电厂灰场对地下水污染的数值模拟及污染预测
——以江苏徐塘电厂炮车灰场 F^- 污染为例

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摘要 以江苏徐塘电厂炮车镇灰场为例, 建立了炮车镇灰场及邻近地区地下水水质(污染)模型, 并选用灰渣溶滤后产生的 F-作为模拟因子, 对地下水水位变化和 F-浓度变化进行了数值模拟. 最后利用模型对地下水中 F-污染的范围和程度进行了预测. 结果表明, 模型可靠、合理、实用, 为建立灰场后所可能引起的对地下水污染的预测预报提供了科学手段.

关键词 地下水污染, 水质模型, 数值模拟, 污染预测, 电厂灰场.

1 研究区水文地质概况

徐塘电厂炮车灰场紧邻新沂市炮车镇居民区, 位于沂河冲积平原上, 地势平坦(图1、图2). 受灰场影响的含水层为全新统最上部一层厚约7m 的砂层, 下伏由粘土、亚粘土构成的隔水层. 地下水水位埋深1—2m, 主要接受大气降水、农用灌溉水入渗补给. 地下水自西北、东北向南流动, 水力坡度较平缓, 地下水的水化学类型为HCO_3-Ca型水. 当地地下水中F^-的背景值约为 0.20mg/L.

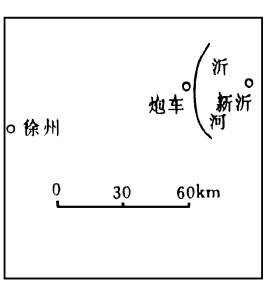

图1 研究区位置图

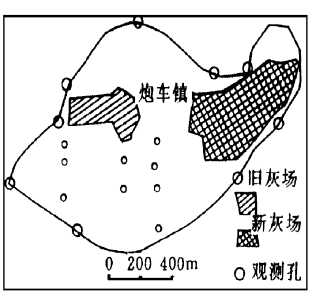

图2 研究区平面图

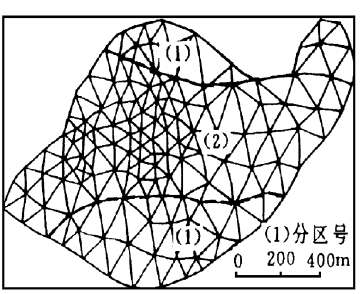

图3 计算区单元剖分图及参数分区图

2 数学模型及数值方法

研究地下水污染需要用2类偏微分方程来描述: 一个方程描述地下水的流动, 另一个方程描述污染物质(溶质)在地下水中的运移, 两者通过运动方程耦合起来. 通过水流方程及相应的初始条件和边界条件构成的地下水流模型[1]可以求出地下水的水位; 再通过地下水运动方程[1], 求出地下水流的实际平均流速, 代入污染物质(溶质)运移方程, 构成污染物质(溶质)运移模型[2], 求解该模型, 即可得到研究区内地. 下水中污染物质的浓度分布.

水流模型应用 Galerkin 有限元法求解. 水流方程为非线性方程, 需用迭代法[3]求解.

运动方程应用 Yeh 的方法求解[4].

求解溶质运移模型时为避免数值弥散, 采用特征有限元法进行求解[5].

3 数值模拟及模拟结果

根据自然条件, 评价需要和现有观测孔的

* 收稿日期: 1997-04-17

位置, 圈定计算区的面积约1. 15km^2(图2) .

根据水位和水质观测资料, 所有边界均作一类边界处理.

采用3角形单元, 线性插值, 将计算区划分成为225个单元, 132个结点. 已填灰渣坑及计划用来填灰渣 的水塘内部划分了相当数量的单元(图2) . 根据地貌、岩性特征, 将计算区分为紧邻及远离古河道的2个区, 每一区的内部假设是均质各向同性的(图3) .

采用1995-04-05的实测资料作为初始流场和初始浓度场(图4、图5) . 模拟时间从1995-04-27至同年08-03, 共分7个时段, 步长为12—22d不等. 对全部10个观测孔各时刻的实测地下水位和 F^-浓度均进行了拟合比较, 结果令人满意

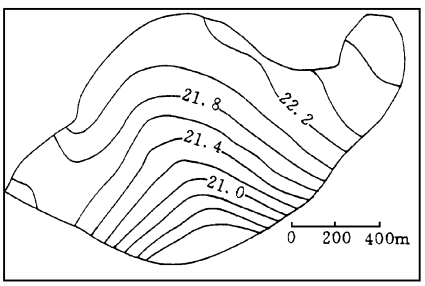

图4 计算区初始流场图(1995-04-05)

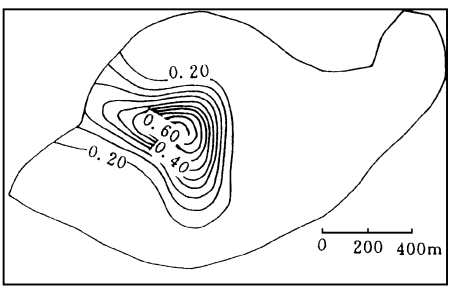

图5 计算区 F^-初始浓度场(1995-04-05)

表1 水位观测值与计算值对比/m

时段	观测孔19		观测孔19		观测孔21		观测孔45		观测孔44		观测孔43		观测孔73	
	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算
1	22. 09	22. 08	22. 16	22. 02	21. 87	21. 85	21. 99	21. 93	22. 19	22. 10	22. 16	21. 95	22. 17	22. 12
2	21. 99	22. 03	21. 96	21. 97	21. 96	21. 81	27. 79	21. 80	21. 49	21. 57	21. 86	21. 87	22. 07	22. 07
3	21. 79	21. 96	21. 86	21. 91	21. 77	21. 77	21. 69	21. 76	21. 49	21. 54	21. 66	21. 84	21. 97	22. 05
4	21. 89	21. 95	21. 86	21. 90	21. 87	21. 74	21. 79	21. 70	21. 69	21. 68	21. 86	21. 79	22. 07	21. 99
5	21. 89	21. 94	21. 76	21. 88	21. 87	21. 71	21. 89	21. 81	21. 89	21. 80	21. 96	21. 73	22. 17	22. 10
6	22. 09	22. 13	21. 96	22. 07	21. 97	21. 91	21. 89	21. 85	21. 99	21. 84	22. 06	21. 95	22. 17	22. 15
7	21. 99	21. 99	21. 86	21. 94	21. 76	21. 80	21. 69	21. 79	21. 79	21. 78	21. 86	21. 88	21. 97	22. 09

表2 F^- 浓度观测值与计算值对比/mg•L^{-1}

时段	观测孔17		观测孔19		观测孔21		观测孔45		观测孔44		观测孔43		观测孔73		观测孔75	
	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算	观测	计算
1	0. 61	0. 58	0. 29	0. 26	0. 20	0. 15	0. 29	0. 23	0. 44	0. 40	0. 29	0. 21	0. 68	0. 64	0. 03	0. 02
2	0. 24	0. 20	0. 20	0. 14	0. 15	0. 11	0. 24	0. 23	0. 44	0. 36	0. 31	0. 25	0. 20	0. 15	0. 43	0. 40
3	0. 20	0. 17	0. 31	0. 26	0. 44	0. 42	0. 19	0. 15	0. 44	0. 41	0. 20	0. 15	0. 28	0. 25	0. 19	0. 15
4	0. 90	0. 86	0. 38	0. 36	0. 30	0. 27	0. 95	0. 91	1. 40	1. 37	1. 10	1. 05	0. 90	0. 86	1. 10	1. 05
5	0. 60	0. 59	0. 38	0. 37	0. 39	0. 35	0. 58	0. 54	0. 62	0. 60	0. 58	0. 51	0. 60	0. 55	0. 38	0. 33
6	0. 46	0. 44	0. 38	0. 35	0. 30	0. 25	0. 54	0. 48	1. 10	1. 07	0. 46	0. 41	0. 32	0. 25	0. 74	0. 70
7	0. 47	0. 43	0. 25	0. 22	0. 25	0. 18	0. 42	0. 39	0. 80	0. 76	0. 56	0. 46	0. 36	0. 31	0. 80	0. 75

(表1、表2) . 模拟值与观测值拟合良好. 应用试估-校正法和单纯形法通过模型识别求得的参数列于表3中.

为了进一步考核模型, 把前面反求出的参数和相应的数学模型模拟1995-08-03—08-29的水位及浓度变化. 各观测孔各时段水位计算

值与观测值的最大绝对误差为0.25m，平均绝对误差为0.11m；相应的 F^- 浓度计算值与观测值的最大绝对误差为0.098mg/L，平均绝对误差为0.05mg/L. 所有结果显示2者基本一致. 图6、图7为模拟所得的计算区流场图和 F^- 浓度等值线图.

表3　参数值

分区号	渗透系数 / m•d^{-1}	给水度	弥散度/m α_L	弥散度/m α_T	降雨入渗系数
1	12.15	0.10	3.9	0.6	0.1
2	18.03	0.12	5.0	0.8	

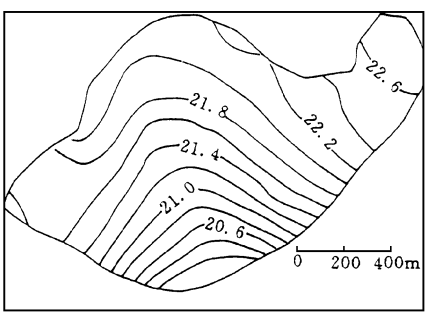

图6　模拟所得的地下水流场(1995-08-29)

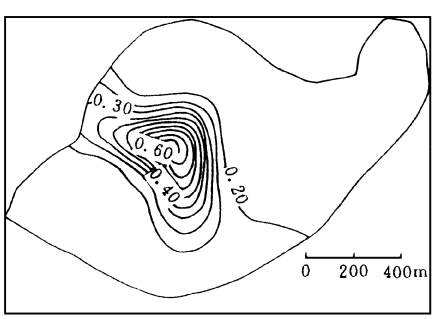

图7　模拟所得的 F^- 浓度等值线图(1995-08-29)

4　模拟结果分析

模拟再现了1995-04—1995-08新沂市炮车镇灰场浅层潜水水位和 F^- 浓度场变化的全过程，有一定的时间长度，情况也比较复杂.

拟合阶段与检验阶段各观测孔各时段水头拟合结果总平均绝对误差为0.15m，相应的 F^- 浓度总平均误差为0.015mg/L，结果令人满意(图6、7).

求得的参数与当地实际资料一致. 弥散度值当地虽无资料可对比，但与我国山东龙口[2]以及国外资料相比在数量级上也是一致的.

所得水头分布和 F^- 浓度分布清晰地显示出地下水位动态及 F^- 浓度逐渐增长并不断向下游扩散的情况，与实际情况一致(图6、7).

本文建立的模型合理，反映了研究区的主要因素，不仅能再现地下水水位动态和 F^- 浓度分布，还能反映抽水条件下，灰场所引起的 F^- 污染的演化和发展. 因此，它能为电厂贮灰场所引起的地下水中污染物的运移及其对环境影响的预测、预报提供科学手段.

5　污染预测

炮车镇西头的灰场早已填满并覆土还田. 按规划2000年起拟利用镇东北2个水塘作为新的贮灰场，由西向东逐步充填，计划2008年填满. 本文预报了新灰场启用后对地下水水质的影响.

根据徐塘电厂提供的有关未来灰渣的数据，假设现有地下水开采量不变，降水量采用多年平均降水量，运用所建模型进行了污染预测，结果显示新灰场起用后下游地下水中 F^- 浓度有所增高，并呈羽状向下游延伸(图8)，但增高量有限，只在新灰场中心附近出现 F^- 浓度超过1mg/L的情况(我国现有饮用水标准中对 F^- 的浓度要求小于1mg/L). 考虑到现有炮车镇灰场附近已观测到地下水中 F^- 浓度超过1mg/L的情况，多年后新灰场附近也可能出现类似情况，需要密切注意.

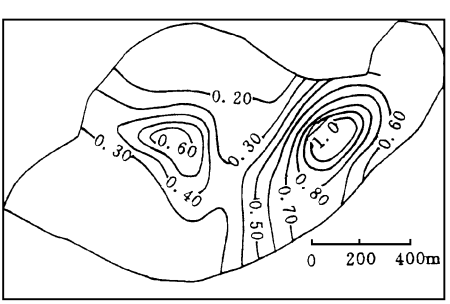

图8　预测的 F^- 浓度等值线图(2010-08-29)

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表5 各水样的致突变结果(MR 值)[1)]

水样	TA98				TA100			
	NF		RO		NF		RO	
	水样剂量/L·皿$^{-1}$	MR	水样剂量/L·皿$^{-1}$	MR	水样剂量/L·皿$^{-1}$	MR	水样剂量/L·皿$^{-1}$	MR
自来水	1	35.7	3	23.3	1	2.7	3	2.7
	0.5	15.5	1	7.5	0.5	2.3	1	1.9
	0.25	12.1	0.5	5.4	0.25	2.0	0.5	1.4
	r= 0.979		r= 0.9966		r= 0.9934		r= 0.9799	
膜[2)]进水	3	38.7	3	10.5	3	2.5	3	2.1
	1	16.6	1	8.6	1	2.0	1	1.7
	0.5	10.7	0.5	7.4	0.5	1.99	0.5	1.3
	r= 0.9999		r= 0.9734		r= 0.9929		r= 0.9188	
膜出水	5	1.18	5	1.5	3	1.4	3	1.8
	3	1.02	3	1.4	1	1.1	1	1.2
	1	0.97	1	1.0	0.5	0.9	0.5	0.95
	0.5	0.43	0.5	0.96				

1) 表中 r 为相关系数 2) 自来水经过活性炭柱和保安过滤器的预处理

表6 RO 与 NF 对离子的去除率比较/mg·L^{-1}

膜		K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	F^-	Cl^-	NO_3^-	SO_4^{2-}
RO	进水	4.453	12.56	37.70	9.123	0.0038	0.615	31.751	15.966	58.78
	出水	0.0397	0.3161	0.007	0.0187	0.000	0.107	0.843	0.221	未检出
	去除率/%	99.11	97.13	99.98	99.80	100	82.60	97.34	98.62	100
NF	进水	4.516	12.64	39.37	9.281	0.0153	0.562	33.403	8.138	67.26
	NF 出水	0.5376	1.413	0.1648	0.0631	0.000	0.100	2.448	0.276	0.263
	去除率/%	88.10	88.82	99.58	99.32	100	82.21	92.67	96.61	99.61

4 结论

(1) 同等压力下, NF 的产水量和回收率比 RO 大1倍, 脱盐率比 RO 低4%左右.

(2) NF 对 TOC 的去除率高于 RO, 对常规项目的去除率与 RO 差别不大. 2种膜对致突变物的去除率都很高. NF 作为饮用水的深度处理技术上是可行的.

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6 结语

新灰场建成后可能会引起炮车地区地下水中 F^- 浓度相应增高. 地下水一旦污染后, 治理非常困难, 而且灰场紧邻炮车镇居民区, 为了保证人民群众的安全, 有关部门必须对周围地下水 F^- 含量及其他可能的污染物进行定期监测, 一旦发现超标, 立即采取相应的措施.

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on *Pagrosomus major and Rhabdosargus sarba*. The acute toxicities of the four pollutants were in the sequence of isofenphos-methyl> Mn> Cu> methamidphos. Mn and methamidphos were equivalently toxic to *P. major and R. sarba*, Cu was almost equivalently toxic to them, while the 96h median lethal concentrations of isofenphos-methyl were 0.02mg/L for*P. major*, and 0.0014mg/L for*R. sarba*, respectively. The toxicity of isofenphos-methyl for *P. major* was 13 times higher than that for *R. sarba*. The toxicity of isofenphos-methyl were 174 times higher than that of methamidphos for *P. major*. The toxicity of isofenphos-methyl was 2500 times that of methamidphos for *R. sarba*. The additive toxicity of Cu-Mn and Cu-isofenphos-methyl for two species fishes was shown to be antagonistic, while that of methamidphos-isofenphos-methyl was synergism.

Key words: *P. major*, *R. sarba*, Cu, Mn, methamidphos, isofenphos-methyl, joint toxicity.

Microbial Treatment Technology for the Electroplating Wastewater. Wu Qianjing et al. (Chengdu Institute of Biology, Chinese Academy of Sciences, Chengdu 610041): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 47—50

This paper has reported the new technology of electroplating wastewater and sludge treated by microbies on the basis of fundamental research, experiment and pilot scale. The demonstration project built on Chengdu Jinjiang Electronic Machine Factory has got a good result. Since then, four processes whose treating capacity ranged from 1 to 175 tons/d in Chengdu Hong Guang Industry Limited Company, Chinese People Liberation Army 5701 Factory etc. were established. The processes have run steadily, safely and reliably for two years. The level of chromium, zinc, copper, nickle, cadmium, lead, COD, BOD, SS, pH, color degree and NH_3-N in effluent is below the national GB8978-88 discharge standard. The water of effluent can be reused, the recovery of heavy metal of sludge can reach above 85%.

Key words: microbe, electroplating wastewater, heavy metal, treatment technology, sludge, reused, recovery.

Denitrification of Landfill Leachate by *Thiobacillus denitrificans*. Koenig Albert (Dept. of Civil and Structural Eng., The Uni. of Hong Kong), Liu Ling hua (Water Quality Research Center, China Institute of Water Resources and Hydropower Research, Beijing 100044): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 51—54

The feasibility of nitrate removal from nitrified landfill leachate in reactors with different sulfur particle size was studied. The results indicate that ① the reactor with sulfur particle size of 2.8- 5.6 mm can effectively remove nitrate from nitrified leachate up to a concentration of 400 mg/L NO_3^--N at a hydraulic retention time of 5.71h; ② the minimum hydraulic retention time necessary for complete denitrification depends on sulfur particle size and influent nitrate concentration; ③ the maximum volumetric loading rate of NO_3^--N depends on sulfur particle size and is approximately 594, 278 and 175.4g/(m^3•d) for sulfur particle size of 2.8- 5.6mm, 5.6- 11.2mm and 11.2- 16mm, respectively; ④ the maximum area loading rate of NO_3^--N, approximately 0.68g/(m^2•d), appears to be the process limiting factor and is practically independent of sulfur particle size.

Key words: autotrophic denitrification, biofilm, *Thiobacillus denitrificans*, sulfur, landfill leachate, nitrate removal.

A Study on Treatment of Chemithermomechanical Pulping Wastewater with the New Technology by Combining ICZs and Activated Sludge Method. Chen Min (Guangdong Uni. of Tech., Environ. & Resource Eng. Dept., Guangzhou, 510090), Songnien Lou and H C laude Lavallée (Université du Québec à Trois-Rivières, Québec, Canada, G9A 5H7): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 55—58

It is investigated that the treatment of Chemithermomechanical Pulping (CTMP) wastewater with new technology by combining Zone of Biological Population selection (ICZs) and activated sludge method. The control of sludge bulking in activated sludge system of CTMP treatment with this technology is discussed. The three month experiments showed that the slowness of filamentous microorganism growth is achieved and the sludgebulking is controlled with ICZs pretreatment by controlling DO below 0.06 mg/L and pH 7- 7.6. The biological treatment system with combining ICZs and activated sludge method can obtain efficient treatment. Removal of BOD_5, COD and TSS is above 97%, 80% and 90% respectively. ICZs pretreatment can remove 49.0% - 62.5% BOD_5 and 18.5% - 21.9% COD with only 20 minutes of HRT.

Key words: activated sludge, chemithermomechanical pulping wastewater, sludge bulking control, filamentous microorganism, zone of biological population selection, BOD_5, COD, TSS.

Numerical Simulation and Prediction for

Groundwater Pollution near Waste Ash Ponds of Coal-fired Power Plant —— A Case Study for F^- Pollution in Paoche Ash Ponds of Xutang Power Plant, Jiangsu Province. LiLi, Hai Huang (Dept. of Earth Sciences, Nanjing University, Nanjing 210093), Fahua Zhu (Nanjing Environmental Protection Research Institute for Electric Power, Nanjing 210031): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 59—61

A 2-dimensional pollutant transport model for groundwater pollution in the aquifer near ash ponds of Xutang Coal-fired Power Plant was established in this paper, and selecting F^- as the simulating factor, the variations of groundwater hydraulic heads and F^- concentration were simulated. At last, the polluted area and pollution degree of F^- were predicted by the model. According to the simulating results, the model is reasonable, reliable and practicable. It provides a scientific method to predict the polluted area and pollution degree caused by the waste ash ponds.

Key words: groundwater pollution, pollutant transport model, numerical simulation, pollution prediction, coal-fired power plant.

A Study of Pulsed Corona Discharges for Methlene Chloride Destruction. Zheng Lei and Jiang Xuanzhen (Dept. of Chemistry, Zhejiang University, Hangzhou, 310027): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 62—64

in this paper, High voltage pulsed corona Discharges has been used for destruction of methlene chloride with concentration of 42.8μmol/L in air. Both positive and negative pulse generators were tested and found that the positive one can give much higher destruction efficiency than that on the nagetive one. The value of capacitors for pulse formation (C_p) and the material of electrodes also influence the destruction efficiency. A packed bed corona reactor with 2—3 mm spherical $BaTiO_3$ pellets as a catalyst was used in this experiments. Enhancement of CH_2Cl_2 destruction and the conversion of 90% were demonstrated. It may be attributed to the partial corona discharge induced by the contacted points between $BaTiO_3$ pellets, and then the density of corona was enchanced. The corona and catalyst combined technology gives a better destruction efficiency compared with that without $BaTiO_3$ catalyst.

Key words: pulse corona discharge, destruction, CH_2Cl_2, $BaTiO_3$.

Comparison of Effect for Removing Mutagens and Inoganic Ions in Tap Watar by Revese Osmosis and Nanofiltration. Li Lingzhi (Dept. of Chem., Pingdingshan Teachers College, Henan, 467002), Zhou Rong and Wang Zhansheng (Dept. of Environ. Eng., Tsinghua Uni., Beijing 100084): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 65—67

In order to get superior drinking water, tap water was treated respectively by reverse osmosis (RO) and nanofiltration (NF) in the laboratory. The removal effects of mutagens and ions by Ro and NF were compared. The Ames test results showed that both RO and NF could convert mutagenicity from positive to negative, while the ions removal effects of the RO and NF membranes are different, the removal rate of one-valence positive ions (Na^+, K^+) by NF is tenpercent lower than that by RO, the removal rate of two valence positive ions (Ca^{2+}, Mg^{2+}) is a little lower than that by RO. More ions which are beneficial to human health pass through nanofiltration mombrane into drinking water.

Key words: reverse osmosis, nanofiltration, advanced water, mutagens, inoganic ions, Ames test.

Study on Wet Desulphurization with Pyrolusite to Produce $MnSO_4 \cdot H_2O$ in Smelting Plant. Ning Ping, Sun Peishi et al. (Dept. of Environ. and Chem. Eng., Kunming University of Science and Technology, Kunming 650093): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 68—70

An additional experiment, in which reduced pyrolusite (made in laboratory) is used as absorption agent in wet desulphurization to produce $MnSO_4 \cdot H_2O$, has been done in a foam tower at a smelting plant. Optimum conditions for both reduction of pyrolusite and absorption of SO_2 are obtained and pure of 95% $MnSO_4 \cdot H_2O$ has been produced by primary crystallization of the absorption mother liquor.

Key words: sufur dioxide, reduced pyrolusite, wet desulphurization, smelting gas, foam tower.

Study on the Low Pressure Wet Catalytic Oxidation Treatment of High Concentration and Refractory Organic Wastewater. Yang Runchang, Zhou shutian (Dept. of Environ. Eng., Dept. of chem. Eng. Xiangtan University. Xiangtan 411105): *Chin. J. Environ. Sci.*, **18**(5), 1997, pp. 71—74

Based on catalytic wet air oxidation and Fenton reagent, a new wet catalytic oxidation (LPWCO) method, which requires low pressure for the treatment of high concentration and refractory organic wastewater was studied. The method compared with general catalytic wet air oxidation, the pressure of the treatment is 0.1—0.6MPa, and the latter is 3.5—10MPa. In addition, its temperature is