

Table of Contents

1	Introduction, Sampling, Local Testing, etc.	1
1.1	General	1
1.1.1	Water resources	1
1.1.2	Water management	3
1.1.3	Water analyses	3
1.2	Local inspection and sampling of water	5
1.2.1	Sampling of water	5
1.2.2	Local investigations	5
1.2.3	Geology and Hydrogeology	6
1.2.4	Technical information on the water resource	7
1.2.5	Possibilities of environmental influences on the water resource	8
1.2.6	Hygienic considerations	8
1.3	Techniques of water sampling	8
1.3.1	General	8
1.3.2	Bottle material	9
1.3.3	Techniques of sampling	10
1.4	Water sampling in practice	14
1.4.1	Local investigations	14
1.4.2	Sampling for microbiological analysis of water	14
1.4.3	Sampling for physico-chemical analyses	14
1.4.4	Sampling for chemical analyses (see also 1.3)	15
1.4.5	Water sampling for gas analyses	15
1.4.6	Radioactive inert gases	16
1.5	Special instructions for sampling water of various origins and for various investigation purposes	17
1.5.1	Surface water	17
1.5.2	Ground water	17
1.5.3	Salt water	18
1.5.4	Bathing water	18
1.5.5	Industrial water	19
1.5.6	Irrigation	19
1.5.7	Expanses of water devoted to fish cultivation	21
1.5.8	Waste water	21
1.5.9	Sludge	23

1.6	Local investigations (see also 1.7)	24
1.6.1	Preservation of water samples	25
1.6.2	Inorganic substances contained in the water	26
1.6.3	Organic substances contained in the water	27
1.6.4	Radioactivity	27
1.7	Local analyses (see also 1.6)	28
1.7.1	Sensory examination on site	28
1.7.2	Colouring	30
1.7.3	Transparency and turbidity	31
1.7.4	Temperature	32
1.7.5	Hydrogen-ion activity (pH) (cf. also Chapter 2)	32
1.7.6	Electrical conductivity	35
1.7.7	Redox potential	39
1.7.8	Oxygen (cf. also Section 3.6)	42
1.7.9	Ozone	46
1.7.10	Chlorine	49
1.7.11	Determination of chlorine dioxide (ClO ₂) and chlorite (ClO ₂ ⁻)	51
1.7.12	Carbon dioxide (CO ₂), titrimetric determining process on site (cf. also Section 3.6)	57
1.7.13	p- and m-values (acid-base consumption, HCO ₃ ⁻ and CO ₃ ²⁻)	57
1.7.14	Corrosive carbonic acid	58
1.7.15	Settleable substances	61
1.7.16	The investigation of wastes and sludges in the context of water pollution	62
1.7.17	The importance of site inspections for biological assessment of water resources (cf. also Section 1.2, 1.4 and 1.5 above)	66
2	Theoretical Introduction to Selected Methods of Water Analysis (Classic and Instrumental Methods)	71
2.1	Concentration processes such as evaporation, distillation, precipitation, coprecipitation, adsorption, ion exchange and extraction	71
2.1.1	Evaporation	71
2.1.2	Distillation	72
2.1.3	Precipitation	72
2.1.4	Coprecipitation	73
2.1.5	Adsorption and ion exchange	73
2.1.6	Extraction	73
2.1.7	Volumetric analysis	74
2.2	Electrochemical processes of analysis	74
2.2.1	Introduction	74
2.2.2	Coulometry	76
2.2.3	Potentiometry	79
2.2.3.1	Ion-sensitive electrodes	82
2.2.4	Polarography	84

2.3	Spectrophotometry (or photometry)	89
2.3.1	Measurable variables of light absorption	90
2.3.2	The Lambert-Beer Law	91
2.3.3	Design and mode of operation of an absorption spectrophotometer	93
2.3.4	Photoelectric photometers	94
2.3.5	Evaluation	95
2.4	Flame-emission spectrophotometry (FES)	98
2.4.1	Design of the instrument	98
2.4.2	Evaluation	100
2.5	Emission spectrum analysis	101
2.6	X-ray Fluorescence Analysis	102
2.7	Atomic Absorption Spectrometry (AAS)	103
2.7.1	Design of the equipment	104
2.7.2	Scope	105
2.7.3	General aspects of calibration and analysis	107
2.7.4	AAS measurements using the graphite furnace technique	108
2.7.5	Example of an AAS measuring system after Perkin-Elmer	109
2.8	Atomic Emission Spectrometry with Inductively Coupled Plasma Excitation (ICP-AES)	110
2.8.1	General	110
2.8.2	Equipment	112
2.8.3	Analytical limits	114
2.9	Fluorescence Spectrometry	115
2.9.1	Equipment	116
2.9.2	Interference	117
2.10	Infrared Spectroscopy	117
2.10.1	General remarks	117
2.10.2	Evaluation of an IR spectrum	120
2.10.3	Preparation and handling of the samples	123
2.11	Chromatographic methods	127
2.11.1	General	127
2.11.2	The main chromatographic techniques used in water analysis	128
2.11.3	General comments on GC-MS techniques in water analysis	128
2.12	Introduction to gas chromatography	134
2.12.1	Principles and definition of the method	134
2.12.2	Structure of gas-chromatographic apparatus	135
2.12.3	Identification of sample components	137
2.12.4	Determination of sample concentrations	137
2.12.5	Sensitivity	138
2.12.6	Speed of analysis and automation	138

2.12.7	Theory of the chromatographic process	138
2.12.8	The separation process	140
2.12.9	General remarks on the formation of the peak shape	141
2.12.10	The partition isotherms	142
2.12.11	Causes of peak broadening	143
2.12.12	The van Deemter equation	147
2.12.13	The number of theoretical plates	148
2.12.14	The efficiency or selectivity of the liquid phase	149
2.12.15	The resolution equation	150
2.12.16	General remarks on GC detectors	152
2.12.16.1	Flame ionization detector (FID)	153
2.12.16.2	Electron capture detector (ECD)	153
2.12.16.3	Thermionic detector (TSB) and alkali flame ionization detector (AFID)	156
2.12.16.4	Flame-photometric detector (FPD)	157
2.12.16.5	Thermal conductivity detector	158
2.12.16.6	Microcoulometric detector	158
2.12.16.7	Mass-selective detector	159
2.12.17	Theoretical considerations regarding detectors	159
2.12.17.1	General remarks	159
2.12.17.2	Characteristic parameters of detectors	163
2.13	Gas-chromatographic headspace analysis (cf. also Chapter 4)	166
2.13.1	General remarks	166
2.13.2	Area of application	167
2.14	High-performance liquid chromatography (HPLC)	168
2.14.1	Basic principles	168
2.14.2	Retention	169
2.14.3	Separation mechanisms	171
2.15	Ion chromatography	172
2.15.1	Ion chromatographs with suppressor	174
2.15.2	Ion chromatography without suppressor	176
2.15.3	Anion separation	177
2.15.4	Examples	177
2.16	Radiochemical analysis of water samples (Introduction)	181
2.16.1	General information	181
2.16.2	Types of radiation	181
2.16.3	Radionuclides in water	182
2.16.4	Units of measurement	183
2.16.5	Radioactive decay	184
2.16.6	Enrichment of radionuclides	184
2.16.7	Measuring preparations	185
2.16.8	Total determination	185
2.16.9	Safety regulations	186
2.16.10	Radiation protection	187
2.16.11	Detectors and measuring equipment	187
2.17	Enzymatic Analysis	194

3	Inorganic Parameters	195
3.1	Total parameters	195
3.1.1	Turbidity measurements (see also Section 1.7.5)	195
3.1.2	Density	197
3.1.3	Total determination of dissolved and undissolved substances	199
3.1.3.1	Undissolved substances	201
3.1.3.2	Cumulative determination of dissolved substances with cation exchangers	202
3.1.4	Sulphide sulphur (H_2S , HS^- , S^{2-}) (see also Chapter 1 and Section 3.6)	204
3.1.4.1	Iodometric determination of sulphide sulphur	204
3.1.4.2	Spectrophotometric analysis of sulphide sulphur as methylene blue	205
3.1.5	Water "hardness" (see also Chapter 1, and Sections 3.2 and 3.3)	210
3.2	Anions	211
3.2.1	Fluoride	211
3.2.1.1	Spectrophotometric determination with lanthanum alizarin complexone, directly or following steam acid distillation	211
3.2.1.2	Determination of the fluoride ion with an ion-selective (ion-sensitive) electrode	215
3.2.1.3	Ion chromatography determination of fluoride ions (see Section 3.2.11)	217
3.2.2	Chloride	217
3.2.2.1	Gravimetric determination	218
3.2.2.2	Volumetric determination with silver nitrate (electrometric indication)	219
3.2.2.3	Volumetric determination with silver nitrate and potassium chromate (visual indication)	221
3.2.2.4	Ion chromatography determination (see Section 3.2.11)	223
3.2.3	Bromide and iodide	223
3.2.3.1	Consecutive iodometric determination of bromide and iodide in one solution	223
3.2.3.2	Ion chromatography (see Section 3.2.11)	226
3.2.4	Nitrite	226
3.2.4.1	Spectrophotometric analysis with sulphanilic acid and l-naphthylamine	226
3.2.4.2	Ion chromatography (see Section 3.2.11)	229
3.2.5	Nitrate	229
3.2.5.1	Spectrophotometric analysis with sodium salicylate	229
3.2.5.2	Nitrate with 2,6-dimethylphenol	230
3.2.5.3	Determination of nitrate after reductive distillation	231
3.2.5.4	Ion chromatography (see Section 3.2.11)	233
3.2.6	Sulphite	233
3.2.6.1	Iodometric determination of sulphite	233
3.2.6.2	Gravimetric determination as barium sulphate after distillation	234
3.2.6.3	Polarographic determination of sulphite (including sulphide and thiosulphate)	236
3.2.7	Sulphate	237
3.2.7.1	Gravimetric Determination as Barium Sulphate	237
3.2.7.2	Nephelometric Determination of Sulphate	238
3.2.7.3	Ion chromatography (see Section 3.2.11)	239
3.2.8	Phosphate	239

3.2.8.1	Orthophosphate (calculated as hydrogen phosphate)	240
3.2.8.2	Sum of orthophosphate and hydrolyzable phosphorus compounds	243
3.2.8.3	Total phosphorus	245
3.2.8.4	Phosphate determination using ion chromatography (see Section 3.2.11)	247
3.2.8.5	ICP-AES (see Section 3.3.12)	247
3.2.9	Carbonic acid, hydrogen carbonate and carbonate (see also Chapter 1 and Section 3.6)	247
3.2.9.1	Acid consumption (alkalinity)	249
3.2.9.2	Acid consumption and base consumption (p and m value)	250
3.2.9.3	Acidimetric determination of carbonate ions and hydrogen carbonate ions (p and m values)	251
3.2.9.4	Base consumption (acidity)	254
3.2.10	Total carbon dioxide (see also 3.6, carbon dioxide)	255
3.2.10.1	Calculation of S_c (diss. CO_2) from the p and m value	256
3.2.10.2	Volumetric determination after distillation	257
3.2.10.3	Gravimetric determination after distillation	260
3.2.11	Ion Chromatography of seven anions	264
3.3	Cations	274
3.3.1	Lithium	274
3.3.1.1	Determination by flame photometry	274
3.3.1.2	Direct determination of lithium by means of atomic-absorption analysis	275
3.3.1.3	Lithium determination with the graphite tube technique (Furnace method)	276
3.3.2	Sodium	276
3.3.2.1	Flame photometry	277
3.3.2.2	Direct determination of sodium by means of atomic-absorption analysis	279
3.3.2.3	ICP-AES (see Section 3.3.12)	279
3.3.3	Potassium	280
3.3.3.1	Determination by flame photometry	280
3.3.3.2	Direct determination of potassium by means of atomic-absorption analysis	280
3.3.3.3	ICP-AES (see Section 3.3.12)	281
3.3.4	Rubidium and caesium	281
3.3.4.1	Determination by flame photometry	281
3.3.4.2	Determination of rubidium and caesium in water samples by means of AAS	284
3.3.4.3	Direct determination of rubidium by means of atomic-absorption analysis	285
3.3.4.4	Direct determination of caesium by means of atomic-absorption analysis	286
3.3.4.5	Basis of the method of concentration	286
3.3.5	Ammonium (ammonia)	287
3.3.5.1	Photometric determination of NH_4^+ as indophenol	287
3.3.5.2	Acidimetric determination of NH_4^+ or NH_3 after distillation	290
3.3.6	Magnesium	292
3.3.6.1	Direct determination of magnesium by means of atomic-absorption analysis	293
3.3.6.2	Complexometric analysis (see Calcium, Section 3.3.7)	293
3.3.6.3	ICP-AES (see Section 3.3.12)	293
3.3.7	Calcium	293
3.3.7.1	Direct determination of calcium by means of atomic-absorption analysis	294
3.3.7.2	Chelatometric determination of calcium ions and magnesium ions	294
3.3.7.3	ICP-AES (see Section 3.3.12)	298

3.3.8	Strontium	298
3.3.8.1	Direct determination by means of atomic-absorption analysis	298
3.3.8.2	Determination by flame photometry	299
3.3.8.3	ICP-AES (see Section 3.3.12)	300
3.3.9	Barium	301
3.3.9.1	Direct determination of barium by means of atomic-absorption analysis	301
3.3.9.2	Method of enrichment of barium	301
3.3.9.3	Barium determination with the graphite tube technique (Furnace method)	303
3.3.9.4	ICP-AES (see Section 3.3.12)	303
3.3.10	Iron	303
3.3.10.1	Direct determination of iron by means of atomic-absorption analysis	304
3.3.10.2	Iron determination with the graphite tube technique (Furnace method)	305
3.3.10.3	Spectrophotometric determination of iron (II) ions with 2,2'-bipyridyl (Fresenius-Schneider)	305
3.3.10.4	Spectrophotometric determination of total iron with 2,2'-bipyridyl	307
3.3.10.5	Spectrophotometric determination of total iron with thioglycolic acid	308
3.3.10.6	ICP-AES (see Section 3.3.12)	309
3.3.11	Manganese	309
3.3.11.1	Direct determination of manganese by means of atomic-absorption analysis	309
3.3.11.2	Manganese determination with the graphite tube technique (Furnace method)	310
3.3.11.3	Spectrophotometric determination as permanganate following oxidation by peroxodisulphate	310
3.3.11.4	ICP-AES (see Section 3.3.12)	313
3.3.12	Atomic-emission spectrometry with inductively coupled plasma (ICP-AES, see also Chapter 2)	313
3.4	Trace substances (inorganic) (For ICP-AES determination of 24 elements see Section 3.3.12)	325
3.4.1	Trace detection of elements in parallel by emission spectrography survey analysis (see also Chapter 2)	325
3.4.1.1	Concentration by trace precipitation	325
3.4.1.2	Concentration by extraction	327
3.4.2	Aluminium	328
3.4.2.1	Direct determination by means of atomic-absorption analysis	329
3.4.2.2	Aluminium determination with the graphite tube technique (Furnace method)	330
3.4.2.3	Spectrophotometric determination with eriochromcyanine R	331
3.4.3	Arsenic	333
3.4.3.1	Determination of arsenic using the hydride AAS technique	333
3.4.3.2	Spectrophotometric determination of total arsenic with silver diethyl dithiocarbamate	336
3.4.3.3	Iodometric determination of arsenic (III)	338
3.4.3.4	Separating arsenic (III) and arsenic (V)	340
3.4.4	Antimony	340
3.4.4.1	Determination of antimony using the hydride AAS technique	340
3.4.4.2	Spectrophotometric determination with rhodamine B	342
3.4.5	Beryllium	345

3.4.5.1	Direct determination by means of atomic-absorption analysis	345
3.4.5.2	Basis of the method of concentration	346
3.4.5.3	Beryllium determination with the graphite tube technique (Furnace method)	347
3.4.5.4	Spectrophotometric determination using chromazurol S	347
3.4.6	Lead	349
3.4.6.1	Spectrophotometric determination of lead with dithizone	350
3.4.6.2	Direct determination by means of atomic-absorption analysis	352
3.4.6.3	Basis of the method of concentration	353
3.4.6.4	Lead determination with the graphite tube technique (Furnace method) . . .	354
3.4.6.5	ICP-AES see Section 3.3.12	354
3.4.7	Cadmium	354
3.4.7.1	Direct determination by means of atomic-absorption analysis	355
3.4.7.2	Cadmium determination with the graphite tube technique (Furnace method)	355
3.4.7.3	Spectrophotometric determination of cadmium with dithizone	356
3.4.7.4	ICP-AES see Section 3.3.12	358
3.4.8	Chromium	359
3.4.8.1	Direct determination by means of atomic-absorption analysis	359
3.4.8.2	Total chromium	360
3.4.8.3	Determination of hexavalent chromium	361
3.4.8.4	Chromium determination with the graphite tube technique (Furnace method)	361
3.4.8.5	Photometric determination of total chromium using diphenyl carbazide . . .	362
3.4.8.6	ICP-AES (see Section 3.3.12)	366
3.4.9	Germanium	366
3.4.9.1	Determination of germanium by emission spectrography	366
3.4.9.2	Determination of germanium using graphite-tube AAS technique	367
3.4.10	Cobalt	368
3.4.10.1	Spectrophotometric determination as thiocyanate/tetraphenyl arsonium complex	368
3.4.10.2	Direct determination of cobalt by means of atomic-absorption flame analysis	370
3.4.10.3	Cobalt determination with the graphite tube technique (Furnace method) . .	371
3.4.10.4	ICP-AES see Section 3.3.12	371
3.4.11	Copper	371
3.4.11.1	Direct determination by means of atomic-absorption flame analysis	372
3.4.11.2	Copper determination with the graphite-tube technique (Furnace method) .	372
3.4.11.3	Spectrophotometric determination using NaDDTC	373
3.4.11.4	ICP-AES see Section 3.3.12	375
3.4.12	Molybdenum	375
3.4.12.1	Spectrophotometric determination as a molybdenum (V) thiocyanate complex	375
3.4.12.2	Direct determination of molybdenum by means of atomic-absorption flame analysis	378
3.4.12.3	Principle of the method of extractive concentration	379
3.4.12.4	ICP-AES see Section 3.3.12	379
3.4.13	Nickel	380

3.4.13.1	Spectrophotometric determination with diacetyl dioxime (dimethylglyoxime)	380
3.4.13.2	Direct determination by means of atomic-absorption flame analysis	383
3.4.13.3	Method with concentration	384
3.4.13.4	Nickel determination with the graphite tube technique (Furnace method)	385
3.4.13.5	ICP-AES see Section 3.3.12	385
3.4.14	Mercury	385
3.4.14.1	Mercury AAS with cold vapour method	386
3.4.15	Selenium	388
3.4.15.1	Determination of selenium using the hydride AAS technique	389
3.4.15.2	Spectrophotometric determination of selenium with o-phenylenediamine	391
3.4.16	Silver	393
3.4.16.1	Direct determination of silver by means of atomic absorption flame analysis	393
3.4.16.2	Silver determination with the graphite tube technique (Furnace method)	396
3.4.16.3	Spectrophotometric determination with dithizone	396
3.4.16.4	ICP-AES (see Section 3.3.12)	399
3.4.17	Thallium	399
3.4.17.1	Direct determination of thallium by means of atomic-absorption analysis	401
3.4.17.2	Thallium determination with the graphite tube technique (Furnace method)	401
3.4.17.3	Determination of thallium by inversion voltammetry	402
3.4.17.4	Determination of thallium with X-ray-fluorescence analysis	403
3.4.18	Titanium	403
3.4.18.1	Photometric determination of titanium	403
3.4.18.2	ICP-AES (see Section 3.3.12)	406
3.4.19	Uranium (see also Section 3.7)	406
3.4.19.1	Fluorimetric determination of uranium in a sodium fluoride/alkali carbonate melt	407
3.4.20	Vanadium	409
3.4.20.1	Direct determination of vanadium by means of atomic absorption analysis	409
3.4.20.2	Concentration: Principle of the method of extractive concentration	410
3.4.20.3	Vanadium determination with the graphite tube technique (Furnace method)	411
3.4.20.4	ICP-AES (see Section 3.3.12)	411
3.4.21	Zinc	412
3.4.21.1	Spectrophotometric determination with dithizone	412
3.4.21.2	Direct determination by means of atomic-absorption analysis	415
3.4.21.3	Zinc determination with the graphite-tube technique (Furnace method)	415
3.4.21.4	ICP-AES (see Section 3.3.12)	416
3.4.22	Tin (Sn)	416
3.4.22.1	Turbidimetric determination with nitrophenol arsonic acid (iP no AAS facilities are available)	416
3.4.22.2	Direct determination of tin by means of atomic-absorption analysis	418
3.4.22.3	Determination of tin using the AAS hydride technique	419
3.4.23	Zirconium (Zr)	420
3.5	Undissociated substances (for H ₂ S see also Sections 3.1 and 3.6)	420
3.5.1	Boron compounds	420
3.5.1.1	Spectrophotometric determination with 1,1'-dianthrimide	421

3.5.1.2	Spectrophotometric determination with azomethine-H	423
3.5.1.3	Volumetric determination following distillation	425
3.5.1.4	Extraction of boron	427
3.5.1.5	ICP-AES (see Section 3.3.12)	428
3.5.2	Silicic acid	428
3.5.2.1	Spectrophotometric analysis with ammonium molybdate	428
3.5.2.2	Gravimetric determination as silicon dioxide (silica)	431
3.6	Gaseous Substances	432
3.6.1	Sampling and gas-chromatographic analysis	432
3.6.2	Carbon dioxide (see also Chapter 1 and Section 3.2)	438
3.6.2.1	Direct titration with sodium hydroxide solution	439
3.6.2.2	Alternative: Gas diffusion method	441
3.6.2.3	Back-titration method for the determination of "free, dissolved carbon dioxide"	442
3.7	Radioactivity measurements in water (see also Chapter 2)	444
3.7.1	General	444
3.7.1.1	General guidelines	444
3.7.2	α -activity	445
3.7.2.1	Direct measurement of radon 222	447
3.7.2.2	Radium 226	452
3.7.2.3	De-emanation of water sample (isolation of radon 222)	457
3.7.3	Measurement of β -activity of water samples	457
3.7.3.1	Analysis of radioactive strontium and barium in water samples	460
3.7.3.2	Rapid method of estimating strontium 90 content in water	464
3.7.4	Other radionuclides in water (General analytical information)	464
3.7.5	Measurement of radionuclides in water	465
3.7.5.1	Radionuclide determination in water	466
3.7.5.2	Total activity or individual nuclide determination	466
3.7.5.3	Criteria governing the selection of the detection method	467
3.7.5.4	Modern measuring instruments for determining total activity?	468
3.7.5.5	Detection limit in theory and practice	470
3.7.5.6	Notes on measurement	471
4	Organic Parameters	477
4.1	Overall organic parameters	477
4.1.1	TOC/DOC (Total Organic Carbon/Dissolved Organic Carbon)	477
4.1.2	Oxidizable Organic Substances	480
4.1.2.1	Oxidizability	481
4.1.2.2	Chemical oxygen demand (COD)	484
4.1.3	Biochemical oxygen demand (BOD)	488
4.1.4	UV absorption	494
4.1.5	Determination of organically bound halogens as overall parameters (EOX/AOX)	495
4.1.6	Cyanide	501
4.1.6.1	General	501
4.1.6.2	Total cyanide	502

4.1.6.3	Spectrophotometric method of analysis using barbituric acid-pyridine in the distillate	505
4.1.6.4	Volumetric analysis using silver nitrate	506
4.1.6.5	Easily released cyanide	507
4.1.6.6	Spectrophotometric analysis using barbituric acid-pyridine	509
4.1.7	Detergents (surfactants)	509
4.1.7.1	Determination of total detergents (surfactants)	509
4.1.7.2	Photometric determination of anionic detergents (surfactants) with methylene blue (Methylene blue active substances, MBAS)	510
4.1.7.3	Determination of nonionic detergents (surfactants)	512
4.1.7.4	Cationic detergents (surfactants) after ion exchange	517
4.1.8	Determination of hydrocarbons (Oil and greaselike extractable substances)	518
4.1.8.1	Gravimetric determination following extraction with n-hexane	519
	Appendix 1 to Method 4.1.8.1 (Extraction with n-hexane)	
	Appendix 2 to Method 4.1.8.1 and to Appendix 1	
	Appendix 3 to Method 4.1.8.1 and Appendix 1	
4.1.8.2	Determination of hydrocarbons by infrared intensity spectroscopy	524
4.1.8.3	Determination of hydrocarbons (measurement of UV fluorescence)	533
4.1.9	Phenol (phenol index)	536
4.1.9.1	Determination of phenol-type substances which are capable of coupling, in natural waters, with p-nitroaniline	537
4.1.9.2	Phenol index with 4-aminoantipyrine without extraction after steam distillation	538
4.1.9.3	Phenol index with 4-aminoantipyrine after extraction and also if necessary after distillation	539
4.1.9.4	Separation by gas chromatography of phenol-type substances including halogenated phenols (see Section 4.2)	540
4.1.10	Nitrogen compounds	540
4.1.11	Organic acids	543
4.1.11.1	Determination of organic acids which are volatile with steam	543
4.1.11.2	Quantitative analysis of organic acids after separation by column chromatography	544
4.1.11.3	Analysis of organic acids using gas chromatography	546
4.1.12	Isolation and measurement of humic substances	547
4.1.13	Urochrome	549
4.2	Organic compounds	552
4.2.1	Polycyclic aromatic hydrocarbons	552
4.2.1.1	Detection of polycyclic aromatic hydrocarbons using thin-layer chromatography	552
4.2.1.2	Determination using high pressure liquid chromatography	554
4.2.2	Determination of phenols in water (see also Section 4.1.9)	555
4.2.3	Determination of aromatic hydrocarbons, kerosene, heating oil, diesel oil or petrol (gasoline) etc. in water	559
4.2.4	Systematic determination of highly volatile halogenated hydrocarbons (HHC) in water samples using gas chromatography	565

4.2.5	Determination of nitroaromatics and higher-boiling halogenated compounds in water	572
4.2.6	System of determination of organochlorine pesticides, organophosphorus pesticides and triazines in water	579
4.2.7	System for the determination of phenylurea and herbicidal carbamates in water	586
4.2.8	System for the determination of phenoxyalkane carboxylic acids in water	587
4.2.9	Determination of pesticides in water by gas chromatography according to the methods of the Deutsche Forschungsgemeinschaft (German Research Society GRS)	589
4.2.10	Organophosphorus pesticides, thiophosphoric acid esters, chlorinated hydrocarbons and triazine herbicides	593
	Appendix to 4.2.9 and 4.2.10	
4.2.11	Gas chromatography head-space analysis	598
4.2.12	Determination of plasticizers in water	603
4.2.13	Determination of antioxidants in water	607
4.2.14	Enzymatic determination of urea	611
5	Biological Analysis	615
5.1	Significance of biological and ecological investigations when evaluating the quality of flowing water	615
5.1.1	Significance of worm eggs in waste water, sewage sludge, surface water, swimming-pool water, drinking water and process water	616
5.1.2	A clear classification of water quality was published in 1985 by the West German organization "Länderarbeitsgemeinschaft Wasser" – LAWA (Water Study Group of the German Federal States)	617
5.2	Microbiological water analysis	623
5.2.1	General remarks	623
5.2.2	Microorganisms in water	623
5.2.3	Direct counting of germs	624
5.2.4	Indirect methods of counting germs	624
5.2.5	Indicator germs	625
5.2.6	General requirements for microbiological work	628
5.2.7	Taking and transporting water samples for microbiological investigations	629
5.2.8	Performing the microbiological analysis of the water	631
5.2.8.1	Determining the total colony counts	631
5.2.8.2	Detection of <i>Escherichia coli</i> and coliform bacteria	633
5.2.8.3	Detection of faecal streptococci	638
5.2.8.4	Detection of sulphite-reducing, spore-forming anaerobes	639
5.2.8.5	Detection of <i>Pseudomonas aeruginosa</i>	640
5.2.8.6	Occurrence, significance and detection of sulphate-reducing bacteria	641
5.2.8.7	Autotrophic microorganisms in water	642
5.2.8.8	Sulphur bacteria	646
5.2.8.9	Distribution of worm parasites	648

5.2.9	Preparation of culture solutions and culture media	664
5.2.10	Prepared culture media	680
5.2.11	Detection reagents for biochemical reactions	681
5.2.12	Work sheets for microbiological water analysis	683
5.2.12.1	Sheet 1 – Taking and handling samples	683
5.2.12.2	Sheet 2 – Determining the colony count	685
5.2.12.3	Sheet 3 – Detection of <i>Escherichia coli</i> and coliform bacteria	687
5.2.12.4	Sheet 4 – Detection of faecal streptococci, <i>Pseudomonas aeruginosa</i> and sulphite-reducing <i>Clostridia</i>	689
5.2.12.5	Sheet 5 – Cleaning with sterilization	691
5.3	Biological toxicity tests	693
5.3.1	Bacterial inhibiting tests	693
5.3.1.1	Respirometric measurements	694
5.3.1.2	Test using <i>Pseudomonas fluorescens</i>	696
5.3.2	Fish test for sewage	699
6	Evaluation of Analysis Data	703
6.1	Introduction to statistical evaluation	703
6.2	Applications of statistical methods in water analysis	705
6.2.1	Calibration	705
6.2.2	Calibration when using new methods of analysis	705
6.2.3	Calibration in routine analysis	708
6.2.4	Detection limit and determination limit	710
6.2.5	Blank values	712
6.2.6	Standard addition	713
6.2.7	Matrix effects	713
6.2.8	Comparison of analytical methods	714
6.2.9	Optimizing analytical methods	716
6.3	Quality control	716
6.3.1	Internal quality control	716
6.3.2	External quality control	718
6.4	Data evaluation	718
6.4.1	Univariate statistical evaluation	719
6.4.2	Bivariate statistical evaluation	719
6.4.3	Multivariate statistical investigations	720
6.4.3.1	Principal component analysis	720
6.4.3.2	Cluster analyses	721
6.4.3.3	Multidimensional discriminatory analysis	722
6.5	Time-series analyses	722
6.6	Technical advice	724
6.7	Assessment of water analysis findings	724
6.7.1	WHO Guidelines for drinking water quality (1984)	725

6.7.2	Directive of the Council of the European Communities on the quality of water for human consumption	735
6.7.3	Federal Republic of Germany: Recommendations on halogenated hydrocarbons	752
6.7.4	Treatment of surface water to obtain drinking water	752
6.7.5	Waste water	758
6.7.5.1	Stipulations applying to the discharge of industrial sewage	758
6.7.6	Requirements to be satisfied by bathing waters	759
6.7.6.1	Quality requirements for bathing water	761
6.7.7	Substances used for treating drinking water	766
6.7.8	Concluding remarks	777
7	Subject Index	779