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Drought in Bulgaria

A Contemporary Analog for Climate Change

Edited by

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Foreword

This book provides an excellent example of international and interdisciplinary collaboration on an issue of deep concern in the 21st century. What can we learn from the drought years in Bulgaria in 1993-1994 that can help us prepare for climatic changes in the future? The book shows that we can learn a lot by combining detailed information from the past with projections for the future. The abnormally dry conditions of the early 1990s in Bulgaria could become the norm by the middle of this century, and this bears consequences for the environment, economy and society. The roles of water management and communication of scientific results to the public and to decision-makers appear to have been critical in the past and will be most important in the future.

The topics addressed in this integrated study are at the heart of research on the human dimensions of global environmental change, which looks at the causes and consequences of, as well as the responses to, change. The vulnerability of ecosystems and society to change, the institutions that contribute to change and respond to it, the linkages between research, observation, assessment and decision-making, and issues of human security are all central to the human dimensions research agenda. The innovative methodology used in the study provides a strong basis for looking at human-environment interactions.

At the World Summit on Sustainable Development held in Johannesburg in 2002, there was considerable emphasis on the role of science. Science for sustainable development must be integrative across all disciplines; it must be "place-based" and it must address the human-environment system as a whole. This study is an example of such work. The challenge will be to ensure that its warnings are taken seriously by the decision-makers at local, regional and global levels. The book demonstrates clearly that future threats to environment and society as a result of climatic change are real and well-founded management decisions will be necessary. At the same time, it demonstrates the importance of looking at the evolving social, economic and cultural contexts in which global environmental change is taking place.

Finally, I would encourage scholars and practitioners who read this book to think about carrying out other similar case studies in order to improve our understanding of the challenges that sustainable development poses in the 21st century.

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Chapter 9

The Impact of Drought on Surface Water Quality

Galia Bardarska, Hristo Dobrev

Background

The term "water quality" describes the physical, chemical, and microbiological characteristics of water. Surface water quality depends on a complex system of inputs and feedbacks. Superimposed on natural chemistry are factors like catchment land use, deposition of atmospheric pollutants, discharge of urban and industrial wastewater, drainage from urban areas, and accidental pollution. The effects of drought on surface water quality depend very much on local environmental conditions as well as on legislative and economic pressures, such as water quality targets for individual rivers and the price of licenses for effluent discharges.

In this chapter, the reservoir water in protected areas is investigated. These areas were selected so that the impact of human activity on water quality in the drought period 1982-1994 could be minimized. The main message to decision-makers is that with the use of appropriate technological schemes and chemical products, polluted reservoirs could provide a safe and sustainable source of water during drought periods.

Existing Regulatory Framework for Assessment of Water Quality

In the period 1982-1994, most water quality assessments and regulations were primarily based on two documents, which include Regulation No. 7 on flowing surface waters issued in 1986 by the Committee on Environmental Protection in the Ministry of Public Health and the Committee on Regional Construction and Spatial Planning, and Bulgarian State Standard BSS 2823-83 for "Drinking Water." According to Regulation No. 7, the categorization of rivers in the Republic of Bulgaria is based on the quality of river water measured in 1967 and amendments to the Regulation introduced in 1985. Table 9.1 shows the main indices used in determining the three categories of

Table 9.1 Main indices for determining surface water quality according to Regulation No. 7/1986

	Indices	Flowing surface water categories		
		Category I	Category II	Category III
1	Iron, mg/1	0.5	1.5	5
2	Manganese, mg/1	0.1	0.3	0.8
3	Dissolved oxygen, mg O_2/l	6	4	2
4	Oxidizability ($KMnO_4$), mg O_2/l	10	30	40
5	BOD_5, mg O_2/l	5	15	25
6	Ammonium, mg/1	0.1	2	5
7	Phosphorus, mg/1	0.2	1	2
8	Suspended solids, mg/1	30	50	100

rivers as they are currently defined. Category I refers to waters suitable for drinking water. Those belonging to Categories II and III are generally acceptable from an ecological point of view, but are not of sufficient quality to be used for potable water. The categories of surface waters with respect to the values of their quality indicators differ from European standards. For instance, according to European directives, the values of the indicator Biological Oxygen Demand in 5 days (BOD_5) are as follows: Category I-3 mg O_2/l; Category II - 5 mg O_2/1; and Category III - 7 mg O_2/l

Within Bulgaria, qualitative monitoring of surface waters is primarily carried out by the Regional Inspectorates of Environment and Water, the Executive Environmental Agency within the Ministry of the Environment and Water, the National Institute of Meteorology and Hydrology, and the Forest Research Institute with the Bulgarian Academy of Sciences. Responsibility for the control of potable water lies with the Inspectorates of Hygiene and Epidemiology, the Water Supply and Sewerage Companies, and the National Center of Hygiene, Medical Ecology and Nutrition.

BSS 2823-83 "Drinking water" addressed 39 specific water quality indicators. The most frequent deviations of raw waters occur with measurements for turbidity, oxidizability, iron, manganese, ammonium, nitrites and nitrates, as well as for phytoplankton and microbiological indicators. The Bulgarian standard for drinking waters did not address all of the pollutants monitored by the World Health Organization (1993) nor those considered in European standards (1998).

With respect to potable water supplies, the control of compounds formed when surface water is treated with different reagents and disinfectants is of particular importance. For instance, when aluminum-containing reagents are applied, the content of residual aluminum should not exceed the recommended and obligatory norms of 0.05 mg/1 and 0.2 mg/1, respectively (Holdsworth 1991). When potable water is disinfected with chlorine products, the quantity of trihalomethanes should also be controlled (Holdsworth 1991; Dore 1989). Obligatory control of these two parameters, in addition to the indicators that are subject to permanent control according to BSS 2823-83, is indispensable, especially when water pollution increases during periods of drought and larger quantities of chemical products are needed to assure safe water supplies.

Existing Infrastructure and Related Problems

About 98.7% of the Bulgarian population is connected to a centralized water supply network. During the period under review (1982-1994), the relative percentage of human settlements served by centralized potable water systems increased from 80% to 84.7% of the total number of human settlements in the country. Of 9,688 potable water sources, 39% are of the gravity type and 61% are of a pumping-type. Forty-six potable water treatment plants (PWTPs) have single-layer rapid filters for physical-chemical treatment with aluminum sulfate and gaseous chlorine for disinfection. Some also have horizontal sedimentation tanks. Additionally, ozonation processes for disinfection are in operation at potable plants in Breznik and Kardjali. One exception to this typical approach is the process used in the two PWTPs in towns of Targovishte and Preslav. In these plants, only micro-sieves, ozonators, and chlorinators are used for treatment of water that is supplied by the Ticha Reservoir, which was designed for irrigation purposes. The applied treatment system has no specific facilities. for retention of mechanical substances and oxidized organic compounds.

Under normal conditions (those periods without torrential rainfall or prolonged drought), the majority of potable water treatment plants deliver drinking water in compliance with BSS 2823-83. In the case of small human settlements without potable water treatment plants, direct application of $Ca(OCl)_2$ or NaOCl is typically utilized for disinfection of natural waters.

Under certain conditions, the water supply network itself can act as a source of additional pollution of the water supplied to consumers. Approximately 77.36% of the 22,388km of main water delivery pipe systems and 81.38% of the municipal water supply network within Bulgaria are made of asbestos-cement. Breakage of these asbestos-cement water pipelines (most of which were laid down between 25 and 30 years ago) can increase at a particularly high rate as a result of the frequent switching on and off of water supplies during periods of water rationing (regimes). Such breakdowns usually result in long-term pollution of the water distribution networks and changes in the quality of the supplied water. In an assessment of the state-of-repair of the Water Supply and Sewerage Company in the city of Sofia in 1992, the French company SAUR found that disruptions of the water distribution network not only had a negative effect on water quality but also added considerable losses to the water reserves in the Iskar Reservoir. This exemplifies the aggravating conditions that occur in periods of drought and water rationing (SAUR 1992).

In the majority of cases when deviations between monitored water quality and defined water criteria are observed, either urgent amelioration measures are taken or the water supply is purposely interrupted. Due to the fact that most urban areas have centralized water supply systems, there is much more concern for rural areas where local water supplies are obtained from wells and other local water sources without sanitary protection. In these areas, the existence of septic pits and the application of natural fertilizers are cited as reasons for both the increased content of ammonium compounds and phosphates, as well as the increase in the number of microbes in groundwater. Similar problems are also encountered in the case of wells for centralized water supply systems that do not have sanitary protection zones. For instance, the Bivolare watershed near the town of Pleven has been polluted by an urban waste water collector (DEPA 1998).

Incomplete or inadequate sewerage systems throughout the country are another source of permanent anthropogenic pollution of water sources. As shown in Table 9.2, only 35.7% of the population is connected to wastewater treatment technologies (National Statistical Institute 1998).

The poor quality of aeration systems in the case of biological wastewater treatment, and the absence of facilities for treatment of separated sludge, are also reasons for disruption of the operational duty cycle of the plants and for the discharges of untreated wastewater to water bodies in violation of Regulation No. 7. The historical use of mechanical and biological methods of

Table 9.2 Wastewater treatment plants (WWTPs)

Treatment technologies	Number of WWTPs	Design capacity, m^3/d	Working capacity, m^3/d	Connected population, %
Mechanical (first step)	13	41,452	29,747	0.9
Biological (second step)	38	1,811,326	1,153,829	34.8
Total	51	1,852,778	1,183,576	35.7

waste water treatment has not sufficiently reduced problems of heavy metals, nitrogen, and phosphorus in Bulgaria (Halcrow 1999; Ecoglasnost 1999). The control of wastewater in urban areas is further hampered by the discharge of untreated wastewater from industrial enterprises. Consequently, during extensive dry periods, increased control and application of specific measures are necessary for wastewater treatment plants and septic pits of small human settlements located in the area of sanitary protection zones of potable water sources.

The poor state of the water supply and sewerage systems of the country, as described above, indicates that in the case of diminished water resources in periods of drought, the preconditions for deterioration of water quality increase.

A Case Study on the Impact of Drought on Water Quality

The period under review (1982-1994) coincides with a period of tremendous change in the economic system of Bulgaria, in which a transition from a centrally-planned socialist economy to a market-oriented economy has taken place. Since November 10, 1989, state ownership in the areas of agriculture, forests, and industry was discontinued, resulting in a substantial reduction in agricultural activities and the closure of a number of enterprises. During this transition, the environmental situation in Bulgaria has actually shown some improvement. Figure 9.1 illustrates trends in water quality improvement in two major rivers, Maritsa and Iskar, during the period 1989-1996.

Figure 9.2 shows a similar improvement trend for the Vit River, which is located in the most polluted section of the area near the village of Bivolare (DEPA 1998). This particular stretch of river is designated as Category III, and is downstream from some of the largest sources of pollution in the area, such as a petroleum refinery and the towns of Pleven and Dolna Mitropolia, both of which have well-developed industrial and agricultural sectors.

It is evident that drought has negatively impacted the quality of flowing surface waters during the economic transition period that has occurred since 1989. The relationship between water quality and drought conditions has been exhibited by three different reservoirs: Studena, Kamchia, and Iskar (see Figure 17.1 in this book for their location). In each case, a general deterioration of water quality has been observed in association with a precipitous drop in the water level behind the dams, whereby water contamination may be facilitated by increased interaction between the water and sediments at the bottom of the reservoir. The measured concentrations

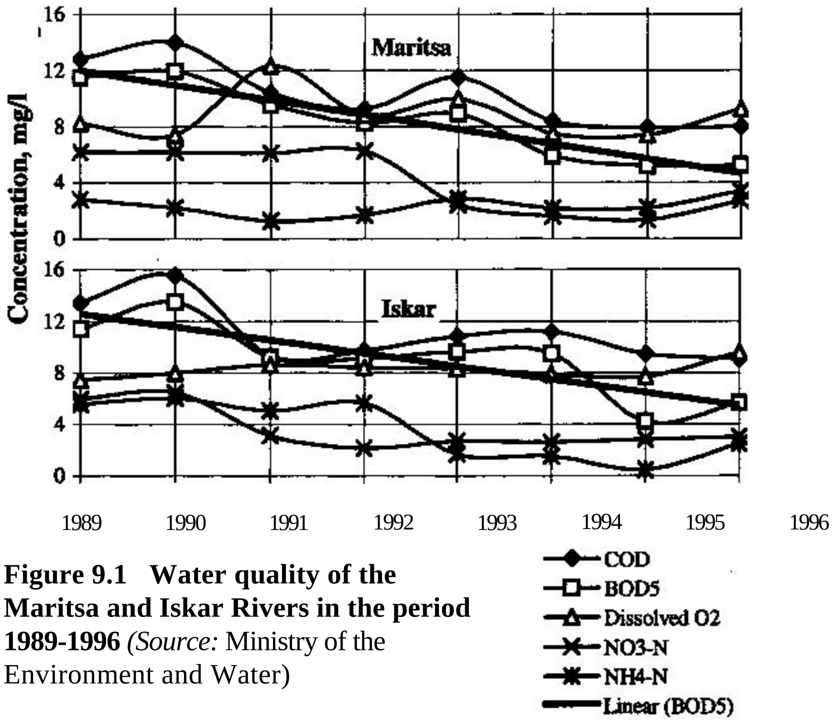

Figure 9.1 Water quality of the Maritsa and Iskar Rivers in the period 1989-1996 *(Source:* Ministry of the Environment and Water)

of iron, manganese, and aluminum of the water in the pores of the sediment of Iskar Reservoir in May 1994 were recorded as 1.2, 0.25, and 0.7 mg/1, respectively (Hrischev *et al.* 1994). The increased bottom-layer pollution also leads to reduction of the dissolved oxygen content of the water.

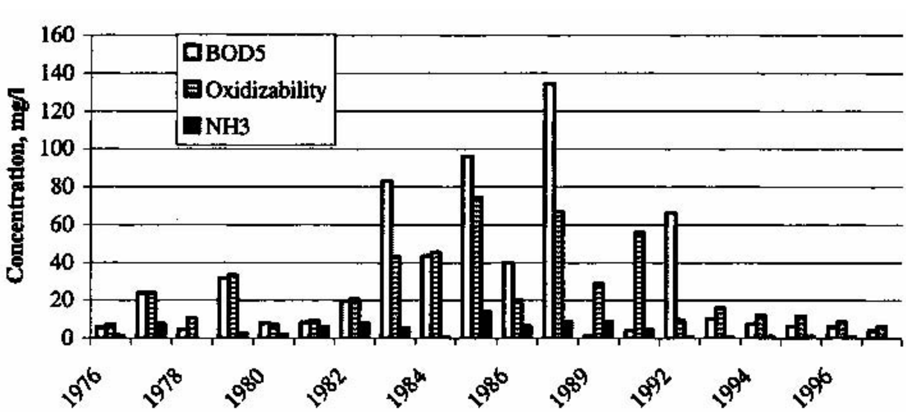

Figure 9.2 Water quality of the Vit River at the village Bivolare in the period 1976-1997 ***(Source:*** **DEPA 1998)**

Similarly, measurements of dissolved oxygen in the water of Studena Reservoir by horizons for the period of October 1991 through September 1993 showed values far below the norm of 2.0 mg O_2/1 for surface water of Category III. The value of dissolved oxygen was 0.99 mg O_2/l in February 1992, 0.91 mg O_2/l in February 1993, and 0.2 mg O_2/l in August 1993 (ECO AQUA TECH 1994). During the same time period, the lowest value of dissolved oxygen in the Kladnishka and Matenitsa Rivers, which discharge to the Studena Reservoir, was measured in August 1993 at a level of 6.19 mg O_2/l in the Kladnishka River. Therefore, in terms of dissolved oxygen, all rivers meet the standards for Category I surface water (ECO AQUA TECH 1994). The highest concentrations for forms of iron and dissolved manganese for the same period have been measured at 27m below the surface of the Studena Reservoir (2.4 mg Fe/1 in June 1993 and 2.32 mg Mn/1 in February 1992; ECO AQUA TECH 1994).

Another indicator for deterioration of water quality is the presence of phytoplankton whose development is accelerated by temperature increases, low water levels, and the presence of nutrients. The quantity of phytoplankton cells of larger dimensions and fiber-type forms is a threat because phytoplankton may clog filters used in water treatment plants, or may pass into the water supply network.

The problems of several PWTPs in terms of their technology and operational practices during the period 1982-1994 are discussed below in parallel with the quantity and quality of water in the three reservoirs. Observations and experimental studies for the Studena and Pancharevo PWTPs provide a basis for making concrete recommendations on the use of adequate technological schemes, treatment equipment, and reagents in periods of drought.

Specific Indicators of Drought Impact on Reservoir Water Quality

Studena Reservoir: During the period 1982-1994, the volume of water in the Studena Reservoir was below 50% of its total capacity of 25.2 million m^3, and was below its "dead volume" of 2.4 million m^3 during the months December 1993-March 1994.

Removal of turbidity typically does not present a problem when a treatment plant is operating according to standard procedures, but under drought conditions, attaining of requirements for potable water standards in terms of manganese content and phytoplankton is much more difficult when using the classical method of applying aluminum sulfate as a coagulant. In the case of both low and high turbidity values, the older two-step Studena

Table 9.3 Turbidity of the Studena Reservoir and treated water at Studena Drinking Station

	Turbidity of the Studena Reservoir mg/1	Turbidity of treated water at the new PWTP, mg/1	Turbidity of treated water at the old PWTP, mg/1
24.03.1993	30	15	2.8
25.03.1993	29	5.2	1.4
26.03.1993	32	20	2.2
28.03.1993	31	12	2.2
29.03.1993	24	7.2	1
31.03.1993	28	12.4	2.4
01.04.1993	25	12	5.2
20.10.1994	7	3.2	0.3
21.10.1994	6	2.5	0.45
22.10.1994	6.5	3	1.9
23.10.1994	7	3	2.2
24.10.1994	6.5	3.2	0.4

Source: Water Supply and Sewerage Company, Pernik municipality

treatment plant (whose equipment included sediment tanks and rapid sand filters) typically achieved better treatment results than the newly constructed one-step Studena plant featuring only rapid sand filters (Table 9.3).

Due to extremely low water levels, manganese content in reservoir water exceeded the allowed value of 0.1 mg/1 for drinking water during the years 1983, 1986, and 1990-1994. Water treated with aluminum sulfate had manganese content that ranged from 0.13 mg/1 (23 March 1993) up to 0.33 mg/1 (29 January 1990). The worst deterioration of the hydro-biological indicators was recorded in August 1993 when the reservoir was characterized by mass development of blue-green algae. The quantity of general chlorophyll "a" (Parsons-Strickland) in the phytoplankton was also the highest in August 1993 (ECO AQUA TECH 1994).

Kamchia Reservoir: The Kamchia Reservoir (228.8 million m^3 total capacity and 74.6 million m^3 "dead volume") is the main water source for the towns of Burgas and Varna. During the period 1989-1990, the population was subject to a period of drastic water rationing. In December 1990 the volume of water reached 50.4 million m^3 and the water quality gravely deteriorated, as exhibited by readings of 60.3 mg/1 for turbidity, 4.4 mg O_2/l for oxidizability, 1.14 mg/1 for iron, and a manganese content 0.65 mg/1. With increased levels of turbidity, concomitant deterioration was noted for other monitored

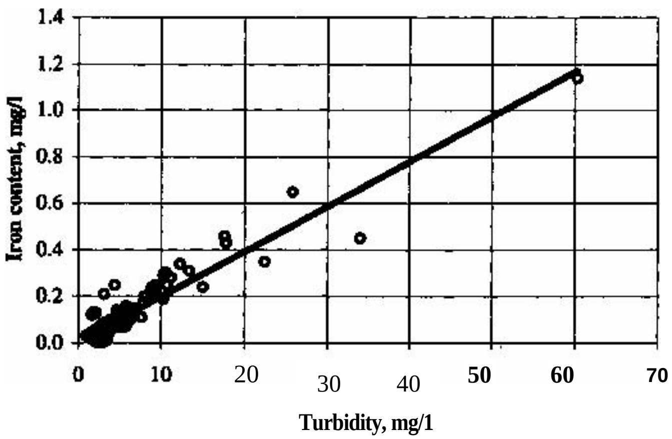

Figure 9.3 Relationship between iron content and turbidity of the Kamchia Reservoir water, August 1985-December 1998

indicators as well. For example, Figure 9.3 provides an example of the linear dependence between turbidity and iron content.

During the water rationing period, the Kamchia PWTP faced difficult operating conditions not only with respect to the provision of the required quantity of water for the population, but also in terms of the desired quality of the drinking water.

Iskar Reservoir: In December 1994, the Iskar Reservoir which has a total volume of 670 million m^3 and an allowable "dead volume" of 90 million m^3, was emptied to 66 million m^3 water. Despite the low water temperatures of 1-2°C during the winter of 1994/1995, both the iron and manganese content and the quantity of phytoplankton increased above the allowed values of 0.2 mg/1, 0.1 mg/1 and 100 cell/ml, respectively. The quantity of phytoplankton in the reservoir reached 6,349 cell/ml (14.02.1994) and 2,860 cell/ml in the treated water (14.03.1994). The relationship between the water volume of Iskar Reservoir and manganese content is shown in Figure 9.4.

In addition to the water shortage during the period November 1994-May 1995, the Water Supply and Sewerage Company of the capital city of Sofia had difficulties in the treatment of reservoir water at the Pancharevo PWTP. The imposed monthly limits on drinking water consumption by industrial enterprises (2.46 million m^3 in 1994 and 1.04 million m^3 in 1995) and the obligatory use of water from proprietary sources for technological applications reduced the water flow from the Iskar Reservoir below the operative capacity of 4.5 m^3/s for the Pancharevo PWTP (Water Supply and Sewerage-Sofia 1994). Despite this drop in water supply from Iskar

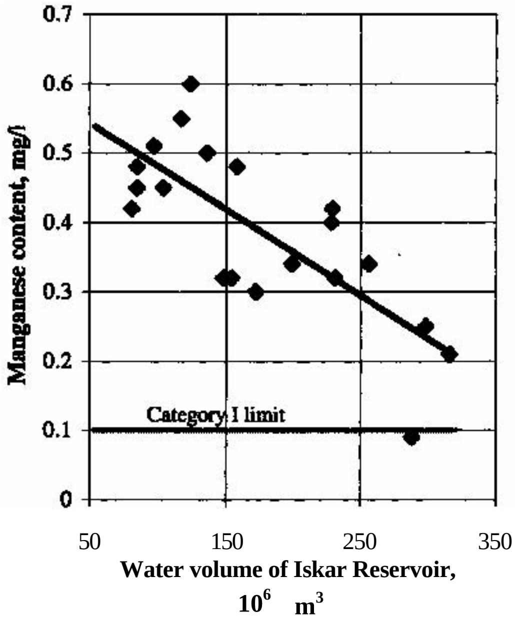

Figure 9.4 Relationship between water volume of Iskar Reservoir and manganese content in the period March 1993-April 1995

Reservoir, part of the water reached the consumers directly from the reservoir subjected only to chlorination, and water passing through the treatment plant was not treated by reagents for physical-chemical purification. For the period January 1994-April 1995 alone, the total quantity of untreated reservoir water supplied to the population amounted to 82 million m^3 (Water Supply and Sewerage—Sofia 1994). The higher concentrations of chloroform in the Sofia urban water supply network compared to the values measured at the exit of the potable water treatment plant Pancharevo provides evidence that untreated drinking water had been supplied to consumers (Table 9.4; Hrischev *et al.* 1994). As a result of poor water management, pollution of the water delivery network set in, and the recorded values of a number of quality indicators of consumed water were higher than those of reservoir water (e.g., 1.4 mg/1 for iron and 0.97 mg/1 for manganese; Gopina and Vassilev 1998).

Despite these conditions, the supply of drinking water of poor quality to the consumers and the pollution of the water pipeline network could have been avoided if the coagulant-flocculant-sorbent CFS-SOLVO® had been used in the Pancharevo PWTP. As shown in Figure 9.5, this reagent appeared to perform well when tested on 1/6 of the equipment in the plant in November-December 1995 (Dobrev and Bardarska 1996). During the course of the investigation, a maximum water flow through the sedimentation tank (Pulsator type) under observation was maintained (2600-2700 m^3/h), as was the added reagent (from 26 to 54 1/h). The dose was in the range of 10 to 20

Table 9.4 Trihalomethanes (THM) in Sofia water, May 1994

Water sample from:	Chloro-form	Dichlorbrom-methane	Dibromchlo-rmethane	Bromo-form	Total THM
Iskar Dam	< 1	< 0.1	< 0.1	<1	0.0
Exit, potable water station "Pancharevo"	14.7	2.7	0.4	<1	17.8
Water supply of Sofia region "Mladost"	25.3	6	0.8	<1	32.1

ml solution to 1m^3 treated water. The cost of the reagent is about US$ 0.0015-0.003 per m^3 treated water. As noted in this instance, even with low turbidity and temperature of reservoir water, a stable duty cycle of sedimentation in the Pulsator typically sets in quite rapidly (in this case, 9-10 hours after the initial feeding of CFS). The large and heavy floccules that are formed settle at the bottom of the Pulsator and make a stable cloud that cannot be disrupted by the upward water flow. In actual fact, the exceptionally good formation of floccules ensures the absence of residual aluminum in the treated water (from 0.00-0.04 mg/1), and has a considerable purification effect on all surveyed indicators including manganese immediately after passing through the Pulsator (Figure 9.5). Manganese elimination depends on the turbidity of raw water. Over 70% manganese elimination after sedimentation can be achieved by means of CFS application when the turbidity of the reservoir water is greater than 5 mg/1.

As a result of complaints by inhabitants of the Lyulin housing complex in Sofia about the poor drinking water quality during the water crisis, lawsuits were deposited with the City Prosecutor's Office (Ref. No. 3607/1994) and the National Investigation Office (Ref. No. 96/1995). Unfortunately, though, the cases were discontinued for lack of any laws that assign personal responsibility to those guilty of supplying drinking water of poor quality.

Conclusions

The drop in industrial and agricultural production in 1982-1994 on the whole produced some improvement in the quality of surface and ground water during the periods of drought. Still, deviations from legislated requirements for drinking water quality per Bulgarian State Standard 2823-83 "Drinking

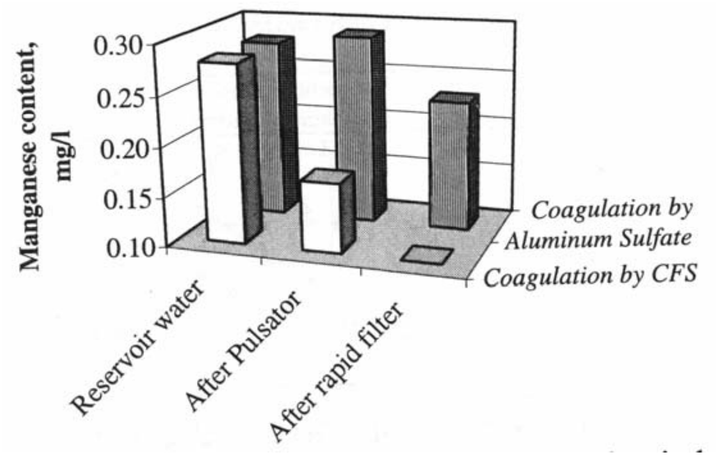

Figure 9.5 Manganese elimination by different chemical products at Pancharevo PWTP on December 3,1994.

Water" have been observed as a result of a drop in reservoir water levels and the concomitant introduction of water rationing. Several conclusions may be drawn based on observations made for three reservoirs (Studena, Kamchia, and Iskar) during the drought period. At very low water levels, deviations from BSS 2823-83 can occur in reservoir water with respect to color, turbidity, oxidizability, iron, manganese, and phytoplankton content. The application of aluminum sulfate in plants that are in a state of technical disrepair is not adequate to ensure quality treated drinking water under adverse conditions. Thus, the supply of improperly treated surface water to the water supply network under drought conditions can lead to additional long-term pollution of the system. Currently, there is no regulatory framework that allows consumers to seek personal responsibility of decision makers who have allowed the supply of poor-quality drinking water.

Recommendations

The deterioration of drinking water quality from surface waters during periods of drought may be avoided by using a variety of strategies. Sanitary protection zones around water sources should be defined and strictly observed. Construction of two-step technological treatment schemes using effective sediment tanks and rapid filters for surface waters and application of adequate filtering materials and reagents for physical and chemical treatment should be undertaken. Water supply systems should be adequately maintained, and water rationing by interrupting supply (regimes) should be avoided—regimes do not always lead to water savings because hydraulic shocks can disrupt water distribution pipes and because vacuum is created when the water flow is stopped. Secondary compounds (trihalomethanes, chlorpicrine, residual aluminum, etc.) above allowed values are health risks that must be controlled. Consumers could implement home treatment mechanisms (boiling, tablets, filtering, etc.) for tap water during periods of drought. Finally, national legislation should hold officials responsible when drinking water of inadequate quality is provided by water supply systems in violation of national standards.

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