02.04 Quality of Near-surface Groundwater (Edition 1993)

Overview

Groundwater qualities are determined by diverse natural and human influences. Negative effects on groundwater quality arising from impurities and pollution of groundwater result from

- small business and industrial production processes, including storage and disposal of waste materials (waste disposal sites, old contaminated sites),
- contamination of soils by accidents and improper storage of water-endangering materials,
- agricultural and forestry (input of nutrients and pesticides) and
- operation of sewage farms.

Water economy laws require the protection not only of groundwater within defined drinking water protection zones, but the protection of all groundwater resources everywhere from any preventable damage, for reasons of environmental precaution. Geological conditions in Berlin create a high degree of pollution risk primarily for drinking water taken from the first level of groundwater. The high permeability of covering layers results in the relatively unhindered transport and impact of pollutants into groundwater in a relatively short period of time. An urban metropolitan area like Berlin requires **long-term** securing of **drinking water supplies** through groundwater protection measures.

Statistical Base

Monitoring Programs

No uniform body of data for Berlin is currently available. This compelled the use of different measuring programs for East and West Berlin.

The quality of near-surface groundwater in **West Berlin** is regularly monitored by the **Routine Measurement Program** of the Berlin Department of Urban Development and Environmental Protection. The program is comprised of 118 street wells and 75 groundwater monitoring wells. Water samples are taken in intervals of a half-year, in the winter and summer half-year.

Investigations in the physical-chemical area include the following parameters:

temperature; turbidity; odor; coloring; pH; conductivity; acid capacity to pH 4.3; sulfates; ammonium-nitrogen; nitrite-nitrogen; nitrate-nitrogen; inorganic nitrogen; orthophosphate-phosphorus, manganese, iron; magnesium, calcium, chlorides, organic carbons, and chemical oxygen demand (tests for oxidation capability by potassium-permanganate consumption were ended in 1987).

The routine measuring program is supplemented by **special investigations**, such as for heavy metals and AOX (adsorbable halogenated hydrocarbons). Street wells are tested by boroughs in a three-year cycle, determining the bacteriological and physical-chemical parameters of drinking water quality according to the Drinking Water Regulations of 1990.

The **Waste Disposal Site Monitoring Program** of the Berlin Department of Urban Development and Environmental Protection has regularly tested old and current disposal sites since 1985. Approximately 500 groundwater monitoring wells have been installed in the inflow and outflow areas of contaminated sites. Four measurements a year are usually conducted.

Data for **East Berlin** was available from 320 measuring points of the **Groundwater Quality Measuring Network** of the GDR Water Economy Direction or the High River Master of Berlin (Oberflussmeisterei), which were usually tested twice a year.

Selected Monitoring Points

The statistical base for **West Berlin** was formed by the selection of 94 street wells and 68 groundwater monitoring wells from the Routine Measurement Program. Criteria for selection was filtering in the first groundwater aquifer. A uniform distribution of measuring points was also attempted. 17 measuring points of the Waste Disposal Site Monitoring Program were included as supplement. The maps here depict mean values from measurements in 1989. No determinations of oxidibility (capability of oxidation) have been made since 1987, thus it was necessary to use measuring results from 1986. Tests for amounts of dissolved organic carbon were viewed as sufficient for the evaluation of organic material impacts.

The statistical base for **East Berlin** was based on analysis protocols of the Groundwater Quality Measuring Network of the GDR (East) Berlin Water Economy Direction from 1989-90. Here too a mean value was derived from samples of each measuring point. Only 59 measuring points could finally be used for depiction. The number of measuring points was considerably reduced by a lack of measurements and location coordinates, as well as the filtering of wells in deeper groundwater aquifers. Measuring points of the project "Ecological Resource Planning for Berlin and Surrounding Areas“ were included as a supplement (BMUNR/UBA 1992). These data originated from hydrological explorations conducted in 1988-1991. A total of 95 measuring points are available for East Berlin. Most of them are private water supply facilities and street wells.

Determination of **pesticide contamination** was made by a special measuring program testing 48 groundwater monitoring wells in West Berlin in 1990, and 31 measuring points, primarily in East Berlin, in 1991. A few measuring points with contamination were tested both in 1990 and 1991. The map uses the most current value. A total of 69 measuring points are shown.

The **AOX** data are from a special examination program which tested measuring points in the West Berlin routine program one time in 1989. A few analyses of water samples taken from groundwater in the course of construction in all Berlin in the years 1989 to 1992 were included for these parameters.

Methodology

Choice of Indicators

Standard parameters were chosen as indicators for the quality of near-surface groundwater: chlorides, sulfates, ammonium, nitrates, oxidibility, conductivity and levels of AOX and pesticides.

Ammonium and **nitrate** are considered parameters for pollution of near-surface groundwater by sewage water and feces. The **oxidibility** gives indications for organic pollution. Electrical **conductivity**, a sum parameter for dissolved substances in groundwater, is a parameter for contaminations of inorganic matter and a standard for general pollution of salts. The same is true for **chlorides**. 'Chemically stable', chlorides do not transform and can thus be followed over long distances. Groundwater deterioration from high **sulfate** impacts indicate debris underground or waste disposal sites with large amounts of building rubble. **AOX** stands for adsorbable halogenated hydrocarbons and serves as indicator for intensive industrial use. The presence of AOX is also characteristic for pollution from the storage of industrial waste (old contaminated sites).

Limits

The graphic depiction of results is oriented to legal limit values of the **Drinking Water Regulations**. It must be noted that limit values are valid in a strict sense only for drinking water (pure water). They are used here as critical parameter for groundwater because other criteria are lacking. Basically, a ground water quality without anthropogenic influences should be attained. Table 1 gives selected parameters and limit values set by drinking water regulations.

Tab. 1: Limit Values of the Drinking Water Regulation for Selected Parameters

Parameter	Limit Value
Chloride	250 mg/l
Sulfate	240 mg/l
Nitrate	50 mg/l analogous 11,5 mg/l nitrate-nitrogen
Ammonium	0,5 mg/l analogous 0,39 mg/l ammonium-nitrogen
Oxidibility (KMnO4 consumption as O2)	5 mg/l
Conductivity	2 000 µS/cm
Pesticides	
Single Substance	0,0001 mg/l
Sum	0,0005 mg/l
AOX *)	0,01 mg/l

*) The Drinking Water Regulation give no limit value for AOX. The critical parameter used here is the sum limit value in the Drinking Water Regulation for 5 organic chlorine compounds of 0.01 mg/l, valid since January, 1992.

Tab. 1: Limit Values of the Drinking Water Regulation for Selected Parameters

The detectable limit of **AOX** in the measuring program was 0.01 mg/l. No differentiation below the limit value could be made. Levels exceeding limit values by ten times are characterized separately.

Several substances were found at many locations during **pesticide investigations**. A sum limit value of 0.0005 mg/l was used for evaluation in the map.

Description

Isolines (lines following identical concentrations of a substance) or contour maps which illustrate surface distributions of concentrations were not used in depiction. Test calculations with the aid of geostatic processes (Kannenberg 1992) have shown that, particularly for groundwater pollutions due to specific pollution points and thus locally limited, point data cannot be transferred to surface because of the insufficient density of measuring points. The estimation errors are too large. Better results are clearly obtained for materials that are introduced by diffuse sources, like sulfates. Measuring values are always point-referenced, in the interest of uniform depiction.

The map gives an overview of the distribution of tested substances in groundwater. Locally limited pollutions, such as those caused by old contamination sites, can not or can only be somewhat registered by the given measuring point density.

Map Description

Oxidibility

Oxidibility is slightly high, with a mean value of 3.0 mg O_2/l over the entire urban area. The limit value of the Drinking Water Regulations was exceeded in 25 cases. This is about 10% of all sampled measuring points. Causes are waste disposal sites and old contaminated sites, as well as the influence of operations of sewage farms and waste water processing areas. Higher values tended to appear in the area of the Pleistocene watercourse (= Urstromtal). A conspicuous frequency of high values is observed north and south of the large Müggelsee Lake. The influence of inflows from waste water processing areas and settlement areas without sewage treatment facilities is apparent here.

Conductivity

Electrical **conductivity** is considered a parameter for impacts of inorganic matter. The subsurface shows the effects of inputs containing salts such as nitrates, phosphates, chlorides and sulfates. Both East and West Berlin show similar conditions in reference to mean values. The mean value for the entire city area is about 1,000 µS/cm. Levels exceeding limit values were only found at 3 measuring points. However, if the lower guide value of 1,000 µS/cm from the EU guideline "Quality Requirements of Surface Waters for Drinking Water Use" is applied, there were values exceeding the limit at 92 measuring points.

Ammonium

Ammonium is produced as a decomposition product from animal and plant protein. Only traces of ammonium are generally present in unpolluted groundwaters. Its presence in near-surface groundwater usually indicates pollution from waste water and feces. Health dangers from ammonium ions are not currently known, but their presence in groundwater is hygienically disturbing, because of their usual origins in feces.

Causes for the **relatively high ammonium concentrations** in groundwater are primarily due to sewage farms which discharged large amounts waste waters into the groundwater for decades. Further impacts followed from percolation of effluents in settled areas without sewer systems and from leaking sewage pipelines. High ammonium values can also appear under natural conditions in low-oxygen groundwaters, such as under moors, because ammonium impacts cannot be oxidized there. Limit values of the Drinking Water Regulations were exceeded at 123 measuring points. This is about 45% of sampled measuring sites. The mean value for ammonium-nitrogen in Berlin is 1.2 mg/l, well above the limit value set by the Drinking Water Regulations. The significantly lower ammonium amounts in groundwater samples from flat uplands in comparison to the Pleistocene watercourse are clearly evident. It can be supposed that the covering layers of marl are significantly more able to hold back inputs of ammonium than the very permeable sands.

Nitrates

High nitrate impacts in drinking water in parts of **Germany** was a subject of public discussion in recent years. Nitrates in higher concentrations are considered toxic. It can be reduced to nitrite in the intestinal tract. Nitrite then binds with hemoglobin in the blood and restricts the transport of oxygen in the blood circulatory system. This leads to oxygen deficiency manifestations (methemoglobinemia) which can be deadly for children, especially infants. The transformation of nitrates can also release nitrosamines, which are carcinogenic.

Nitrate impacts in **Berlin** groundwater are **generally low**, with a mean value of 8 mg/l. Limit values of the Drinking Water Supply Ordinances were exceeded at only 13 measuring points, about 5% of measured sites. This is because intensive agriculture areas do not exist in the city, for all practical purposes. Agriculture and its considerable use of mineral fertilizers and liquid manure is considered a primary cause of high nitrate impacts in groundwater. The concentration of levels exceeding limit values in the north of the Pankow district is due to the large sewage farms, both closed and still operating.

Sulfates

Sulfate impacts in groundwater are **relatively high** in Berlin. Groundwater in sediment stone is generally high in sulfates, it's true, but the high values in Berlin are mainly man-made. The cause is the underground distribution of building rubble - especially debris - over large areas (most of it war damage). Building rubble and debris contain sulfurous plasters, which are washed-out by precipitation waters. Thus there is a tendency for higher values in the city center than in outlying areas. High local values are also found in the sphere of influence of waste disposal sites which have a large proportion of building rubble and debris; such as the Teufelsberg. Values at 54 measuring sites exceeded the limit value of the Drinking Water Regulations, about 20% of sampled measuring sites. The average value of 202 mg/l in West Berlin is higher than the 132 mg/l in East Berlin. The average value for the entire city is 181 mg/l.

Chlorides

Chlorides are not toxicologically alarming, but they can be considered a measure for general pollution. The chloride impacts in Berlin groundwater are **relatively low** in general. The limit value of the Drinking Water Regulations was locally exceeded at 12 measuring sites. The spatial distribution of chloride impacts is generally even. Only in Köpenick were there conspicuously high values, due to geological conditions. Groundwater containing salts sometimes climbs from deeper layers to the surface. Other exceeded limit values were found in the vicinity of waste disposal sites.

AOX

The presence of **AOX** (adsorbable halogenated hydrocarbons; **AOX** = adsorbierbare halogenierte Kohlenwasserstoffe) in groundwater is always due to anthropogenic activity - the effects of small business-industrial use and pollution from old contaminated sites. It has been demonstrated that more than half the groundwater measuring sites show levels that **considerably exceed** the selected critical parameter. There is a clustering of high values in Spandau. Sites with high AOX values are also located outside this area, which can be traced back to local polluters and old contamination sites. 14 measuring sites were determined to have values over 0.1 mg/l, 10 times the critical parameter.

A particular problem is presented by the group of highly-volatile chlorinated hydrocarbons (CHC - LCKW). This material is detected along with other materials in the determination of AOX. As the studies of Brühl et al. (1991) document, the boulder marl overlying the groundwater aquifer are not an effective protective barrier against this material group. In fact, the highly-volatile CHCs penetrate boulder marl overlappings relatively easily. Under the reduction conditions which predominate during this migration there is some transformation into degradation products that are even more strongly water-endangering.

Pesticides

Pesticide was found in 16 of 31 groundwater samples tested for pesticides in 1991. The value limit of the Drinking Water Regulations was exceeded 11 times at tested measuring sites. The sum limit value, used in the map as critical parameter, was exceeded twice. The Working Group of States for Water considers the simple presence of pesticides disturbing - in any measured concentration.

Measuring sites with the highest values are in the old border strips between East and West Berlin. The very great use of pesticides for many years to maintain border security boundaries ("death strips") is noticeable. Pesticides were primarily detected in East Berlin at agricultural areas, but the concentrations are in a relatively low range.

Triazine and metabolites were usually detected, but Lindane and DDT also. A material from the phenoxycarbon acid group was found in 10 samples in East Berlin measuring sites. It is not certain that these impacts come from use of herbicides.

Cadmium

Data were also evaluated for **cadmium** impacts in groundwater. Cadmium is considered a representative indicator for heavy metal impacts in groundwater, because of its environmental behavior. It has a high accumulation rate in soils. Even the bare possibility of remobilization and washout is a considerable point of danger for groundwater. Cadmium is severely toxic to the human organism. Liver, kidneys and bone marrow are the most susceptible organs or accumulation points in chronic or acute cadmium exposure. Most cadmium absorption proceeds above the digestive tract.

A depiction in the map was declined, however, because data for East Berlin is insufficient, and no contaminations worth mentioning have been registered in Berlin groundwater. Cadmium was detected at only 14 measuring sites. The remaining 165 measuring sites were negative or below the detection threshold.

Overall Perspective

All groundwater resources in the Berlin area have been altered by anthropogenic impacts greatly beyond those of geological conditions and is noticeably polluted. A comparison of Berlin groundwater and unimpacted groundwater from a reference area in Lüchow-Dannenberg shows that the groundwater in Lüchow-Dannenberg clearly has lower levels of most of the tested substances, both in average value and in maximum value (cf. Tab. 2).

Tab. 2: Comparison of Minimum, Maximum and Mean Values of Selected Groundwater Contents in the Upper Groundwater Aquifer in Berlin and Lüchow-Dannenberg (Brühl et al. 1991)						
Substance	**Groundwater from Uncovered Groundwater Aquifers with low Surface Usage from Berlin (n = 12)**			**Unpolluted Groundwater from Lüchow-Dannenberg (n = 13)**		
	Minimum	Maximum	Average	Minimum	Maximum	Average
	(mg/l)			(mg/l)		
Sodium	7	44.5	21	5.2	20.1	13.2
Potassium	0.8	8.8	4.4	0.7	3.5	1.8
Calcium	37	158	102	14.1	118	49.1
Magnesium	2.2	13	8.4	1.4	8.5	4.6
Chloride	8.2	69	33.2	19.4	40.3	26.5
Sulfate	51.8	243	124	30	113	79
Hydrogencarbonate	12.2	293	195	18.3	159	86.2
Phosphate	nn	1.8	0.3	nn	0.5	0.09
Nitrate	nn	42.4	13.5	nn	12.6	4.5
Nitrite	nn	0.1	0.02	nn	nn	nn

n = number of measuring points
nn = undetected (value below the detection limit)

Tab. 2: Comparison of Minimum, Maximum and Mean Values of Selected Groundwater Contents in the Upper Groundwater Aquifer in Berlin and in the Lüchow-Dannenberg Area (Brühl et al. 1991)

Ammonium and AOX values are high in the entire city and exceed limit values of the Drinking Water Regulations or the parameter of valuation chosen for AOX. It must be taken into consideration that ammonium is oxidized to nitrates during processing at waterworks. The nitrate level is indeed raised, but is not disturbing at these low concentrations. Table 3 shows these changes during water processing, as well as data for raw and pure water at wells of the Berlin Waterworks. The values of raw water supplied from wells are listed across from the values of purified water fed into the drinking water network.

Tab. 3: Raw and Pure Water Characteristics of Berlin Waterworks (average values 1991)						
	Ammonium-Nitrogen	Nitrate-Nitrogen	Chloride	Sulfate	Oxidibility (KMnO4 Consumption as O2)	Conductivity
	mg/l					µS/cm
Waterworks	**Pure Water**					
Gallery	**Raw Water 1)**					
Beelitzhof	0.00	0.7	63	85	2.0	710
Lieper Bucht	**0.93**	0.0	51	81	3.0	670
Lindwerder	**0.77**	0.0	42	82	3.0	630
Rehwiese	**0.57**	0.0	50	72	4.0	650
Großes Fenster	**1.05**	0.0	54	87	3.0	690
Wiesenleitung	**0.69**	0.0	205	51	4.0	1,130
Jungfernheide	0.00	0.9	87	190	3.0	910
E I	0.22	0.5	77	200	3.0	940
E II	0.31	0.4	108	180	3.0	940
E III	**0.52**	0.7	75	180	3.0	880
Kladow	0.01	0.6	65	98	2.0	710
	0.56	0.0	59	110	3.0	710
Riemeisterfenn	0.00	0.6	40	210	2.0	800
	0.7	0.0	40	210	2.0	810
Spandau	0.00	0.2	48	92	3.0	660
Gallery North	0.13	0.0	33	79	3.0	580
Gallery South	0.31	0.0	76	120	3.0	800
Horizontal Wells	**0.53**	0.0	22	73	4.0	610
Kuhlake	0.25	0.0	31	83	3.0	570
Tegel	0.00	1.3	61	130	3.0	770
Baumwerder	**0.67**	0.5	60	120	4.0	720
Saatwinkel 1 2)	**1.27**	0.2	67	130	3.0	790
Saatwinkel 2 2)	**0.67**	0.5	54	140	3.0	770
Horizontal Wells	**1.27**	0.3	61	120	4.0	750
Tegelort North	**1.00**	0.0	58	120	3.0	720
Tegelort South	**1.04**	0.1	50	92	4.0	660
Gallery East	**2.06**	0.1	69	140	3.0	850
Gallery West	**1.15**	0.1	68	150	3.0	810
Tiefwerder	0.00	0.8	84	120	2.0	860
North + South	**1.17**	0.0	92	130	4.0	890
Rupenhorn	**0.77**	0.0	72	110	3.0	760
Schildhorn	**0.65**	0.0	76	110	2.0	860
Johannisthal	0.08	1.2	89	197	2.5	1,025
new and old Königsheide	**0.99**	0.0	86	200	3.9	1,000
Teltow Canal Gallery	**2.09**	0.0	97	188	3.6	–
Köpenick	0.07	0.7	88	114	1.6	785
	0.44	0.2	84	113	2.2	720
Kaulsdorf	0.02	0.6	50	100	1.1	664
	0.02	0.2	50	102	1.4	645
Friedrichsfelde	0.09	0.3	58	155	1.5	844
	0.32	0.1	57	157	2.0	843
Buch	0.07	0.1	44	93	0.9	648
	0.22	0.0	44	102	1.1	598
Altglienicke	0.1	0.1	48	133	1.0	–
	0.22	0.0	48	135	1.4	–
Wuhlheide	0.09	1.8	64	203	2.2	920
Gallery East	**3.64**	0.0	69	179	2.9	855
Gallery West	**1.17**	0.0	64	207	2.9	905
Private Wells (Gallery East)	**3.63**	0.1	67	170	3.0	890
Stolpe	0.09	0.7	67	59	3.3	668
Gallery North	**0.47**	0.0	72	45	3.4	825
Gallery South	**0.75**	0.2	68	52	4.4	–
Friedrichshagen	0.05	0.6	65	129	1.7	692
Gallery A	**5.62**	0.0	80	172	3.1	988
Gallery B	**0.86**	0.0	50	117	2.1	691
Gallery C	**0.4**	0.0	50	145	2.4	638
Gallery D	**0.55**	0.0	50	136	2.5	635
Gallery E	**0.59**	0.0	54	135	2.6	623
Gallery F	**0.45**	0.0	74	131	2.2	691
Gallery G	**0.66**	0.0	**299**	102	3.3	1,317
Gallery H	**0.66**	0.3	114	117	**6.4**	839
Gallery I	**0.55**	0.0	56	101	3.0	609
Gallery K	**0.8**	0.2	125	106	2.2	824
Gallery L	0.34	0.0	100	95	1.6	698
Gallery M	0.31	0.0	44	132	2.0	593

– no measuring value available

1) Levels exceeding limit values of the Drinking Water Regulations (TrinkwV) 1990 are printed bold.
Limit values according to TrinkwV 1990 (mg/l): ammonium-nitrogen = 0.39, nitrate-nitrogen = 11.5, chloride = 250, sulfate = 240, oxidibility (KMnO4 consumption, given as O2) = 5, conductivity = 2,000 µS/cm

2) The gallery Hohenzollern Canal is included in Saatwinkel 1 and 2.
In pure water (drinking water generated by plant) no values in excess of limits were recorded. In raw water (groundwater) from individual catchment areas excesses of ammonium were recorded. Drinking Water Regulations do not apply to raw water.
Cited only for purposes of comparison.

Tab. 3: Raw and Pure Water Characteristics of Berlin Waterworks (average values 1991)

The situation for AOX must be judged more critically, for this material can be removed from water only with a great technical expenditure. Other substances which could give indications of industrial pollutants of groundwater, such as arsenic, PAK or mineral oil, have only been tested for at certain sites. They cannot be depicted in a map encompassing all areas.

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