

潍河流域水质管理模型

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摘要 水质管理模型包括河流模型、农业非点源污染模型和水库富营养化模型。河流模型选择 QUAL2EU 模型并加以改进, 增加了模拟 COD 转化, 底泥泛起和水体养鱼的非点输入功能, 并将非点源模型和水库模型作了技术处理使之同河流模型有机结合在一起。模型计算结果与实际的监测结果吻合很好。已成为当地水质管理和决策的有力工具。

关键词 流域管理模型, QUAL2EU, 非点源污染, 河流水质, 水库。

潍河流域面积 6494 km², 属于中小流域。流域内拥有山东省最大的水库——峡山水库。近年来, 气候干旱, 河水中清水径流很少, 工业废水和城市生活污水排入河道, 造成 BOD、COD、N 和 P 超标, 河流水质下降, 峡山水库已开始富营养化, 并对下游水源地水质产生影响, 进而威胁到潍坊市城区的饮用水供应。为此, 进行了“潍河流域水污染控制系统规划研究”, 潍河流域水质模型的研究是其中的重要组成部分。流域的水质管理是一个多步骤的过程, 数学模型以其定量描述和动态操作在流域管理中起着重要作用^[1]。作为河流水质模型, QUAL2EU 以及改进型 QUAL2EU 是世界范围内广泛应用的模型^[2,3], 但对于季节性变化大的干旱地区, 这些模型出现了很大的局限性。此外, 非点源模型与河流水质模型的接合在我国尚未见报道。

1 方案设计

潍河流域具有以下特点: ① 流域面积小, 功能全; ② 地表径流少, 季节变化大, 除 6—10 月份外, 潍河基本为断流和少流状态; ③ 流域内进行污水灌溉、施肥, 这些污染物随降雨径流进入水体, 造成较严重的非点源污染; ④ 污染源划分为 4 个区, 各个区相对独立。因此, 这个流域的水系统关系相对比较简单。

针对以上特点, 选择了综合水质模型进行研究, 此综合水质模型的框架见文献[4]。把河

流模型、水库模型和非点源农业径流模型有机结合在一起, 形成了一个综合的模型以解决潍河流域的水质问题, 以期合理地削减重点污染物的排放量, 保护好下游水源地。同时, 可以直观地了解流域环境的动态变化, 为流域内废水处理厂的建立和流域水质质量控制, 提供了一个重要的参考依据。

由于潍河经常出现季节性断流, 故将潍河分为 2 季处理: 枯水期和丰水期。丰水期 5 月至 9 月, 按 75% 保证率情况下水量计算。枯水期 10 月至来年 5 月, 通过实地测量, 坝底渗流量及污水排放量作为枯水期流量。

2 参数选择

在模型中选用的动力学参数一部分是用实验方法在潍河当地测定, 另一部分在其他水域测定并根据当地的条件进行修正。应该指出, 随着将来得到更多检测数据和对系统的了解, 模型参数还应在模型建立后几年内进一步修正。

2.1 新引入变量

流域内主要污染源是造纸、酿酒、食品加工、纺织、化工等工业污染物和城市污水, 以及非点源污染物。笔者选择美国环保局最新版本 QUAL2EU 模型用于模拟潍河, 并对 QUAL2EU 做如下几方面改进。由于此模型没有模拟 COD 的功能, 在研究了模型框架结构基

础上,根据监测数据的 COD、BOD 值,引入一个新的指标 COD2,即 COD 中非生物降解部分: $COD2 = COD - BOD$ 。将 COD2 代入 QUAL2EU 中,作为一个非守恒物质加以模拟。通过实验测定, COD2 经光解,颗粒吸附等原因所造成的降解属于一级反应动力学,反应参数范围 0.01—0.05。

2.2 一级反应动力学参数

反应的数学表达式:

$$\frac{dc}{dt} = kc$$

符合此表达式有 BOD 衰减(0.0—0.21), COD2 衰减, BOD 沉降(0.0—0.12), COD2 沉降(0.0—0.12), 氨氧化(0.15); 亚硝酸盐氧化(1.5), 有机氮水解(0.1), 有机氮沉降(0.1—0.25), 有机磷转化(0.01—0.1), 有机磷沉降(0.0—0.12)。大气复氧的表达式与上式略有差别,但属于同一类型。系数范围在 2.5—10。

2.3 径流模型^[5]

该方程用于预测 t 日在土壤 i 上作物 j 产生的径流深 Q_{ijt} (mm)。

$$Q_{ijt} = \begin{cases} \frac{(R_t - 0.2S_{ijt})^2}{R_t + 0.8S_{ijt}} & (R_t \geq 0.2S_{ijt}) \\ 0 & (\text{其它情况}) \end{cases}$$

R_t : 第 t 日的降雨量(mm); S_{ijt} : 滞洪系数,它是土壤水文分类和状况、作物、耕作方式以及前期 5 d 降雨量的函数。

2.4 指数型参数

非点源污染模型的理论基础是采用径流模型、泥沙模型^[6]和农业径流中的污染物模型^[7]。非点源污染模型与 QUAL2EU 河流丰水期模型之间留有 5 个接口。

非点源污染负荷数学表达式为:

$$L = aQ^b$$

符合此表达式的有单位面积(km^2)的 BOD_5 , COD, 固体悬浮物, 氮磷营养物的输出与所产生的径流流量的关系, 其中 a 与 b 是无量纲的常数。流量单位是 m^3/s 。模型中用的 a 、 b 值列在表 1 中。

表 1 指数型参数

参数[(g/km ² ·s)]	a 值	b 值
BOD 输出	2.635	1.194
COD 输出	28.478	1.204
悬浮物输出	285.376	1.69
颗粒 N 输出	0.6335	1.69
溶解 N 输出	0.643	0.9
颗粒 P 输出	0.1472	1.69
溶解 P 输出	0.032	0.9

2.5 地表截流

在实验中,发现地表的微景观结构对非点源污染物质的传输有一定的持留作用。该持留率是大地粗糙程度、水陆交错带总长度的函数,在上述参数固定的情况下, V 主要受小流域面积的影响: $V = aA^b$, A 为小流域面积(km^2), a 为 0.345, b 为 -0.207。

2.6 底泥泛起

潍河主河道上建起 6 座拦河坝,这使得各个断面水文特征变化很大。水坝放水或大雨过后,造成底泥泛起。根据潍河的实际情况,沉积泛起主要在 2 个点源输入口下游造成。假设底泥泛起的污染物浓度与排污口排污量成正比,底泥泛起造成的流量按下面公式计算:

$$Q_{Increment Flow} = 0.0357 \times Q^{0.0454}$$

其中, $Q_{Increment Flow}$ 是流量增加时泛起底泥的输入量(m^3/s),在模型中按 Increment Flow 输入河段。 Q 是河流流量(m^3/s)。

2.7 水库网箱养鱼

网箱养鱼每年生产每 t 鲜鱼所产生的平均污染负荷为 30 个人口当量(PE)的 BOD_5 , TN 和 TP^[8]。以此标准代入模型中相应部位(Incremental Flow Card),使网箱养鱼的污染负荷平均地输入该河段,使得 QUAL2EU 增加了模拟网箱养鱼的功能。

2.8 水库模型

根据现有监测数据,采用富营养化经验模型:

$$\begin{aligned} \lg CHLa &= 1.45 \times \lg P - 1.14 & N/P > 12 \\ \lg CHLa &= 1.4 \times \lg N - 1.9 & N/P \leq 4 \end{aligned}$$

若 $4 < N/P < 12$, 则用 2 个式子分别计算后, 取较小的结果。这个模型可以根据春季 N、P 浓度预测夏季藻类最高生物量。

图 1 是 BOD、COD 和 DO 在丰水期和枯水期随河段的模拟变化值。

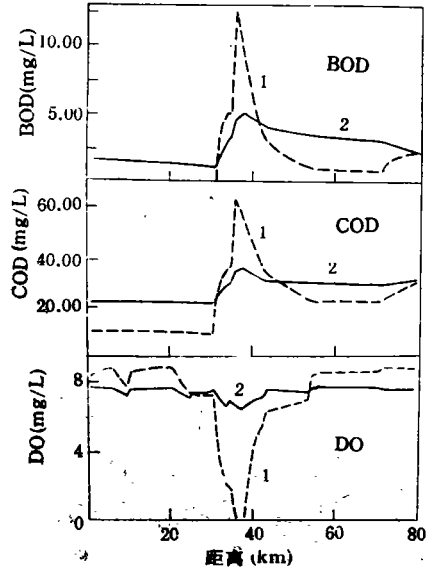


图 1 不同参数在丰水期和枯水期随河段的模拟变化值
1. 枯水期 2. 丰水期

3 淮河流域水质模型检验

模型的参数估值丰水期用的是 1990-08 数据, 枯水期是 1990-05 数据。丰水期检验使用 1991-07 数据, 枯水期检验使用 1990-10 的数据。3 个监测点所在位置是: 第 2 河段即枳沟河段第 2 km 断面处, 第 9 河段即九台河段第 2 km 处, 第 13 河段第 1 km 处即峡山水库入口处。

表 2 显示了丰水期、枯水期 BOD、COD₂、DO 的检验结果。枯水期 COD₂ 检验结果良好, 在 3 个监测断面中, 除在枳沟监测断面相对误差为 -23.9% 外, 在其余 2 个监测断面九台, 峡山水库入库口相对误差不超过 15%。DO 的模拟也有良好的结果, 各断面的相对误差大都不超过 ±14.0%。BOD 的模拟亦有较好的结果, 在枳沟及峡山水库入库口 2 个监测断面误差分别为 -9.4%、23.0%。枯水期 DO 值的模拟程度最好, 枳沟、九台、峡山水库入库口误差分别为 5.9%、-26.1%、0.7%, 在个别河段模拟值和监测出现较大误差, 分析原因可能是枯水

表 2 丰水期 BOD、COD₂、DO 检验结果

模拟时间	河段	BOD			COD ₂			DO		
		模拟值 (mg/L)	监测值 (mg/L)	误差 (%)	模拟值 (mg/L)	监测值 (mg/L)	误差 (%)	模拟值 (mg/L)	监测值 (mg/L)	误差 (%)
枯水期	2	1.45	1.60	-9.4	21.30	27.98	-23.9	7.36	7.0	5.1
	9	4.60	3.20	43.8	32.09	36.24	-11.5	6.83	6.0	13.8
	13	2.94	3.82	-23.0	28.22	24.60	14.7	7.49	8.65	-13.4
丰水期	2	0.07			10.12	9.18	10.2	8.47	8.00	5.9
	9	5.81			44.84	27.34	64.0	4.14	5.60	-26.1
	13	1.38	3.20	-56.9	22.48	9.47	137.4	8.81	8.75	0.7

期河水流量太小和排放污水不匀所致。

4 结论

本流域水质模型在下列方面有所创新:

(1) 首次将河流模型、水库模型和非点源径流模型结合, 形成了一个综合水质模型, 并分为干、枯季 2 个模型, 解决了中小流域, 季节性河流的流域水质模型问题。

(2) 对 QUAL2EU 河流模型进行改进, 在计算机上实现了模拟一条分级落差, 各段相异的台阶形河流。找出了流量变化对底泥泛起 BOD、COD 的影响规律, 使得 QUAL2EU 增加了模拟 COD、底泥泛起和网箱养鱼的功能。解决了淮河流域主要污染物为造纸厂和河流水量不均造成的污染问题。

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硫化化合物的重要来源。

表 3 几种污染物浓度的比较(μg/m³)

污染物	燕山	黄庄 ²⁾	昌平 ²⁾	大兴 ²⁾
NO ₃ ⁻	9.40	10.74	6.83	7.19
SO ₄ ²⁻	28.22	18.63	16.09	12.96
O ₃	122.90	79.60	97.50	63.30
SO ₂	15.80 ¹⁾	9.50	10.40	19.00
NO _x	26.80 ¹⁾	19.90	27.00	38.50

1) 为历年平均值(由燕山石化公司监测站提供)

2) 为北京地区 1986 年的实测结果

3 小结

(1) 该地区大气颗粒物中 NO₃⁻ 和 SO₄²⁻ 的浓度随季节的变化而发生急剧的变化。这一事实说明在 NO₃⁻ 和 SO₄²⁻ 的气相形成过程中日照的影响尤为显著;

(2) 在不同采样地点 NO₃⁻ 和 SO₄²⁻ 的浓度分布不同, 这说明其浓度与采样地点的地理位置和气象条件密切相关;

(3) 在该地区的大气中, 颗粒物中 NO₃⁻ 和

SO₄²⁻ 的浓度之间存在着较为明显的相关关系。二者随时间的变化趋势与 O₃ 基本一致。因 NO_x 的气相转化反应与 SO₂ 的气相转化反应相比更为重要, 且更易于受光氧化剂浓度的影响。因此, NO₃⁻ 与 O₃ 浓度之间的线性相关趋势不容忽视, 应作进一步长期监测和考察。

致谢 燕山石化公司炼油厂及监测站在采样过程及提供有关数据等方面都给予了大力协助与支持, 在此致以诚挚的谢意。

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(3) 根据淮河流域实际情况, 编制了非点源污染模型, 并同 QUAL2EU 进行接口, 解决了污水灌溉、农业施肥造成的非点源污染问题。

(4) 此综合模型应用于淮河流域, 计算结果与实际监测值吻合良好, 此模型是开发者和使用者反复交流共同开发的, 已经作为淮河流域的水质管理和决策的有力工具。

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Abstracts

Chinese Journal of Environmental Science

Study on the Subjective Assessment on a Noise Comprising Different Direction Components. Fu Lixin (Dept. of Environ. Eng., Tsinghua University, Beijing 100084), Qin Youguo and Ce Shiguang (Dept. of Architecture, Tsinghua University, Beijing 100084); *Chin. J. Environ. Sci.*, **16**(5), 1995, pp. 1—5

It was found that in a sound field different people would have different subjective sensation levels, although a same level of real sound pressure was exerted on them. Psychological experiments were carried out on the loudness and noisiness of a noise in a free sound field, a reverberant sound field and an intermediate sound field between them, and a noise comprising different direction components in a free sound field, to give the degree of difference in subjective sensation levels in these cases and the corresponding difference in sound pressure levels. The results show that both loudness and noisiness were higher in a reverberant sound field than in a free sound field, with a distinct degree of about 0.3, corresponding to a sound level divergence of 1—2 dB. There was a positive correlativity of about 0.4 between loudness and noisiness. In a horizontal plane, the distinct divergence of sensation occurred at a noise in a wide range of frequency over 2 kHz. Subjective loudness and noisiness were smaller in a rear semi-plane than in a front one, with a distinct degree of about 0.6 and 2 dB, respectively. The results would be useful in noise reduction and the environmental impact assessment of indoor noise.

Key words: reverberant sound field, direction composition, noise reduction, subjective assessment.

Electrode Behavior in the Process of Magneto-Electrolysis for Industrial Wastewater Treatment. Zhu Youchun et al. (Dept. of Environ. and Resources Eng., Guangdong Univ. of Technology, Guangzhou 510090); *Chin. J. Environ. Sci.*, **16**(5), 1995, pp. 6—9

For the sake of raising the electrolytic efficiency, reducing the energy consumption, and improving the characteristics of recovered deposit, the influences of applied magnetic field on the electrode process were studied by means of magneto-electrolytic tests and polarization curve determination for industrial wastewater containing copper. The

results indicate that during the magneto-electrolytic treatment of industrial wastewater the allowable current density was increased by over 100%, and the overpotential under the condition of tested current density was decreased by over 50%. Thus the cell voltage and the energy cost were decreased, and the metal deposit with excellent characteristics was obtained.

Key words: industrial wastewater, magneto-electrolysis, electrode behavior.

Production Process of Ferric Solution Based on the Catalytical Oxidation by Pyrolusite Tailings. Tian Baozhen and Tang Hongxiao (Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085); *Chin. J. Environ. Sci.*, **16**(5), 1995, pp. 10—13

Pyrolusite tailings containing more than 32% of β - MnO_2 were found to be a catalytical oxidizer for the oxidation of Fe(II) to produce ferric solution. The kinetic characteristics and mechanism of Fe(II) oxidation reaction catalyzed by pyrolusite tailings were studied. It was found that the Fe(II) oxidation reaction proceeded at an extremely fast rate of 309 g/(L · h) and more than 80% of Fe(II) were removed within the first 15 minutes of the Fe(II) oxidation reaction. There was a saturated oxidation value of up to 0.49—0.73 g of Fe(II) per gram of pyrolusite tailings, depending on the content of MnO_2 in the pyrolusite tailings. The pyrolusite tailings and the resulting ferric solution were analyzed with the X-ray diffraction X-ray fluorescent spectrometry method and ICP, respectively. The results show that after the Fe(II) oxidation the pyrolusite tailings were corroded so that most of manganese species were reduced and entered into the liquid phase, and the remaining manganese and other elements entered into the sediment.

Key words: ferrous oxidation, oxidizer, catalytical oxidation rate, pyrolusite tailing.

The Output of Carbon by Plants and the Storage of Carbon in Soils of the Haihe River Basin in North China. Huang Yinxiao et al. (Institute of Botany, Chinese Academy of Sciences, Beijing 100044); *Chin. J. Environ. Sci.*, **16**(5), 1995, pp. 14—17

The results show that the output of carbon significantly varied with different crops and so did the

management and decision-making.

Key words: river basin management, model, QUAL2EU, non-point sources pollution, river water quality, reservoir.

Study on the Thermal Effects of Cooling Water from Power Plants on Young Mullet (*Liza haematochlia* Temminck and Schlegel). Ru Shaoguo (Marine Life College, Qingdao Ocean University, Qingdao 266003), Hou Wenli et al. (Dept. of Environ. Sciences, Northeast Normal University, Changchun 130024); *Chin. J. Environ. Sci.*, 16(5), 1995, pp. 30–32

The title study was carried out by measuring various critical temperatures for young mullet. The results show that under the condition of a natural water temperature of 25°C, young mullet had its avoidance temperature, TL₅₀, UILT, MWAT, CTM and short-term exposure maximum temperature of 34°C, 36.7°C, 38.75°C, 30.52°C, 40.82°C and 35.32°C, respectively. The areas where young mullet was sensitive to a thermal effect were mapped, and a temperature-time equation $\log t(\text{min}) = 17.9422 + 0.4202 T(^{\circ}\text{C})$ and a safe temperature equation $T(^{\circ}\text{C}) = (\log 1440 - a)/b - 2$ were established. A high temperature shock of $\Delta T = 15^{\circ}\text{C}$ for 2 minutes led to a mortality of 25%, that of $\Delta T = 14^{\circ}\text{C}$ for 5 minutes led to a mortality of 15% and the maximum tolerable ΔT was less than 15°C.

Key words: cooling water from power plant, young mullet, thermal effect.

Comparative Study on Ecological Suitability of Cities Within a Region. Yang Yongtai (Foshan City's EPA, Foshan 528000); *Chin. J. Environ. Sci.*, 16(5), 1995, pp. 33–37

The principles and specific indicators for urban ecological suitability were described. Based on the natures of urban ecosystems, the factors composition analysis and fuzzy maximum tree method were suggested to estimate the homogeneity and heterogeneity of the ecological suitabilities among cities within a region. By exemplifying the group of cities in the Pearl River Delta, the scores of compositional factors and the fuzzy sub-tree sets for the ecological suitabilities of cities were calculated. The results show that the method gave reasonable conclusions and was more practical.

Key words: urban ecological suitability, composition factor, fuzzy maximum tree, comparative study.

Development of a Multifunctional Swell and Permeability Apparatus and Its Application to

the Permeability Test of Compacted Bentonite. Zhou Kanghan, Li Guoding and Yu Ke (Dept. of Environ. Eng., Tsinghua University, Beijing 100084); *Chin. J. Environ. Sci.*, 16(5), 1995, pp. 38–40

A multifunctional swell and permeability apparatus has been developed and can be used for many different purposes, for example, the tests of soil for solidifiability, permeability and swellability. It was found that it is particularly useful in the study on a highly compacted and less permeable bentonite of $\rho > 1.5 \text{ g/cm}^3$. With this apparatus, a sample of a permeability in the range of 10^{-12} – 10^{-6} cm/s was precisely measured under the condition of a hydraulic gradient in the range of $(2-4) \times 10^3$. It is also useful to study those highly compacted, less permeable and swellable clays.

Key words: permeability apparatus, permeability, compacted bentonite.

Experimental Studies on Firing a Glazed Colored Glass-Brick from Chromic Slag. Wang Yongzeng et al. (Tangshan Longge Ceramic and Rere Farth Development Corp. Tangshan 063000); *Chin. J. Environ. Sci.*, 16(5), 1995, pp. 41–44

Firing a glazed colored glass-brick from chromic slag was carried out as a high-level research on processing chromic slag harmlessly in ceramic industry. The experiment results show that the leaching amount of hexavalent chromium was lower than the national standard, with its physical and chemical properties conforming to the relative national standard requirements under the conditions of adding 20% chromic slag and a certain amount of fluxing agent into the base material, and controlling the shaping pressure, technological parameters and condition in the firing processes.

Key words: chromic slag, glazed colored glass-brick, hexavalent chromium.

Study on the Treatment of Gentamycin and Aureomycin Wastewaters and the Measures for Pollution Control. Zhou Ping and Qian Yi (Dept. of Environ. Eng., Tsinghua University, Beijing 100084), Su Chengyi (Chinese Research Academy of Environ. Sciences, Beijing 100012); *Chin. J. Environ. Sci.*, 16(5), 1995, pp. 45–47

A gentamycin wastewater, an aureomycin wastewater and a mixture of both wastewaters were subjected to an anaerobic treatment, an aerobic treatment or a combination of both treat-