

污水处理对渭河宝鸡市区段的水环境影响

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摘 要:渭河作为陕西境内的主要河流, 长期以来污染严重, 宝鸡位于渭河陕西段上游, 研究该段的水质及城市污水处理对水质的影响具有重要意义。采用一维多点稀释自净模型, 以现有多年的水文及水质资料, 预测了在各种保证率下修建城市污水厂对渭河水质改善程度。在分析渭河宝鸡市区段水污染状况的基础上, 比较了宝鸡市建与不建污水厂对该段水质状况的影响。结合宝鸡市污水处理工程规划和生态城市建设规划, 分析2020年宝鸡市污水处理工程全部建成后渭河宝鸡段水环境变化, 认为宝鸡市污水处理工程建设对实现宝鸡市生态园林城市建设具有重要意义。

关键词:渭河宝鸡段; 水环境; 水质预测; 污水处理

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渭河发源于甘肃省渭源县鸟鼠山, 由西向东流经甘肃、陕西, 干流全长 818 km, 流域面积 $13.6 \times 10^4 \text{ km}^2$ ^[1]。渭河宝鸡市区段地处渭河盆地, 地形西高东低。该段规划范围西起林家村宝鸡峡大坝引渭渠首, 东至宝鸡市陈仓区虢镇大桥下游蟠溪河口, 全长约 34 km。区间内十七条支流汇入; 其中渭河北岸四条, 南岸十三条, 分布于金台、渭滨、陈仓三区。该市现有十里铺污水厂一座, 于 2004 年建成投产运行, 处理能力 $9 \times 10^4 \text{ m}^3/\text{d}$, 仅能处理部分城市污水, 仍有大量污水无法集中处理而直接排放, 造成该流域严重的水体污染。本文将结合城市排水工程规划, 通过水质预测模型分析宝鸡市城市污水处理对于恢复和保护渭河水体的作用。

1 无污水处理时渭河纳污现状及水质状况评价

该市目前污水排放口大部分设于渭河干流, 排入支流的污水经部分稀释最终也汇入干流, 城区污水排放严重污染渭河市区段水体, 污水排放主要集中在桥南姜谭地区、市区中心、虢镇地区。图 1 为该市无污水厂时各主要监测断面部分常规水质指标多年平均监测结果^[2]。

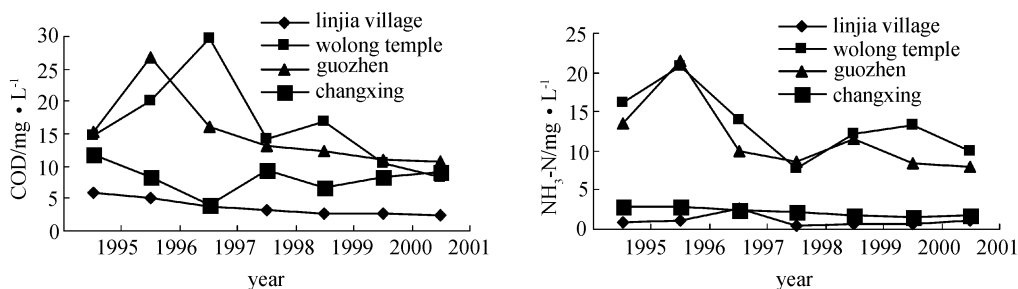


图 1 无污水处理厂时河流各断面水质状况

Fig. 1 Water quality of different section without wastewater treatment plant

从空间分布看, 各段水体均受到不同程度污染, 部分水域如卧龙寺、虢镇断面在市区范围内, 其水质

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明显差于上游林家村、下游常兴断面,尤其氨氮已经远远超过 Ⅲ类水体 2 mg/L 的标准. 时间分布上,大部分年份水质存在超标现象. 1998 年后尽管呈现小幅波动,水质整体状况呈好转趋势,但是仍高于宝鸡市水域功能划分中规定的渭河干流标准(Ⅲ类).

2 污水处理对渭河宝鸡市区段的水质影响预测

2.1 污水处理工程规划概况

为了恢复和保护渭河水体,据宝鸡市污水处理远景规划,截至 2020 年该市将建成四座污水处理厂,现状排放口将关闭,如表 1 所示,届时污水量将达到 $90 \times 10^4 \text{ m}^3/\text{d}$,总处理规模约为 $76 \times 10^4 \text{ m}^3/\text{d}$,污水处理率约 85 %(宝鸡市城市总体规划(1996 - 2020)). 为了具体地分析污水处理对该段水域的影响,有必要通过水质预测模型预测污水处理厂建成后渭河宝鸡段未来水质变化的具体状况.

表 1 宝鸡市污水处理工程规划(2020)

Tab.1 Plan of wastewater treatment in Baoji City(2020)

Planning district	Wastewater plant	Treat scale/ $\text{m}^3 \cdot \text{d}^{-1}$	Wastewater quantity/ $\text{m}^3 \cdot \text{d}^{-1}$
Northwest district	Shilipu Wastewater plant	18×10^4	21×10^4
Southwest district	Shizuitou Wastewater plant	20×10^4	24×10^4
Midst district	Bayu Wastewater plant	18×10^4	21×10^4
East district	Xiguo Wastewater plant	20×10^4	24×10^4
Total quantity		76×10^4	90×10^4

2.2 预测范围及评价因子确定

渭河宝鸡市区段西起林家村东至虢镇大桥,全长约 34 km. 该段内存在金陵河、清姜河、千河三条较大支流. 经过分析,渭河干流各主要排污口位置与待建污水厂的位置以及支流入口位置距离相差不大,为便于对比,使污水处理前后水质变化状况具有可比性,将各污水口位置近似看作与新建水厂和河流入口位置一致,即将排放口概化为新建水厂的位置. 各分段的具体地点分别为该河段起始点林家村、各污水厂下游马营桥、卧龙寺桥、凤凰桥、虢镇大桥,清姜河、金陵河、千河入水口,分别分段分析污水处理对下游断面的影响.

根据渭河干流段水域功能和水质现状分析,该段河流以有机型污染为主,拟选择 COD_{Cr} 和 $\text{NH}_3\text{-N}$ 作为评价因子. 主要支流入水口、污水厂以及各监测断面的位置见图 2.

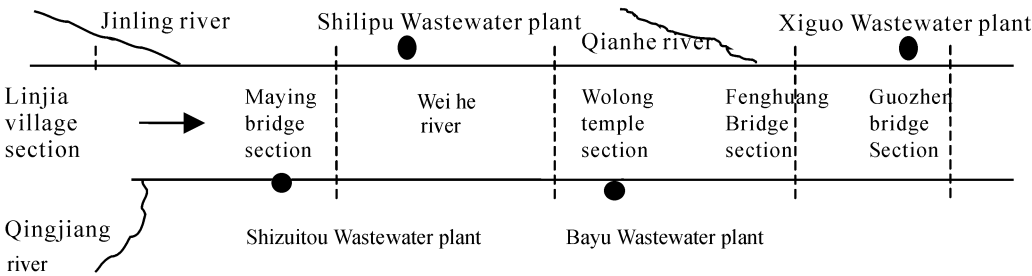


图 2 渭河市区段污水处理厂、分支河流、预测断面分布状况

Fig.2 Positions of wastewater plants ,cross sections and subsidiary rivers

2.3 水质预测模型的选择

从理论上说,污染物在水体中的迁移、转化过程要用三维水质模型预测描述. 三维模型适用于污染物浓度在横向、纵向、垂向均变化的状况,但是该模型结构过于复杂. 当河流中污染物浓度在一个方向上是均匀的,而在其余两个方向是变化的情况下,计算污染物浓度分布需要采用二维水质模型. 在横向和纵向变化均不大的稳态情况下,通常使用一维模型预测污染物在断面上分布比较均匀的中小型河流水质状况. 考虑到渭河水深较浅,河段平均流速较小,污染物浓度在水深方向即垂向(z 轴方向)上的分

布是较均匀的,此外,渭河宝鸡段近年来由于水量减少,河床宽度大大减小,浓度在横向(Y轴方向)上变化很小.综合考虑渭河河流自然条件、地形地貌、水质状况等条件,污染物入河后能较快地与河水混合均匀,采用一维多点稀释自净模型较为合理,该模型基本方程的通式为^[3-8]:

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial X} = D \frac{\partial^2 C}{\partial X^2} - KC \quad (1)$$

假设河段水力条件是稳态且入河污染物的浓度和流量稳定,在均匀河段定常排污条件下,截面积、流速、流量、污染物输入量、弥散系数都不随时间而变化时, $\frac{\partial C}{\partial t} = 0$. 此时(1)式变为:

$$\frac{d^2 C}{dX^2} - \frac{u}{Kd} \frac{dC}{dX} - \frac{KC}{D} = 0 \quad (2)$$

边界条件: $X = 0$ 时, $C = C_0$; $X = \infty$ 时, $C = 0$. 该常微分方程的特征多项式为:

$$\lambda^2 - \frac{u}{D} \lambda - \frac{K}{D} = 0 \quad (3)$$

其特征值 $\lambda_1 = u(1 + \sqrt{1 + \frac{4KD}{U^2}})/2D$; $\lambda_2 = u(1 - \sqrt{1 + \frac{4KD}{U^2}})/2D$. 方程的通解为:

$$C_X = A e^{\lambda_1 X} + B e^{\lambda_2 X} \quad (4)$$

因为 $(1 - \sqrt{1 + \frac{4KD}{U^2}})$ 是在排污口下游区域($X > 0$), $(1 + \sqrt{1 + \frac{4KD}{U^2}})$ 是在上游区域($X < 0$)无意义的. 因此舍弃 λ_1 取 λ_2 , $X = 0$ 时, $C_X = C_0$, 则 $B = C_0$. 所以

$$C_X = C_0 \exp\left[\frac{u}{2D}(1 - \sqrt{1 + \frac{4KD}{U^2}})X\right] \quad (5)$$

渭河是内陆河流,不受潮汐流影响,弥散系数很小可以令 $D = 0$, 则一维河流方程为

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial X} = -KC \quad (6)$$

该偏微分方程可以改写成两个常微分方程

$$\begin{cases} \frac{d(X(t))}{dt} = u \\ \frac{d(C(X(t), t))}{dt} = -KC \end{cases} \quad (7)$$

式中: $X(t) = ut$; 当 $X(t) = 0$ 时, $C = C_0$, 则

$$C_X = C_0 \exp[-KX/u] \quad (8)$$

其中: u 为河流流速, m/s ; K 为污染物降解系数, L/d ; C_X 为下游污染物浓度, mg/L ; X 为经过距离, km ; C_0 为上游断面污染物浓度, mg/L .

对于多点源情况,下游污染物浓度为:

$$C_X = C_1 \exp[-KX_1/u_1] + C_2 \exp[-KX_2/u_2] + \dots + C_n \exp[-KX_n/u_n] \quad (9)$$

假设污染物排入河流后迅速完全混合,并且各排污口排污均匀、连续,各支流入水口流量及污染物浓度稳定,此时干流各入水口污染物浓度由质量平衡原理得出:

$$C_i = \frac{C_a Q_a + C_b Q_b}{Q_a + Q_b} \quad (i = 1, 2, \dots, n) \quad (10)$$

其中: C_i 为干流污染物浓度, mg/L ; C_a 为上游污染物浓度, mg/L ; C_b 为各排污口或支流污染物浓度, mg/L ; Q_a 为上游河水流量, m^3/s ; Q_b 为各排污口或支流河水流量, m^3/s .

2.4 模型计算参数的确定

(1) 河流分段长度:由宝鸡市城市规划地形图结合排水状况得出河段各控制断面至预测断面的距离,具体数值见表 3.

(2) 污染物浓度综合降减系数 K :综合降解系数主要体现污染物在水体中降解速度的快慢. 它与河流量、水温、流速、水深、泥沙含量、水体的污染程度关系密切. 该系数的测定方法一般包括现场测定

法、经验公式法等。现场测定法适用于河段内无其他污染源输入的情况,渭河是遭受严重污染的河流,沿岸污染源众多,要选择合适的河段进行试验准确确定其 COD_{Cr} 降解系数比较困难。本文参照国内外相关研究^[9-10],结合课题组在渭河流域的水质监测数据(宝鸡林家村至潼关 13 个断面)采用计算式 $K_i = U_i / x_i \ln(C_{Ai} / C_{Bi})$ 求平均值进行估算,式中 C_{Ai} 、 C_{Bi} 为第 i 河段上、下断面 COD_{Cr} 浓度(mg/L); U_i 为第 i 河段平均流速(m/s); x_i 为第 i 河段长度(m); K_i 为第 i 河段 COD_{Cr} 衰减系数,通过计算 COD_{Cr} 降解系数估算值为 0.15。通过一元线性回归方法求得 $\text{NH}_3\text{-N}$ 降解系数与 COD_{Cr} 的降解系数之间的相关关系,得出 $\text{NH}_3\text{-N}$ 降解系数比 COD_{Cr} 的降解系数小,约为 COD_{Cr} 降解系数的 80% 左右,即 0.12。

(3) 上游起始断面污染物浓度 C_0 :林家村断面位于渭河上游,污染源较少,污染状况较小,其水质长期变化不大,以该段面的多年水质监测均值作为渭河干流预测初始值^[3],具体数值见表 4。

(4) 支流量、浓度及污水厂出水浓度:设各规划污水厂进出水水质与十里铺污水厂一致,十里铺污水厂平均进水 $\text{COD}_{\text{Cr}} = 235 \text{ mg/L}$, $\text{NH}_3\text{-N} = 25 \text{ mg/L}$;出水 $\text{COD}_{\text{Cr}} = 33 \text{ mg/L}$, $\text{NH}_3\text{-N} = 4 \text{ mg/L}$ (宝鸡市十里铺污水处理厂进出水水质监测报告)。各支流水质状况以汇流口处多年监测均值为准,见表 2。

表 2 主要河流流量、流速及水质状况

Tab. 2 The quantity, velocity and quality of main rivers

River's name	parameter	$P = 50 \%$	$P = 75 \%$	$P = 95 \%$	Average	$\text{COD}/\text{mg} \cdot \text{L}^{-1}$	$\text{NH}_3\text{-N}/\text{mg} \cdot \text{L}^{-1}$
Weihe River	runoff/ $10^8 \text{ m}^3 \cdot \text{a}^{-1}$	35.72	25.84	15.96	38.00	11.7	0.32
	velocity/ $\text{m} \cdot \text{s}^{-1}$	1.74	1.26	0.78	1.84		
Qingjianghe River	runoff/ $10^8 \text{ m}^3 \cdot \text{a}^{-1}$	1.35	0.98	0.63	1.46	14.8	0.60
Jinlinghe River	runoff/ $10^8 \text{ m}^3 \cdot \text{a}^{-1}$	0.474	0.344	0.210	0.513	17.26	0.83
Qianhe River	runoff/ $10^8 \text{ m}^3 \cdot \text{a}^{-1}$	3.89	2.59	1.48	4.47	15	0.5

2.5 水质预测计算

经过对同步测量的河流天然径流量进行统计概率计算可得 1956 - 2000 年渭河干流及各支流平水期 ($P = 50 \%$)、偏枯期 ($P = 75 \%$)、枯水期 ($P = 95 \%$) 三个保证率下的年径流量(陕西省宝鸡市水资源调查评价报告),见表 2。利用上述水质预测模型通过分析计算不同保证率下河流中污染物在不同断面的浓度变化状况,得出污水处理对河流水质的改善程度。假定河水流量沿河长呈线性增长且流速稳定,河流流速按照流量与河流平均断面面积的比值计算求得。表 3、表 4 和表 5 分别为不同保证率下 COD_{Cr} 和 $\text{NH}_3\text{-N}$ 在各预测断面的水质变化状况。

2.6 预测结果分析

经计算得到如图 3 所示污染物浓度变化趋势。宝鸡市水域功能分区水质目标规定渭河干流应达到地表水 Ⅲ类标准($\text{COD}_{\text{Cr}} < 30 \text{ mg/L}$, $\text{NH}_3\text{-N} < 1.5 \text{ mg/L}$)。以现状即 9 万 m^3/d 处理能力时的水质状况来看:污染物浓度呈显著上升趋势。 $P = 50 \%$ 时为丰水期, COD_{Cr} 到终点虢镇桥时达到 27 mg/L , $\text{NH}_3\text{-N}$ 接近 2 mg/L , 已经超标; $P = 75 \%$ 时, COD_{Cr} 在终点前还可达到标准,至终点处达 31 mg/L 开始超标, $\text{NH}_3\text{-N}$ 最终达到 2.5 mg/L , 其间有超标状况,后又因干河的汇入而有所好转,至终点处由于排污再次超标; $P = 95 \%$ 时, COD_{Cr} 至八鱼时已经超标, $\text{NH}_3\text{-N}$ 至十里铺地区时超标,至终点时 COD_{Cr} 甚至超过 40 mg/L , $\text{NH}_3\text{-N}$ 接近 4 mg/L , 超出 Ⅲ类水质标准($\text{COD}_{\text{Cr}} < 40 \text{ mg/L}$, $\text{NH}_3\text{-N} < 2 \text{ mg/L}$)。若按照《宝鸡市城市总体规划》至 2020 年新建或扩建污水厂均正式投产运行,则各保证率下的 $\text{NH}_3\text{-N}$ 指标均可保持在地表水 Ⅲ~Ⅳ类标准之间, COD_{Cr} 也完全可以保证在 Ⅲ类标准以内。

3 结论

宝鸡市规划污水处理厂的投产运行对该市城市水环境的改善具有十分有利的影响,使渭河宝鸡段干流的水质在 $P = 50 \%$ 、 $P = 75 \%$ 和 $P = 95 \%$ 保证率条件下改善至地表水 Ⅲ~Ⅳ类标准,优于水域功能分区标准地表水 Ⅲ类标准。宝鸡市现有污水处理厂不足以达到该市建设生态园林城市的要求,必须尽快按规划建设城市污水处理厂,它是实现宝鸡市创建生态园林城市及国家环保模范城市的重要保证。

表 3 $P = 50\%$ 时各断面的水质状况

Tab. 3 The water quality of different cross sections with $P = 50\%$

Point source	Section Concentration $C_0/\text{mg} \cdot \text{L}^{-1}$								X / km	Next section concentration $C/\text{mg} \cdot \text{L}^{-1}$			
	With wastewater plant				Without wastewater plant								
	no mixing		mixing		no mixing		mixing			With plant		Without plant	
norms	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N		COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N
Linjia village	11.7	0.32	11.7	0.32	11.7	0.32	11.7	0.32	6.4	11.63	0.32	11.63	0.32
Qingjiang he	14.8	0.60	11.74	0.33	14.8	0.60	11.74	0.33	2.8	11.71	0.32	11.71	0.32
Jinling he	17.26	0.83	11.78	0.33	17.26	0.83	11.78	0.33	2.4	11.75	0.33	11.75	0.33
Shizoutou	235	25	16.84	0.90	33	4	12.24	0.42	1.6	16.82	0.89	12.22	0.42
Maying bridge	16.39	0.88	16.82	0.89	11.82	0.40	12.22	0.42	2.4	16.78	0.89	12.19	0.42
Shilipu	235	25	19.36	1.19	33	4	12.60	0.49	4.2	19.28	1.19	12.55	0.48
Wolong temple	18.56	1.15	19.28	1.19	11.95	0.46	12.55	0.49	2.4	19.23	1.18	12.52	0.48
Bayu	235	25	23.38	1.64	33	4	12.92	0.55	1.2	23.35	1.64	12.90	0.55
Qianhe	15	0.5	22.61	1.54	15	0.5	13.09	0.55	1.2	22.59	1.54	13.08	0.55
Fenghuang	21.72	1.49	22.59	1.54	12.41	0.52	13.08	0.55	6.2	22.48	1.53	13.01	0.54
Xiguo	235	25	26.64	1.99	33	4	13.04	0.61	2.0	26.60	1.99	13.38	0.61

表 4 $P = 75\%$ 时各断面的水质状况

Tab. 4 The water quality of different cross sections with $P = 75\%$

Point source	Section Concentration $C_0/\text{mg} \cdot \text{L}^{-1}$								X/km	Next section concentration $C/\text{mg} \cdot \text{L}^{-1}$			
	With wastewater plant				Without wastewater plant								
	no mixing		mixing		no mixing		mixing			With plant		Without plant	
norms	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N		COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N
Linjia village	11.7	0.32	11.7	0.32	11.7	0.32	11.7	0.32	6.4	11.60	0.32	11.60	0.32
Qingjiang he	14.8	0.60	11.71	0.33	14.8	0.60	11.71	0.33	2.8	11.67	0.33	11.67	0.33
Jinling he	17.26	0.83	11.74	0.33	17.26	0.83	11.74	0.33	2.4	11.70	0.33	11.70	0.33
Shizoutou	235	25	18.68	1.10	33	4	12.38	0.45	1.6	18.64	1.10	12.34	0.45
Maying bridge	18.06	1.08	18.64	1.10	11.80	0.43	12.34	0.45	2.4	18.59	1.10	12.30	0.45
Shilipu	235	25	22.04	1.49	33	4	12.86	0.54	4.2	21.93	1.49	12.79	0.54
Wolong temple	20.90	1.44	21.93	1.49	11.98	0.51	12.79	0.54	2.4	21.86	1.49	12.75	0.54
Bayu	235	25	27.39	2.09	33	4	13.28	0.63	1.2	27.35	2.09	13.26	0.63
Qianhe	15	0.5	26.35	1.96	15	0.5	13.40	0.62	1.2	26.32	1.96	13.38	0.61
Fenghuang	25.05	1.89	26.32	1.96	12.48	0.58	13.38	0.61	6.2	26.14	1.95	13.29	0.61
Xiguo	235	25	31.67	2.56	33	4	13.81	0.70	2.0	31.61	2.56	13.78	0.70

表 5 $P = 95\%$ 时各断面的水质状况

Tab. 5 The water quality of different cross sections with $P = 95\%$

Point source	Section Concentration $C_0/\text{mg} \cdot \text{L}^{-1}$								X/km	Next section concentration $C/\text{mg} \cdot \text{L}^{-1}$			
	With wastewater plant				Without wastewater plant					With plant		Without plant	
	no mixing		mixing		no mixing		mixing						
norms	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N		COD _{cr}	NH ₃ -N	COD _{cr}	NH ₃ -N
Linjia village	11.7	0.32	11.7	0.32	11.7	0.32	11.7	0.32	6.4	11.53	0.32	11.53	0.32
Qingjiang he	14.8	0.60	11.66	0.33	14.8	0.60	11.66	0.33	2.8	11.59	0.33	11.59	0.33
Jinling he	17.26	0.83	11.66	0.33	17.26	0.83	11.66	0.33	2.4	11.60	0.33	11.60	0.33
Shizoutou	235	25	22.67	1.55	33	4	12.66	0.51	1.6	22.59	1.55	12.62	0.51
Maying bridge	21.66	1.51	22.60	1.55	11.77	0.48	12.62	0.51	2.4	22.49	1.54	12.56	0.51
Shilipu	235	25	27.72	2.14	33	4	13.40	0.65	4.2	27.50	2.13	13.30	0.65
Wolong temple	25.72	2.02	27.50	2.13	12.06	0.60	13.30	0.65	2.4	27.37	2.12	13.24	0.65
Bayu	235	25	35.66	3.04	33	4	14.03	0.78	1.2	35.58	3.03	13.99	0.78
Qianhe	15	0.5	34.11	2.85	15	0.5	14.07	0.76	1.2	34.03	2.84	14.04	0.76
Fenghuang	31.77	2.69	34.03	2.84	12.65	0.70	14.04	0.76	6.2	33.67	2.82	13.89	0.75
Xiguo	235	25	41.85	3.72	33	4	14.67	0.88	2.0	41.71	3.71	14.62	0.88

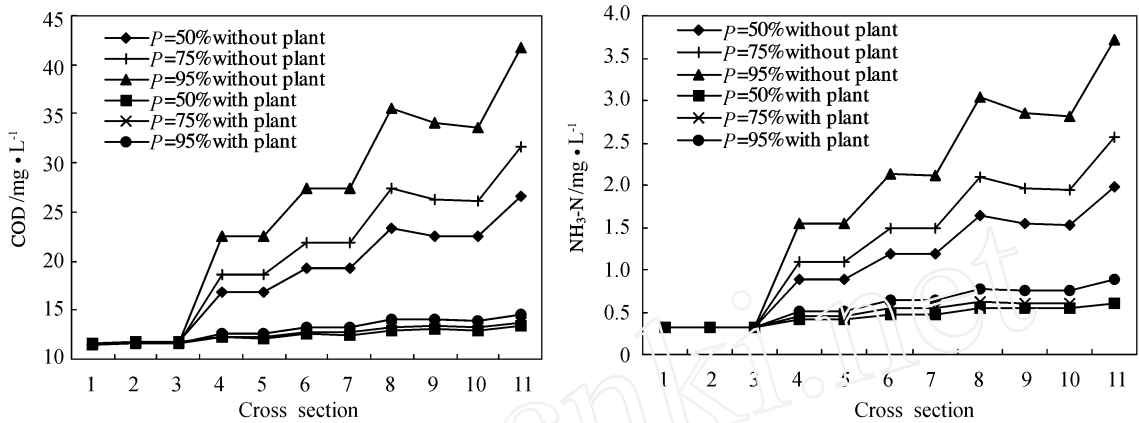


图 3 规划污水厂建成前后各断面水质比较

Fig. 3 Water quality before and after the construction of wastewater treatment plants

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Effects of wastewater on the water environment of the Weihe River at Baoji

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Abstract: As the main river running across Shaanxi Province, the Weihe River has been polluted seriously. Baoji City is situated in the upper reaches of the Weihe River. The water quality research of Weihe River in Baoji section and wastewater treatment influence on water quality are both important. By using the one-dimension dilute self-purification model, and based on hydrology and water quality data, the paper predicted the improvement degree of the Weihe water quality after the construction of city wastewater plant under the different guarantee rate. Based on the present water pollution status and wastewater drainage of Weihe River in Baoji City, the water quality of the Weihe River inside Baoji section is calculated respectively before and after the establishment of wastewater treatment plant. With reference to the wastewater treatment engineering plan and eco-city construction plan, we compared the water environment system before treatment with that which has been treated, and concluded that the plan of wastewater treatment of Baoji city will benefit the construction of an ecological city.

Key words: Weihe River inside Baoji Section; water system; water quality forecast; wastewater treatment

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Research on purification effects of reeds on the stagnant landscape watercourse in urban areas

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Abstract: Based on the field experiments by using constructed enclosure in the stagnant reach of Weihe River Basin in Baoji city, the purification effects of reeds on rivers under the conditions of different inundated water level and hydraulic residence time (i.e. HRT) have been studied. The research indicated that the purification effects of reeds are prospectively fine. Under the condition of HRT being 7d and the inundated water level being 0.4m, the removal rates of TN, NH_4^+-N , TP, COD_{Mn} are 54.5%, 59.6%, 67.3% and 10.5% respectively; under the condition of HRT being 5d and the inundated water level being 0.6m, the area removal rates of TN and NH_4^+-N reach 137.4 and 54.5 $\text{mg} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$ respectively. And under the condition of HRT being 2d and the inundated water level being 0.6m, the TN's area removal rate reaches the maximum value, i.e. 15.3 $\text{mg} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$. It shows that the nitrogen and phosphorus in rivers can be effectively removed by reeds. However, the reeds' removal effects will largely decrease if the river's COD_{Mn} value is low. And the removal efficiency is only 10%.

Key words: constructed enclosure; manmade water body; reeds; water purification

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