6.3.2 城市生活污水回用于火电厂生产用水要达到的处理程度

从上述对火电厂水的用途、用水量及各种不同用水水质的分析可以看出，目前火电厂用水量最大的是冷却水，其次是冲灰水。污水回用首先就要考虑能否用于这两方面。用于冲灰水在我国已有成功的经验。但用于循环冷却水仅见少量研究报道。借鉴国外的发展经验，结合我国的实际情况及目前的污水处理技术，污水回用于火电厂循环冷却水是可行的。首先分析生活污水的水质及经处理后的情况。

表 6-12 生活污水及常规处理后的水质特性

水质参数	原污水	出水水质	
		一级	二级
BOD[mg/L]	300	100	30
COD[mg/L]	480	220	40
SS[mg/L]	230	100	26
浊度 (JU)	250	150	50
磷 [mg/L]	12	9	6
大肠菌 [MPN/1mL]	50×10^4	15×10^4	2.5×10^4
氨氮 [mg/L]	21	20	20
SO_4 [mg/L]	168	-	-
注： MPN：最大可能数；JU：杰克逊单位			

经对比分析可知，生活污水经常规处理后还不能满足火电厂循环冷却水的水质要求，但由于现代水处理技术的发展，各种深度处理技术可以将污水进一步得到净化，使其所含污染物质浓度大为降低[176-178]，表 6-13 为各种深度处理技术组合后处理污水水质的情况[173][174]。

从表 6-13 可以看出，污水经深度处理后，特别是几种深度处理工艺组合处理后，水质得到了明显的改善。基本上可以满足循环冷却水的要求。在美国科罗拉多州的普林斯顿建成采用生活污水生物滤池二级处理的出水，深度处理后回用于电厂冷却塔补充水，它的处理流程为[175]：

生物滤池出水 ⟶ 石灰混凝澄清 ⟶ CO_2 再碳酸化 ⟶ 沉淀 ⟶ 过滤 ⟶ 活性碳吸附 ⟶ 供电厂使用。

表 6 -13 污水深度处理预计水质情况

二级处理	深度处理	BOD [mg/L]	COD [mg/L]	浊度 JU	磷酸盐 [mg/L]	SS [mg/L]	NH_3-N [mg/L]
高负荷生物滤池	F	10-20	35-60	6-15	20-30	10-20	20-30
	C, S	10-15	35-55	2-9	1-3	4-12	20-30
	C, S, F	7-12	30-50	0.1-1	0.1-1	0-1	20-30
	C, S, F, AC	1-2	10-25	0.1-1	0.1-1	0-1	20-30
	C, S, NS, F, AC	1-2	10-25	0.1-1	0.1-1	0-1	1-10
常规活性污泥法	F	3-7	30-50	2-8	20-30	3-12	20-30
	C, S	3-7	30-50	2-7	1-3	3-10	20-30
	C, S, F	1-2	25-45	0.1-1	0.1-1	0-1	20-30
	C, S, F, AC	0-1	5-15	0.1-1	0.1-1	0-1	20-30
	C, S, NS, F, AC	0-1	5-15	0.1-1	0.1-1	1-10	
注：C, S-混凝, 沉淀；F-混合滤料过滤；AC-活性炭吸附；NS-氨吹脱；JU：杰克逊单位							

因此，就目前污水处理技术的发展状态看，污水经深度处理后，基本上可以满足火电厂循环冷却水的条件。由于各地区新鲜水质不同，及水污染的加剧等，许多采用新鲜水作循环冷却水的电厂也会出现诸如结垢、腐蚀、微生物繁殖等问题。目前火电厂循环冷却水的趋势也是朝能用低水质水源方向发展。

6.4 本章小结

本章提出了用生物的方法，以硫铁矿为原料制取铁系净水剂。本方法勿需用高温、高压及有毒催化剂，工艺简单；且用的主要原料硫矿铁，来源广，价格低廉，因此，本文研究的混凝剂成本低，初步估计为 PFS 价格的 75%左右。实验室小型试验表明：用自制混凝剂处理电厂灰水，不仅使灰水的 SS 和 pH 降低，达到排放要求，同时也可降低灰水中其它有害成分，如 F^-等。因此，自制混凝剂是一种多功能混凝剂。与 PAC 及 PFS 对比试验表明，用自制混凝剂处理灰水效果较 PAC 好，生成的矾花大，且沉降速度快，但比 PFS 稍差，这主要与自制混凝剂所含成分有关。用自制混凝剂适合处理高 pH、高 SS 的火电厂灰场排水，处理后的排水可达到排放和回用要求。

影响粉煤灰沉降的因素主要与粉煤灰的物理特性有关；在本章中通过对不同电厂粉煤灰进行沉降试验研究发现，不同电厂的粉煤灰，沉降特性不同，因此，在采

用浓缩池处理冲灰水时，应针对不同的电厂作沉降试验，确定设计参数，才能使浓缩池达到最好的处理效果。本文对粉煤灰的沉降规律作了一些理论上的分析，并结合试验作了一些探索。因为沉淀特性是确定设计浓缩池参数的重要依据，而粉煤灰的沉降性能是随粒径分布、浓度等因素而变化的，因此，在用浓缩池对灰水进行处理时，只有重视粉煤灰的沉降试验，考虑到不同电厂的具体情况，才能使设计的浓缩池达到最好的处理效果。

随着水资源的短缺、水污染的加剧，火电厂寻求新的水源也迫在眉睫。本章通过对火电厂各种不同用途水质及污水处理后预计水质分析，认为利用污水作为缺水地区的水源是可行的；但就目前污水处理技术的发展水平及电厂所能承受的费用看，污水回用于电厂主要可用在冷却水和冲灰用水，而这两部分水又正是火电厂用水量最大的。采用污水回用技术，可以缓解一些地区因为缺少水源而限制电力工业发展的状况。但同时必须注意几个问题，一是处理的费用问题，从表 6-13 可以看出污水深度处理后基本可以满足火电厂循环冷却水的需要，但需要几种深度处理工艺组合才能达到较好的水质，这无疑增加用水的费用，当电厂花在处理污水的费用超过其它水源的费用时，污水回用就失去了吸引力。因此寻找价廉、简单而又能保证处理水质的污水处理技术仍是今后最主要的研究方向。二是生活污水中含有大量的洗涤剂、表面活性物质等而现有的污水处理技术对这些物质的去除效果并不理想，这样会引起冷却塔产生大量的泡沫，影响冷却效果。如污水消毒不严，病菌在冷却塔中飞溅，引起周围人群的健康问题。污水中氮、磷造成微生物、藻类在冷却塔、管道中大量繁殖引起堵塞等问题。这些都要求人们进一步研究，以期获得更好的效果。总之，从可持续性发展眼光看，污水是一种资源，只要我们转变观点，合理、科学、有效地利用它，就会有助于经济的发展，同时也保护了我们赖于生存的环境。

第7章 结论与展望

水污染加剧和水资源日趋匮乏是目前全球共同关心的问题，其中重金属污染由于其长期毒性和不可降解性，更引起人们的重视。开发在线、实时、便携的环境检测仪器，及时准确地提供环境污染数据，是一项迫在眉睫的任务，也是当今仪器分析界的一个热门研究课题。

对于重金属离子的检测，传统的方法都是在实验室进行。虽然有种种现场实时检测仪器研究的报道，但由于重金属离子特殊性，还未见有较成熟的技术问世。

本文首先建立了流动注射荧光测定装置，对流动注射装置的性能进行了试验，得到其运行的优化参数；其次筛选出适合重金属离子如 Cu^{2+}、Cd^{2+}及 Zn^{2+}等离子检测的荧光试剂，用流动注射-荧光方法测定上述几种重金属离子得到的检测限要低于德国饮用水标准，线性范围要宽于用常规的荧光测定方法。

采用流动注射-停留方法，实测出了荧光试剂 Newport Green™ 与 Ni^{2+}的化学反应动力学曲线，并推导出了反应动力学方程，进而提出并验证了 Ni^{2+}非稳态测定方法，利用 Zn^{2+}及 Ni^{2+}与 Newport Green™ 反应速度的不同，提出了可以同时测定 Zn^{2+}及 Ni^{2+}的方法，并推导了计算两者浓度的关系式。

将数理统计中的最小二乘法用于同时测定三个或四个重金属离子，在合适的荧光试剂条件下，能够较好地预测水溶液中金属离子的浓度。

本文将流动注射分析方法和激光激发荧光光谱技术结合起来，融合进光纤维传导，CCD 摄象机等高新技术用于现场实时检测重金属离子仪器的研制。对 Cu^{2+}、Cd^{2+}、Zn^{2+}及 Ni^{2+}等重金属离子试验研究结果表明：用该仪器所得到的检测限要低于德国饮用水标准，且线性范围宽。整个仪器装置简单，携带方便，特别适合用于海港，湖泊，及矿山排水等水体中重金属离子浓度的实时检测。

本文对样品的微滤膜处理也进行了试验研究，微滤膜是用于有机物污染较轻的样品处理的较好方法。

在上述一系列试验研究的基础上，开发出用于实时检测水体中的金属离子的传感器，试验研究结果表明：该装置用于测定水中金属离子浓度，得到的检测限要远远低于德国饮用水标准。

就目前研究的情况看，该仪器适合用于海港，湖泊，及矿山排水等有机物污染较轻的水体中重金属离子浓度的实时检测，对于含有机物浓度较高的废水中重金属的测定，由于有的有机物本身具有荧光特性，所以对准确测定有一定的影响，解决办法是要寻找出合适的样品处理方法。即能去除干扰测定的有机物，又不至于损失要测定的重金属离子，同时方法还应简单，适合于在线检测等，在这方面还应继续研究探索。

本文针对火力发电厂排水对环境产生污染及目前水资源日趋紧张的状况，利用生物方法及价廉的原材料----硫铁矿开发出处理火电厂冲灰水的铁系净水剂。该方法工艺简单、无需用有毒催化剂、无需高温、高压，成本低廉，可以废物利用，利用该水处理剂处理火电厂高浊度、高 pH 的废水具有完全可以满足排放和回用要求。

对电厂粉煤灰的沉降性能进行了研究，指出：粉煤灰的物理特性对粉煤灰在水中的沉降类型会产生很大的影响。在设计浓缩池时，不同电厂，不同类型的粉煤灰应采用不同的计算面积的方法，如 Kynch 理论或固体通量法等，才能使浓缩池达到较好的浓缩效果，本文的研究成果对改进电厂灰水浓缩池的设计，提高浓缩效率提供了有用的试验研究数据。

本文对火电厂各种水的用途，用水量及对水质的不同要求进行了分析研究。认为处理后的城市污水回用于电厂用水量最大的循环冷却水和冲灰水是可行的，但还需继续进行研究，以期以最低的处理费用获得最好的水质满足火电厂的需要。

参考文献

[1] Deutschland Umweltamt. www.weltbundesamt, 1999.

[2] Eupopean Commission. Water Quailty Directive 98/83/EU,1998.

[3] G. Schwedt. *Taschenatlas Der Umweltchemie.* Georg Thieme Verlag, Stuttgart-New York, 1996.

[4] Unibersity of Washington. www.washington.edu, 1999.

[5] J. W. Moore. S. Ramamoorthy. *Impact of Heavy Metals in Natural Waters, in: Springer Series on Environmental Managment: Heavy Metals in natural Waters- Applied Monitoring and Impact Assessment.* Springer Verlag, Berlin, 1984.

[6] S. Leary. *Instrumrentelle Analytik: Grundlagen, Geraete, Anwendungen.* Springer-Verlag, Berlin, Heidelberg, 1996.

[7] 北京大学化学系仪器分析教学组. *仪器分析教程*. 北京大学出版社，北京，1997.

[8] G. Schwedt. *Taschenatlas der Analytik, 2. Auflage*，Springer-Verlag, 1997.

[9] C. Vandecasteele，C. B. Block. *Modern Methods for Trace Element Determination.* John Wiley & Sons, Chichester，Springer-Verlag, Berlin, Heidelberg，1993.

[10] A. Skoog. *Principles of Instrumental Analytics.* Saunders College Publishing, Fort Worth, 1992.

[11] G. B. Levy. Spectroscopy instrumentation at Pittcon'97. *International Laboratory 11*, 1997.

[12] H. JM. *Journal of Analytical Atomic Spectrometry 14*, 137-146, 1999.

[13] A. K. W. Galas. Determination of ten elements in the spice samples using an inductively coupled plasma-atomic emission spectroscopy. *Chemia Analityczna 42*, 403-409, 1997.

[14] S. R. Sutton K, Caruso JA. *Journal of Chromatography A 789*, 85-126, 1997.

[15] S. F. M. J. Duane. On-site environmental water analyses by ICP-MS. *Science of the Total Environment 172*, 133-144, 1995.

[16] H. J. S. K. Grunke. R. Wennrich and U.Franck. Determination of traces of heavy metals(Mn, Cu,Zn, Cd and Pb) in microsamples of teth material by ETV-ICP-MS, *Fresenius Journal of Analytical Chemistrz 354*, 633-635, 1996.

[17] A. Klockenkamper R. *X Ray Spectrometry 25*, 156-162, 1996.

[18] S. N. Barbeira PJS. *Fresenius Journal of Analtical Chemistry 361*, 507-509, 1998.

[19] W. Slavin. A Comparison of Atomic Spectroscopic Analytical Techniques, *Spectr. Intern. 4*, 22-27, 1991.

[20] K. Dittrich. *Flammenlose Atomabsorptionsspektometrie, n: Analytiker Taschen buch*, Springer Berlag, Berlin, 1989.

[21] L. Bouvier. Direct Determination of Traces of Ag, Cd, Pb. Bi, Cr, Mn, Ni, Li, Be, CU and Sb in Environmental Wates and Geological Materials by Simultaneous Multi-Element Graphit Furnance Atomic Absorption Spectrometry with zeeman-Effect Background Correction,

Talanta 42, 269-221, 1995.

[22] M. Siaka. Evaluation of some digestion methods for th determination of heavy metals in sediment samples by Flame-AAS. *Analytical Letters 31*, 703-718, 1998.

[23] Xiaonan Dong. Determination of Chromium, Copper, Iron, Manganese and Lead in Human Hair by Graphite Furnace Atomic Absorption Spectrometry, *Analytical Sciences 14*, 785-789, 1998.

[24] R. Klockenkaemper. Totalreflexions-Roentgenfluoreszenz-Prinzipien und Anwendungen,*GIT Fachz. Lab. 33 33*, 441-447, 1989.

[25] J. R. Klockenkaemper, Knoth. A. Prange, H. Schwenke. Total-Reflection x- Ray Fluorescence Spectroscopy. *Anal. Chem. 64*, 1115A-1123A, 1992.

[26] W. Jin. Simultaneous determination of seven toxic trace and/or ultratrace metals in environmental plants by differential pulse voltammetry without change of solution and electrode. *Analytical letters 30*, 1235-1254, 1997.

[27] Oi-Wah Lau. Determination of zinc in environmental samples by anodic stripping Voltammtry. *Analytica Chimica Acta 376*, 197-207, 1998.

[28] Mary-Luo. Tercier-Waeber. Real-time Continuous Mn(II) Monitoring in lakes Using a Novel Voltammetric in Situ Profiling System. *Environ. Sci. Technol. 32*, 1515-1521, 1998.

[29] E. Mueller-Ackermann. *Konzeption eines faseroptischen sensorarrays zur simultanen bestimmung von schwermetallen in waessriger loesung*. Dissertation, Muenchen ,1996.

[30] 水池敦著，李记欣译. *无机痕量分析的富集技术*. 中国环境科学出版社，北京，1986.

[31] H. Nakagawa K, Ogata T, kato T, Nakata Y, Akatsuka K. *Analytical Sciences 14*, 317-320, 1998.

[32] B. Monardes. *Experimente et considerationes de coloribus P III*. Exp. X Genevee, page 78 1680.

[33] S. G.G.. Philos. Trans. Roz. Soc.. London, 142, 463, 1852.

[34] R. L. Bowman. Fluorescence News 8(1), 1974.

[35] T. Foerster. Fluoreszenz organischer Verbindungen. Vandenhoek & Ruprecht, Goettingen 1951

[36] 李昌厚，孙吟秋等. 荧光分析仪器及市场分析. 分析仪器 17, 27-29, 1995.

[37] 陈国珍等. *荧光分析法*. 科学出版社，北京，1990.

[38] J. H. A. R.M Linares, A. M. Afonso and V.Gonzalez. Quantitative analasis of biogenic amines by high-performance thin-layer chromatography utilizing a fibre optic fluorescence detector. *Analytical Letters 31*, 475-489, 1998

[39] 潘祖华,姚礼峰等. 荧光光度法测定肠虫清片中的阿苯达唑. *分析试验室* 18(1),1999.

[40] 高建华，林鹏，陈彬. 荧光分光光度法直接测定炎痢停片中的甲氧苄氨嘧啶和氟哌酸, *分析实验室* 18(1), 1999.

[41] 姜聚会,赵录庆等. 锰(II)-邻菲罗啉-曙红-Triton-100 体系荧光. *分析试验室* 18(1), 1999.

[42] H. M. Widmer. Total Analysis Systems. *Analytical Methods and Instrumentation 2*, 1-2, 1995.

[43] W. I. Bailey, Kotz, A. L., P. L. McDaniel, D. M. Parees, F. K. Schweighart and H. J. Yue. *Anal. Chem(*65), 752-758, 1993.

[44] H. L. C. Meuzelaar. Distributed Analysis and Virtual Laboratories: Are the Walls of the Analytical Laboratory Coming Down?, *Field Analytial Chemistrz and Technology* 1, 249, 1997.

[45] R. Niessner, J. Gottlieb, H. Hotzl, K. Huck. Guest editorial, Field *Analytical Chemistry And Technology 2*, 193-193, 1998.

[46] O. S. W. Vladimir M. Mirsky. Microsensors and Microsystems. *Mikrochimica Acta 131*, 1-1, 1999.

[47] Z. Lin. Second order fiber optic chemical sensors based upon membrane sepaation and spectroscopic. University of Washington, dissertation, U. M.I, 300N. Zeeb Rd. Ann Arbor. MI 48106 1994.

[48] 王柯敏. *光化学传感器理论与方法*. 湖南教育出版社，长沙 1995.

[49] 靳伟，张志鹏等著. *导波光学传感器:原理与技术*. 科学出版社，北京 1998.

[50] L. Cheng. CRC Hand BOBOk of Organic Analytical reagents. CRC Press ,Inc

[51] J. M. B. Yunlong Wang, Sean P. Mcmaughan and Donald r. Bobbitt. Optical Fiber-based sensor for calcium using hydrophobicallz associated calcein and laser-induced fluorescence detection. *Microchemical journal 50*, 385-396, 1994.

[52] M. M. J. Buerck, K. Kraemer. Field experiments with a portable fiber-optic sensor system for monitoring hydrocarbons in water. *Field Analytical Chemistrz and Technology 2*, 205-219, 1998.

[53] M. Y. Wang, Baten, Sean P. McManughan and Donald R. Bobbitt. Optical fiber-based sensor for calcium using bydrophobically associated calcein and laser-induced fluorescence detection. *Microchemical Journal 50*, 385-396, 1994.

[54] 唐登志，董慧茹. 光纤技术在分析仪器中的应用. *分析仪器 7-12*, 1991.

[55] E. J. Poziomek. Fiber optic sensors for environmental monitoring. *Chemoshpere* 33, 1151-1174, 1996.

[56] K. M. Leonard, Development of a fiber-optic chemical sensor for multicontaminant monitoring of environmental systems. *Sensors and Actuators B 1-3*, 1995.

[57] E. A. Mendoza, R. A. Lieberman, D. Robinson, Sol-gel-based fiber optic and integrated optic chemical sensors for environmental monitoring and process control, *Proceedings of the SPIE The International Society for Optical Engineering 3136*, 267-274, 1997.

[58] F. P. Milanovich. S. B. Brown, B. W. Colston, Jr., P. F. Daley. A fiber-optic sensor system for remote long-term monitoring of soil and groundwater contamination,Proceedings of the SPIE The International Society for Optical Engineering 2360, 98-100, 1994.

[59] F. P. Milanovich, D. G. Garvis, S. M. Angel, S. M. Klainer, L. Eccles. Remote detection of organochlorides with a fiber optic based sensor.Analytical Instrumentation 15, 137-147, 1986.

[60] E. A. Mendoza, R. A. Lieberman, D. Robinson, Sol-gel-based fiber optic and integrated optic chemical sensors for environmental monitoring and process control.Proceedings of the SPIE

The International Society for Optical Engineering 3136, 267-274, 1997.

[61] D. Lipson, K. D. McLeaster, B. Cohn, R. E. Fischer. Drilled optical fiber sensors: a novel single fiber sensor.Proceedings of the SPIE The International Society for Optical Engineering 1368, 36-43, 1998.

[62] R. A. Lieberman, D. J. Ferrell, E. M. Schmidlin, S. J. Syracuse, A. N. Khalil, E. A. Mendoza, Reversible sensor for carbon monoxide based on dye-doped porous fiber optic fiber.Proceedings of the SPIE The International Society for Optical Engineering 1996, 324-331, 1996.

[63] R. C. Jorgenson, S. S. Yee. A fiber-optic chemical sensor based on surface plasmon resonance. *Sensors and Actuators* B 213-220, 1993.

[64] M. A. Hughes, A. D. Drake. A fiber optic chemical sensor.Proceedings of the IEEE 21st Annual Northeast Bioengineering Conference 76-77, 1995.

[65] K. Goswami, J. A. Kennedy, D. K. Dandge, S. M. Klainer, J. M. Tokar. A fiber optic chemical sensor for carbon dioxide dissolved in sea water.Proceedings of the SPIE The International Society for Optical Engineering 1172, 225-232, 1996.

[66] 范世福. 光纤在分析技术中的应用和进展. *分析仪器 1*, 1-6,1991.

[67] 霍希琴. 有机分子选择性光化学传感器及其在环境分析中的应用. *上海环境科学*, 12(8),25-28,1993.

[68] 王柯民敏，周雷激等. 一种新的基于折射率变化的光化学传感器. *高等化学学报*, 1999.

[69] R. R.Czolk, H. J. Ache. Optical sensor for determination of heavy metal ions..Altlastensanierung 90, Int. Kfk/TNO Kongr., 3rd 1939-1940, 1991.

[70] S. M. Barnard, D. R. Walt. A fibre-optic chemical sensor with discrete sensing sites. *Nature* 353, 338-340, 1991.

[71] R. J. Czolk R, Ache HJ. *Sensors and Actuators B 7*, 540-543, 1992.

[72] M. R. Delmarre D, Bied Charreton C, Pansu RB. Journal of Photochemistrz and Photobiology A Chemistrzy 124, 23-28, 1999.

[73] A. A. Vaughan, R. Narayanaswamy. Optical fibre reflectance sensors for the detection of heavy metal ions based on immobilised Br-PADAP.*Sensors and Actuators* B 1-3, 1998.

[74] N. R. Kuswandi B. *Analytical Letters 32*, 649-664, 1999.

[75] C. P. Malcik N. Sensors and Actuators B C hemical 39, 386-389, 1997.

[76] O. O. Malcik N, Ozser ME, Caglar P, Bushby L, Vaughan A, Kuswandi B, Narayanaswamy R. Sensors and Actuators B Chemical 53, 211-221, 1998.

[77] G. T. A. Kovacs, C. W. Storment, S. P. Kounaves. Microfabricated heavy metal ion sensor.Sensors and Actuators B 41-47. 1995.

[78] S. H. L. Gregory A. Theriault. Remote in-situ detection of heavy metal contamination in soils using a Fiber Optic Laser Induced Breaddown Spectroscopy(FOLIBS) System, SPIE Prodeedings, pp. 75-83 (1995).

[79] U. Jianzhong. Optical fibre fluorosensor for cadmium with diethylaminoethyl-sephades as a substrate. *Analyst 120*, 453-455, 1995.

[80] E. Mueller-Ackermann. A fiber optic sensor array for the fluorimitric detection of heavy metals. *Analytical Methods and Instrumentatation 2*, 182-189, 1995.

[81] R. H. Y. Kurauchi, N. Egashira, K. Ohga. Fluorimetric Determination of Zinc, Cadmium and Gallium ions with a fiber-optic sensor having a pyridoxal isomer-modified chitosan/agarose Gel as a sensing Probe. *Analytical sciences 8*, 837-840, 1992.

[82] Y. A. Satoshi Sasaki, Makiko Dejima, Yoshiko Arikawa and Isao Karube. A Fluorescence-based sensors for ammonium and Nitrate. *Analytical letters 31*, 555-567, 1998.

[83] W.-H. L. Ying Wang, Ke-Min Wang, Guo-Li Shen, Ru-Qin Yu. Fluorescence optical fiber sensor for tetracycline.*Talanta 47*, 33-42, 1998.

[84] C. F. J. Segura Carretero A, Pereiro R, Sanz Medel A. Talanta 49, 907-913, 1999.

[85] L. M. Fabbrizzi L, Pallavicini P, Sacchi D, Taglietti A. *Analyst 121*, 1763-1768, 1996.

[86] O. S. Wolfbeis. Fluorescence Spectroscopy New Methods and Applications. Springer-Verlag, Berlin Heidelberg New York London Paris Tokyo 1993.

[87] 杨经国等, 用于多组分同时测定的流动注射-CCD 阵列探测分光光度装置研究. *光谱学与光谱分析*, 19(2),1999.

[88] G. Gauglitz. Optical Sensor Array Based on Microtiterplate dimensions. *Mikrochim Acta* 131, 9-17, 1999.

[89] Harald Prestel. Detection of heavy metals in water by fluorescence spectroscopy: on the way to a suitable sensor system.. Fres. J. Anal. Chem. Submitted, 2000.

[90] H. E. Ruzicka J. Flow injection analysis. Wiley, New York 1988.

[91] E. H. Hansen. Flow Injection Analysis: A complementary or Alternative Concept to Biosensors. *Talanta 41*, 939-948, 1994.

[92] P. R. Companeoe. Flow-injection determination of zinc by fluorescence spectrometry. *Analytica Chimica Acta 255*, 325-328, 1991.

[93] S. Johnson. Determination of copper in sea water using a flow-injection method with chemiluminescence detection. *Analytica Chimica Acta 266*, 345-351, 1992.

[94] B. H. K. Schugerl, H. Jurgens, T. Kullick, R. Ulber, B. Weigal. Chanllenges in integrating biosensors and FIA for on-line monitoring and control. *Biotechnology-and Appllied microbiology 14*, 21-31, 1996

[95] A. L. John Mortensen, Andrey ipatov. A flow injection system based on chalcogenide glass sensors for the determination of heavy metals. *Analytica Chimica Acta 403*, 273-277, 2000.

[96] Y. S. Y. Hayashibe, K. Oguma. Sensitive and precise analytical methods for the determination of impurities in hydrometallurgical zinc refining by utilizing flow-injection tehnique.*Spectroscopy Instrumentation Analytical-sciences 45*, 1-18, 1996.

[97] www.globalfia.com, 1999.

[98] R. E. M. a. J. G. D. Beverly F. Johnson. Reduction of Injection Variance in Flow-Injection Analysis. *Talanta 39*, 35-44, 1992.

[99] w. f. c. Alitea Instruments USA INC, 1999.

[100] O.-K. Watanabe-K, Itagaki-M. Fluorometric flow injection determination of average copper

valence in yttrium system superconductor using micro-amounts of sample. *Spectroscopy Instrumentation Analytical-sciences 45*, 341-346, 1996.

[101] M. S. B. Truis Smith-Palmer, Tadeusz Cynkowski and Leonidas G. Bachas. Fluorescence-based flow-injection determination of biotin and biotinylated compounds. *Analytica Chimica Acta 279*, 287-292, 1993.

[102] M. M. Jose, L. F. C. Lima, Ana P. M. M.O. Pinto. Determination of total nitrogen in food by flow injection analysis(FIA) with a potentiometric differential detection system. *Fresenius J Anal Chem 364*, 353-357, 1999.

[103] N. Hiroko Wada. Flow-injection fluoreimetric determination of traces of calcium in brine. *Analztica Chimica Acta 261*, 275-279, 1992.

[104] N. Porter. The use of a pH gradient in flow-injection analysis in differentiating zinc and cadmium in a binary mixture. *Analytia Chimica Acta 281*, 229-242, 1993.

[105] P. W. Alexander. Potentiometric Flow injection detection of copper(II) with a Graphite Carbon Electrode. *Analytical letters 31*, 13-25, 1998

[106] D. W. Hui Chen, Taicheng An and Yanjun Fang. The determination of Mn(II) in water by reversed flow injection spectrophotometry. *Analytical Letters 32*, 787-797, 1999.

[107] M. F. Mousavi, A. R. Jahanshahi. Flow injection spectrophotometric determination of trace amounts of seleniium. *Talanta 46*, 1011-1017, 1998.

[108] T. Perez-Ruiz, V. Tomas and C. Sidrach De Cardona. Flow-injection Fluorimetric determination of Trimeprazine and Trifluoperazine in Pharmaceutical Preparations. *Talanta 40*, 1361-1365, 1993.

[109] Ren-Min Liu. Simultaneous determination of Multicomponents by flow Injection Analysis. *Talanta 40*, 511-514, 1993.

[110] H. E. Ruzicka J. *Flow injection analzsis*. Wiley, New York 1988.

[111] F. R. Compac, J. Guiteras, M. D. Prat. Flow injection method for the fluorimetric determination of Zn with 8(Benzenesulphonamido) Quinoline. *Mikrochimica Acta 124*, 73-79, 1996.

[112] A. Gahr. *Untersuchungen zum oxidativen Abbau von Pestiziden sowie die Entwicklung von Bestimmungsverfahren von anorganischen Flogeprodukten am Beispiel des Bromats*. Herbert Utz Verlag Wissenschaft, Muenchen 1997.

[113] B. A. D. James N. Demas, Patricia B. Coleman. Oxygen Sensors based on Luminescence Quenching.*Analytical Chemistry News & Features* 793A-799A, 1999.

[114] K.-w. P. Ki-Won Cha. Determination of iron(III) with salicylic acid by th fluorescence quenching method. *Talanta*

[115] Z. Zhang. Determination of iron (III) by fiber optic kinetic method with flow injection analysis and fluorescent probe. *Chemical Journal of Chinese universities 17*, 535-538, 1996.

[116] Merck. Katalog, 1999.

[117] Molecular Probe Catalog 1999

[118] M. Probes. BTC-5N Heary Metal Indicator. www.probes.com, Molecular Probes, Inc. ,Eugene,

Oregon USA , 2000.

[119] *Harald Prestel. Detection of heavy metals in water by fluorescence spectroscopy: on the way to a suitable sensor system.. Fres. J. Anal. Chem. Submitted, 2000.*

[120] *A. Taglauer. Fluorimetrischer Nachweis von wassergeloesten Schwermetallionen zur Entwicklung eines Sensorsystems. Dissertation TU Muenchen 1999.*

[121] *Fluka. cataloge, 1999* ,

[122] 中国环境监测总站. 环境水质监测质量保证手册. 化学工业出版社. 北京，1984

[123] S. Li. Lead determinaton at the ppb level using stopped-flow FIA. Talanta 42, 1857-1865, 1995.

[124] *V. C. Moreno, I. Gcmez, M. Garcja-Vargas, Multicomponent Analysis by Flow injetin using a partial least-squares callibration Method. Simultaneous Spectrophotometric Determination of Iron. Cobalt and Nickel at Sub-ppm Levels. Analyst 121, 1609-1612, 1996*

[125] *F. J. O. Hernandez, A. I. Jimenez. multicomponent flow injection based analysis with diode array detection and partical least squares multivariate calibration evaluation. Rapid determination of Ca(II) and Mg(II) in waters and dialysis liquids. Analytica Chimica Acta 320, 177-183, 199.*

[126] *A. M. Garcia Rodriguez, J. M. Cano Pavon and C. Bosch Ojeda. Simultaneous Spectrophotometric Determination of Cadmium. Copper and Zinc, Talanta 40, 1861-1866, 1993.*

[127] *F. J. R. D. Bautista, A. I. Jimenez and J. J. Arias. Multicomponent Analysis: comparison of Various Graphical and Numerical Methods .Talanta 40, 1687-1694, 1993.*

[128] *X. R. Antonio Velasco, Manuel Silva and Dolores Perez-Bendito. Simultaneous Kinetic determination of phenols by use of the kalman filter,, 1993*

[129] L. F. Capitan-Vallvey, I. de Orbe, R. Avidad. Simultaneous determination of the colorants tartrazine. ponceau 4R and sunset yellow FCF in foodstuffs by solid phase spectrophotometry using partial least squares multivariate calibration, *Talanta 47,* 861-868, 1998.

[130] *Abduerrezzak Bozdogan. Simultaneous Determination of Acetaminophen and Caffeine In Tablet Preparations by Partial Least-Squares Multivariate Spectrophotometric Calibration .Talanta 39, 977-979, 1992*

[131] *Y. Ni. Simultaneous determination of copper, cadmium and nickel by ratio derivative polarography. Talanta 47, 137-142, 1998.*

[132] *X. G. Yongnian Ni. Simultaneous spectrophotometric determination of mixtures of food colorants. Analytica Chimica Acta 354, 163-171, 1997.*

[133] 陆晓华主编. *化学计量学.* 华中理工大学出版社，武汉，1997.

[134] M. D. F. L.F. Capitan-Vallvey, I. de Orbe, R. Avidad. Simultaneous determination of the colorants tartrazine. ponceau 4R and sunset yellow FCF in foodstuffs by solid phase spectrophotometry using partical least squates multivariate calibration, *Talanta* 47, 861-868, 1998.

[135] *Abduerrezzak Bozdogan. Simultaneous determination of acetaminophen and caffine in tablet preparations by partial leastsquares multivariate spectrophotometric calibration. Analyst 39, 977-979, 1992.*

[136] 颜杰，丁德荣等. 小波变换-偏最小二乘法及其在复方甲硝唑注射液分析中的应用.*分析测试学报* 19, 71-73, 2000.

[137] Y. W. Yongnian Ni. Simultaneous determination of mixtures of metal ions by complexometric titration and multivariate calibration. *Analytica Chimica Acta* 354, 233-240, 1997.niversities 17, 535-538, 1996.

[138] Z.-l. Fang. Trends of flow injection sample pretreatment approaching the new millennium. *Analytica Chimica Acta 400*, 233-247, 1999.

[139] Y.-Q. S. Qun Fang, Zhao-Lun Fang. Automated continuous monioring of drug dissolution process using a flow injection on-line dialysis sampling-solvent extraction separation spectrophometric system. *Fresenius J.Anal.Chen. 364*, 347-352, 1999.

[140] waternet.com/GetArticle.asp?Article=19051, 1999.

[141] J. W. Carnahan. Continuous Donnan Dialysis Sampler for Flame Atomic Absorption Spectrometry. *Applied Spectroscopy 35*, 447-449, 1981.

[142] T. R. Kissel. Chemical Enrichment and Exclusion with Ion Exchange Membranes. *Analytical Chemistry 44*, 2109-2111, 1972.

[143] K. M. S. Taguchi, Y. Sengoku and I. Kasahara. A transparent membrane filter for the solid-phase specrophotometric determinaiton of trace cationic surfactant in water. *Analyst 124*, 1489-1492, 1999.

[144] S. Ripperger. *Mikrofiltration mit Membranen: Grundlagen. Verfahren, Anwendungen*, VCH Verlagsgesellschaft mbH, Weinheim 1992.

[145] S. C. J. Julia Khandurina, Larry C. Waters, Robert S. Foote, and J Michael Ramsey. Microfabricated Porous Membrane Structure for Sample Concentration and Electrophoretic Analysis. *Analytical Chemistry 71*, 1815-1819, 1999.

[146] M. Elimelech. Colloidal Fouling of Reverse Omosis Membranes: measurements and Fouling Mechanisms. *Environ. Sci. Technol. 31*, 3654-3662, 1997.

[147] K. M. S. Taguchi, Y. Sengoku and I. Kasahara. A transparent membrane filter for the solid-phase spectrophotometric determination of trace cationic surfactant in water. *The Analyst 124*, 1489-1492, 1999.

[148] K. Hwang, K.. *membranes in Separations. Techniques in Chemistry, Vol. II*, John Wiley & Sons.

[149] J. G. A. Bitter, *Transport Mechanisms in Membrane Separation Process*. Plenum Press, New York 1991.

[150] A. M.-D. P.ortega-Barrales, M.I. Pascual-Reguera, L.F. Capitan-Vallvey, Solid-phase spectrophotomeric determination of trace amounts of hydrazine at sub-ng/ml level. *Analytica Chimica Acta 353*, 115-122, 1997.

[151] A. Ensafi. Flow injection spectrophotometric determination of Nickel by complexation and

factorial design optimization method. *Analytical Letters 32*, 111-122, 1999.

[152] M. Zander. *Fluorimetrie*. Springer-Verlag, Berlin, Heidelberg, New York 1981.

[153] H.-G. L. Th. Roch, Th. Meyer. Laser-induced fluorescence analysis of PAC-doped model oils on alumina. sand and soil surfaces, *SPIE Proceedings*. pp. 453-461 (95).

[154] 马兴孝. *激光化学*. 中国科学技术大学出版社，合肥，1990.

[155] www.lasercomponents.de, 2000.

[156] . T. I. Nir. CCD Detectors Record Multiple Spectra Simultaneously. *Laser Focus World August* 111-120, 1991.

[157] M. V. D. Falkin. Charge coupled device forspectroscopy. *Spectroscopy Europe 5*, 16-18, 1993.

[158] J. M. Brian L. Mcclain, and Dor Ben-amotz. Optical Absorption and Fluorescence Spectral Imaging Using Fiber Bundle Image Compression. *Appllied Spectroscopy 53*, 1118-1122, 1999.

[159] 杨经国等. 用于多组分同时测定的流动注射-CCD 阵列探测分光光度装置研究. *光谱学与光谱分析* 19 (3)，1999.

[160] Alitea USA. www.flowinjection.com

[161] 袁果. 燃煤电厂灰水排放及治理. 火电厂废水综合治理学术会议论文集. 1995，8. 27-28.

[162] 有马启、用村学造, 郭丽华, 任玉岭译. *生物净化环境技术*. 化学工业出版社, 1990, 10.

[163] [美]V L Snoeyink, D Jenkins 著, 蒋展鹏, 刘希曾译. *水化学*, 中国建筑工业出版社, 1990. 10.

[164] 胡家峻, 周群英. *环境工程微生物学*. 高等教育出版社, 1988.

[165] 马青山, 贾瑟, 孙丽珉编著. *絮凝化学和絮凝剂*. 中国环境科学出版社, 1988. 3.

[166] 许保玖. *当代给水与废水处理原理讲义*. 清华大学出版社，1983.

[167] 李燕城. *水处理试验技术*. 中国建筑工业出版社, 1989.

[168] 吕梁等. *粉煤灰性能与利用*. 武汉水利电力大学，1995.

[169] 火电厂排水水质分析方法编委会. *火电厂排水水质分析方法*. 水利电力出版社，1986.

[170] 马逢时等. *数理统计*. 高等教育出版社，1989.

[171] 宋珊卿. *动力设备水处理手册（第 2 版）*. 中国电力出版社，1997.

[172] 能源部西安热工研究所. *热工技术手册（电厂化学）*. 水利电力出版社，1993.

[173] 施雯均. *火力发电厂水质净化*. 水利电力出版社，1990.

[174] [美]EJ 米德尔布鲁特斯编，周全等译. *水的回用*. 中国建筑工业出版社，1986.

[175] 王宝贞主编. *水污染控制工程*. 高等教育出版社，1990.

[176] 希利 I 舒瓦尔主编，邱中峙等译. *水的再净化与利用*. 中国建筑工业出版社，1986.

[177] 张杰等. 提高城市污水再生水水质的研究. *中国给水排水*，1997.

[178] [美]RT 卡尔普等著, 张中和等译. *城市污水高级处理手册*. 中国建筑工业出版社，1986.

[179] Zhangjingdong, Harald Prestel, Achim Gahr and Reinhard Niessner.Development of a FIA System for the Measurement of Heavy Metals Using a Fibre Optic Chemical Sensor Based on

Laser-induced Fluorescence, SPIE proceeding. The International Society for Optical Engineering, 06.2000.

[180] Harald Prestel, Zhang Jingdong, Achim Gahr and Reinhard Niesner. On-line-detektion wassergeloester Schwermetallemittels Schwermetallemittels lserinduzierter Fluoreszenzspektroskopie, Conference poster,DECHEMA-Symposium: Natural attenuation,10.1999, Frankfurt/Main.

[181] 张敬东 张家骅. 分煤灰在水中沉降规律研究. *电力环境保护*, Vol. 15 1999.

[182] 张敬东. 关于城市生活污水处理后回用于火力发电厂生产用水的探讨. *工业水处理 3*, 1999.

[183] 张敬东. 用硫铁矿制备 PTX 混凝剂处理燃煤电厂冲灰水的研究. *工业水处理 3*, 1997.

[184] 张敬东, 黄种买. 硫铁矿生物法制酸及其应用研究. *环境科学与技术 3*, 1996.

[185] 张敬东, 张家骅. 污水处理技术的新发展. *环境技术 6*, 1997.

[186] 张敬东, 胡将军. 用硫铁矿制备铁系净水剂的研究. *污染防治技术 2*, 1996

[187] 国家环保局“水和废水监测分析方法”编委会. 水和废水检测分析方法. 中国环境科学出版社, 1989

读博士期间发表的论文

1. Zhangjingdong, Harald Prestel, Achim Gahr and Reinhard Niessner. Development of a FIA System for the Measurement of Heavy Metals Using a Fibre Optic Chemical Sensor Based on Laser-induced Fluorescence,SPIE proceeding,The International Society for Optical Engineering,06.2000
2. Harald Prestel, Zhang Jingdong, Achim Gahr and Reinhard Niesner. on-line-Detektion wassergeloester Schwermetallemittels laserinduzierter Fluoreszenzspektroskopie, Conference poster, DECHEMA-Symposium:Natural Attenuation, 10.1999, Frankfurt/main.
3. 张敬东, 张家骅. 分煤灰在水中沉降规律研究. *电力环境保护*, Vol.15 1999(3)
4. 张敬东, 关于城市生活污水处理后回用于火力发电厂生产用水的探讨. *工业水处理*, 1999（3）
5. 张敬东, 用硫铁矿制备 PTX 混凝剂处理燃煤电厂冲灰水的研究. *工业水处理*, 1997（3）（被“环境科学文摘”1998（1）摘录；被美国“化学文摘”摘录：V127- N25-Dec.22,1997, P924）
6. 张敬东, 黄种买. 硫铁矿生物法制酸及其应用研究，*环境科学与技术*. 1996（3），（被“环境科学文摘”1997（3）摘录）
7. 张敬东, 张家骅. 污水处理技术的新发展. *环境技术*, 1997（6）
8. 张敬东, 胡将军. 用硫铁矿制备铁系净水剂的研究. *污染防治技术*, 1996
9. 张敬东. 煤炭微生物法脱硫研究，中国青年学者论环境(上册)、中国环境科学出版社，1996 年 7 月
10. 张敬东, 水质监测不能轻视的一步—水样采集. *云南环境科学*, 1996（2）
11. 郭银松, 黄种买, 张敬东, 磁处理对水体生物性质影响的研究. *武汉水电大学学报*, 1997（6）

获奖情况:

1. 用硫铁矿制备 PTX 混凝剂处理燃煤电厂冲灰水的研究，武汉水利电力大学科技进步理论成果一等奖，证书号：WS—99—L1005—D1，奖励日期：1999 年 3 月,独立完成
2. 清镇发电厂冲灰水回收系统阻垢技术，武汉水利电力大学科技进步一等奖，证书号：WS98-y105-D2，奖励日期：1998 年 3 月，第二完成人

致　谢

首先我要衷心感谢我的导师郭生练教授，能成为郭教授的学生，亲耳聆听他的教诲，感受他不落俗套的人格魅力，是我的荣幸。导师渊博的知识、对科学前沿敏锐的洞察力、严谨的治学态度、科学的思维方法、对事业孜孜不倦的追求和创新意识以及对学生关心、帮助、真诚待人的崇高品德，将永远影响着学生。他不仅是学业上的导师，同时也是人生道路的指引者。对导师的崇敬和感谢，远非言语所能表达的。

我要特别感谢德国慕尼黑工业大学水环境研究所的 R. Niessner 教授提供给我在他所里工作的位置，使我有幸接触到世界领先水平的科研课题，利用最先进的仪器、采用最先进的方法，顺利完成了我的研究工作和论文。他给予我的学术指导和帮助将使我收益终生。他风趣的谈吐、广泛精深的学识、平易近人态度，以及不分种族，一视同仁的工作作风会使我永远难忘。

在德国学习工作期间，水环境研究所的 Dr. Baumann, Dr. A.Gahr, Herr H.Prestel, Herr Schneider, Herr Dolinger 等等都给了我极大的帮助，使我能够在很短的时间内适应异国他乡的生活，顺利地展开工作。在此我要向他们表示衷心的感谢。

我非常感谢在我攻读博士学位期间，环境工程教研室的黄种买教授、张家骅教授、胡将军副教授及其他老师都给予我的无私的帮助。

我还要感谢我的父母双亲，婆婆公公、姐姐妹妹，他们在我遇到困难时帮助我， 在我沮丧时鼓励我，他们的支持和激励是我完成博士学业的动力。

我要深深感谢的是我的丈夫叶春松先生，没有他对我的容忍、耐心、理解、爱护、支持、帮助和鼓励，我很难完成自己的学业；我的儿子叶鹏昊，在我远离他的两年里，能够健康地成长，不断地进步，是我能够安心工作和学习的重要因素，我也要深深地感谢他！

最后谢谢所有关心、支持并给予我帮助的人们！

INSTITUTE OF HYDROCHEMISTRY
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March 24, 2000

Letter of recommendation for Mrs. Jingdong Zhang

To whom it may concern:

Mrs. Jingdong Zhang has been working at the Institute for Hydrochemistry of the Technical University of Munich for about one year. Mrs. Zhang has consistently carried out excellent research work and has contributed significantly to our ongoing effort to succeed in the development of a heavy metal sensor using laser-induced fluorescence spectroscopy and flow injection analysis.

Based on literature studies dealing with flow injection analysis, analytics and membrane technology, Mrs. Zhang successfully designed and optimized a FIA system for heavy metal sensing using fluorescence spectroscopy for detection. Her tasks also included the evaluation of sample pretreatment by membrane filtration and fluorimetric measurement of metal ions such as Cu, Zn, Cd, Ni and Be. Mrs. Zhang has succeeded in bringing these experiments to completion. She also studied the influence of system parameters in order to evaluate the method by statistical calculations. Behind fluorescence spectroscopy she also made a lot of experience in instrumental operation of atomic absorption spectroscopy and the measurement of total organic carbon.

The results of these investigations were published for the SPIE conference in Wuhan this year. Mrs. Zhang also took part at the DECHEMA symposium "natural attenuation" in Frankfurt last year, attended the lecture on "Water Chemistry" of Prof. Niessner and gave an oral presentation in the institute. During her stay at the institute Mrs. Zhang improved her German language skills to a very high level.

In the course of this work Mrs. Zhang has demonstrated that she is a highly motivated and productive experimental scientist. She collaborates very well with others, and has become an invaluable member of our research team. In summary, I strongly recommend Mrs. Zhang for any position she pursues.

Sincerely,

Prof. Dr. Reinhard Niessner

Curriculum vitae

Reinhard Niessner, Full Professor for Hydrogeology, Hydrochemistry and Environmental Analytical Chemistry at the Technical University of Munich, Germany, was born in 1951. He received the diploma degree in chemistry from the University of Freiburg in 1976 and PhD from the University of Dortmund 1981. After becoming a lecturer in 1985, he served from 1986 to 1989 as a Professor for Inorganic and Analytical Chemistry at the University of Dortmund. Refusing several calls to different university and industry positions, he finally accepted 1989 a call for his current position in Munich.

His research interests are within Environmental Analytical Chemistry, especially devoted to applications of laser spectroscopy, chromatography, and immunoserological techniques. The main subjects of interest are aerosols, hydrocolloids and biofilms, within hydro- and atmosphere.

He received several international and highly prestigious awards, e.g. the Emanuel-Merck-Prize for Analytical Chemistry (1990), the Smoluchowski-Award for Aerosol Research of the Association for Aerosol Research (1991), the Fritz-Pregl-Medal of the Austrian Society for Analytical Chemistry (1996), and the Fresenius-Award for Analytical Chemistry of the German Chemical Society (2000).

Professor Niessner is serving in many national and international scientific organisations, e.g. within IUPAC as a titular member and the European Science Foundation. He is also within the board of directors of the Clean Air Commission of the German Engineers Association (VDI/DIN) and the Hydrochemical Division of the German Chemical Society.

He is currently an associated editor of the American journal „Analytical Chemistry“, and a member within the advisory or editorial board of „Analyst“, „Analytical Sciences“, “Mikrochimica Acta”, “Fresenius‘ Journal of Analytical Chemistry”, „Fresenius Environmental Bulletion“ and „Field Analytical Chemistry and Technology“, some years ago also within the board of „Aerosol, Science & Technology“.

Up to now 292 scientific publications under his authorship appeared in reviewed international scientific journals. Under his guidance 60 PhD and about 90 Diploma students have successfully received their academic qualification.