Zala	Unconfined ground	502	13.3	0.6
Budapest	Bank infiltration	27	0.0	3.5
Hungary total		**4107**	**8.8**	**3.5**

Counties with too few samples printed in italics

2. Distribution system samples

County	Dominant type of source water	No.	Percent objectionable	Percent unacceptable
Csongrad	Confined ground	1639	28.1	10.3
Bacs-Kiskun	Confined ground	3944	9.7	1.7
Komaron	Unconfined ground	1896	2.2	5.4
Vezprem	Unconfined ground	2020	10.2	6.2
Budapest	Bank infiltration	2867	0.3	1.
Hungary total		**59207**	**10.0**	**5.6**

Figure 2. Microbiological quality compliance rates in counties and Budapest (excerpts from the 1997 statistics)

It is also necessary to stress that these data are biased and the realistic proportion of objectionable and unacceptable samples is probably much lower. The logic in this assertion stays with the fact that problem areas are more frequently tested and that the smallest and worst systems are represented with more weight than the bigger and better ones. It does not contradict to the above said, that small systems are under monitored, even if monitoring frequency relative to the water output is highest of all with them.

HEALTH ASPECTS

Almost any human pathogenic microorganisms capable of surviving outside the human body is also capable of being transferred by water from a sick or carrier to a healthy person, but it is mostly the long queue of enteropathogenic microorganisms that are the subject of concern with respect of drinking water.

Figure 3 summarizes some data on pathogenic microorganisms, a lot of which is preferentially called newly emerging agents with the meaning that it was in the past two decades when they have been recognized or occupied a high position among the acknowledged waterborne pathogens. Some of these have got in this group quite recently and it is only a handful of the most developed countries that have any knowledge on their prevalence, occurrence in waters, and epidemiological significance.

Microorganism	Source	Significance worldwide	Significance Hungary
1. Bacteria			
Campylobacter spp.	Inf. Human, animal	++	++
Salmonella spp.	Inf. Human, animal	++	++
S. typhi and S. para-typhi spp.			
Shigella spp.	Inf. Human	++	++
Pathogenic E. coli	Inf. human, animal	++	++
Vibrio cholerae	Inf. Human/environment	++	-
Yersinia enterocolitica	Inf. Human, animal	+	-? (no sign for suspicion)
Legionella spp.	Environment	+	+/to be confirmed
Aeromonas spp.	Environment	+	+
P. aeruginosa	Environment	+	+
Atyp, Mycobacterium	Environment	+	-/+(not well understood)
2. Protozoa			
Cryptosporidium parvum	Inf. Humanb, animal	++	-?/to be confirmed
Giardia intestinalis	Inf. Human, animal	++	-?/to be confirmed
Cyclospora Cayetanensis	Inf. Human, animal	?	?
Isospora beli	Inf. Human	?	?
Enterocytozoon bieneusi	Inf. Human, animal	?	?
2. Viruses			
GE Adenoviruses	Inf. Human	++	Not known
Enteroviruses	Inf. Human	++	Not known
Hepatitis A	Inf. Human	++	++
Hepatitis E	Inf. Human	++	-/probably
Astrovirus	Inf. Human	++	not known
Coronavirus	Inf. Human	++	not known
Rotavirus	Inf. Human	++	+/probably/
Small Round	Inf. Human	++	not known
Structured Viruses	Inf. human	++	

Figure 3. Waterborne pathogen microorganisms with possible potential of spreading through drinking water distribution systems

Only a few of them are those that Hungary is closely acquainted with along with those classical pathogens that are even now of importance with respect of the safety of drinking water supply. Figure 4 shows the recognized drinking water outbreaks of the last twelve years. It was only about 60 percent of these outbreaks that a pathogen could be identified. Among them, Salmonella was the most frequently implicated one. In most of these cases, Salmonella was also isolated from the drinking water.

Date	Locality	Type of source	Type of Supply	Pathogen Involved	No. of cases
April, 1986	Heves	c. groundwater	rural network	not known	171
October, 1986	Szolnok	surface water	urban network	not known	350
March, 1987	Ozd	mixed	urban network	not known	152
April, 1988	Mezotur	c. groundwater	urban network	S. typhimurium	700
May, 1988	Jaszbereny	c. groundwater	urban network	not known	120
June, 1988	Kerepestarca	u. groundwater	urban network	S. enteritidis	115
July, 1988	Bekestarhos	c. groundwater	rural network	S. infantis	90
August, 1988	Pilis	c. groundwater	rural network	not known	151
July, 1991	Tes	u. groundwater	rural network	C. jejuni	550
September, 1991	Kaposvar	mixed	urban network	S. sonnei	140
August, 1992	Kallo	c. groundwater	rural network	S. sonnei	110
October, 1994	Dombovar	c. groundwater	urban network	S. enteritidis	695

Summarized: 12 outbreaks transmitted by public drinking water supply in 12 years with 3344 known cases.
Pathogens: Salmonella spp. Involved in 4 outbreaks
Shigella sonnei involved in 2 outbreaks
Campylobacter jejuni involved in 1 outbreak
Pathogen not recovered in 5 outbreaks
Source water: confined groundwater in 7, unconfined groundwater in 2, mixed type in 2 and surface water in 1 case.

Figure 4. Recognized Outbreaks in Hungary transmitted by Public Drinking Water Supply 1986-97

Two of these cases are of interest. The 1991 campylobacter outbreak in the city of TES is to be mentioned because campylobacter was isolated with the Hungarian Standard method from the water of the well, too, which is not a frequent case at all worldwide. The incident itself was a simple one: unauthorized dumping of liquid communal waste and animal wastes in a forest area happened and the bacteria contained in it had easily found their way to the karstic water well 400 m away. About half of the village supplied developed diarrhea or became carriers.

The other incident had gained a strong meaning for the whole country in the obscurities of the transition and I hope that it can be remembered as a landmark in the recent history of water hygiene. It happened in a medium sized country town supplied by a single waterwork obtaining the water from 6 or 7 deep wells known to be well protected. The water received no other treatment than chlorination. The cases were evenly distributed in the whole town showing that it was not a specific section of the pipework that was the principal place of the contamination. Salmonella was isolated from all of the 18 distribution system samples taken right after the onset throughout the town. The symptoms at the majority of the almost 700 cases were serious with toxic character suggesting a rather high dose. On the exploration of the case, a series of mistakes were uncovered that were characteristic of the country's state of drinking water management and authority control. The personnel were not skilled and experienced enough. They neglected the maintenance works and the chlorination was often out of order. The system has had a two year long history of unacceptable coliform and fecal coliform records that were morever diagnosed in the county's public findings to the authority next door for they were treated as results of a contract job of an accredited laboratory. The information was given to the waterworks that failed to take any measures, and what is worse, the copies of the result sheets could be found in a drawer of the local public health officer who neglected to do anything about them. The original cause could not be found. What is certain is that one of the wells was directly implicated and the salmonella could be isolated from its water, but nobody could find out from where and how they got into it.

Clearly, one of the most important segments of microbiological safety is the system of monitoring. It has had strong traditions in Hungary, but the turn of the political system has brought about a period of uncertainty and ineffectivity in this respect which is hopefully over by now. Formerly, it was only the state's public health service that monitored the supplies on a normative basis, but it in the beginning of this decade has been made to the task of the supplier and public health authorities are only doing an infrequent check. It is, however, their task to check if a supplier complies with the monitoring requirements and to examine if this is formally done, that is, whether appropriate measures are taken if noncompliance occurs. It is this field where the weaknesses are accumulated and it is again the small supplier that are in the worst position. An additional problem is that a considerable part of the monitoring is perfomed by the public health laboratories but in this case as market participants on contract basis. They are reluctant to treat results as public health issues and they feel unable to inform officials on the serious cases of noncompliance. Thus, the information is traveling a lot until it sinks into a drawer as it could be seen in this case.

The new ordinance on water utilities will hopefully contain strong provisions on the treatment of noncompliances and also the flow of information and the position of the health authorities will be correctly regulated.

The general situation has since improved a lot and the public health authorities are much more alert. Last year, an imminent danger of outbreak was detected and prevented in a village: an unauthorized waste disposal of a public toilet group into the soil had infiltrated into the mains of the water distribution network and caused multiple coliform and fecal coliform occurrences. It was fortunate that no pathogens capable of getting into the drinking water in numbers enough to cause clinically overt diseases had been present in the waste. The local health authority was quick enough to discover the cause and take immediate action to the remedy of the situation. This case is, however, very appropriate for showing the multiplicity of factors influencing the probability of the development of an outbreak and informing on the necessity of coincidence of all these to cause an overt waterborne epidemic. The source of contamination is not enough, a source of the pathogenic agent also has to contribute in the same time and the number of pathogens at the source has to be high enough to ensure the minimum infective dose. One of the factors in the change of the classical pathogen's role in the waterborne epidemiology is the overall improvement of the epidemiological situation; where there are no, or very scarce cases of typhoid, the probability of the S. typhi to get through a long series of barriers until the drinking water distribution system is rendered very low. On the other hand, it is the drinking water way that is a potent vehicle of dramatically changing the general epidemiological situation with spreading a new pathogen such as Cryptosporridium, in no time to as many people as e.g. 400,000 as happened quite recently in Milwaukee. The new era of high technical level of the civilization and sophisticated treatment and safety systems involved in water supply favors to those pathogens that are the most robust in tolerating highly unfavorable circumstance for the longest times-as in the case of oocysts of Crypto or any other cysts of protozoa and that are the most effective in infecting people by one or a few living units. For comparison with the general epidemiological data, Figure 5 shows the proportion of waterborne cases of the last 12 years in the Hungarian prevalence statistics.

Outbreaks transmitted through public drinking water supply: 12 no. of cases: 3344
Outbreaks transmitted through publicly used bathing water: 15 no. of cases: 1540
Pathogen involved only S. sonnei

In years 1986-97

Outbreaks 250 cases			
Total no. of hepatitis cases	24,237	(249 deaths)	waterbborne: none
Total no. of shigellosis cases	25,769	(18 deaths)	drinking water: 2 bathing water: 15
Outbreaks 1540 cases			
Total no. of typhoid cases	22	(1 death)	waterborne: none
Total no. of salmonellosis cases:	176,951	(99 deaths)	waterborne: 4
Outbreaks (only drinking water) 1598 cases			

On the basis of laboratory diagnoses:		
Total no. of giardiasis:	31,925	26.6 per 100,000 in average
Total no. of Cryptosporiodiosis:	451	0.37 per 100,000 in average
Total no. of amebic dysentery cases:	1141	0.95 per 100,000 in average

Figure 5. Comparisons

As far as protozoa are concerned, for example, we have only scarce data even on their prevalence in the population. The only one that has had a proven role is Entamoeba hystolitica which had been implicated in a few cases of sewage intrusion into drinking water distribution system and caused amebic dysentery cases in addition to bacterial infections and hepatitis A., waterborne giardiasis or cryptosporiaidasis have never been diagnosed, although both of these protozoa are present in the list of infectious agents occurring in Hungary. The only data on the presence of giardia in water supply systems have been gathered by a colleague in a northern county's public health institute who has tested for the presence of them in a handful of small rural distribution systems about 12-14 years ago and was able to find Giardia only in one with filtering 100 liters of drinking water. Crypto may be very infrequent as these data suggest, however, this pathogen is not routinely tested for even if parasitologic tests are initiated. As shown in Figure 3, a lot of question marks and "not known" remarks in the last column indicate the inability to cope with the burden of finding all these pathogens incases of outbreaks or contamination. It is probably not at all necessary for such a small country to be ready to detect all sorts of rare pathogens, some of them probably not occurring at all. Nevertheless, the necessity is clear to be able to touch on the most important ones and it is most convenient to do on the footprints of the general epidemiological findings on the prevalence of them in the population.

One favorable aspect of the recent political changes could be if the northern atlantic scientific community could effectively help new members in upgrading the knowledge and capacities to more efficiently solve the problems of microbial safety of drinking water supplies.