Filtration of Heavy Metal-contaminated Groundwater Using a Novel Nanofiber Membrane

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Abstract: A novel nanofiber membrane, named M-1, is prepared from chlorinated polyvinyl chloride by high-voltage electrospinning process. The removals of divalent metal cations including Cu^{2+}, Pb^{2+} and Cd^{2+} from the simulated groundwater by M-1 have been investigated. To obtain the best heavy metal removal, several filtration methods using M-1 have been presented, including direct filtration, soil addition filtration, diatomite-addition filtration and micellar enhanced filtration (MEF). The best filtration method for M-1 to remove heavy metal cations is MEF whose optimal experimental conditions are 10-layer filtration and sodium dodecyl benzene sulfonate (SDBS) concentration of 5 mmol/L. The experimental results show that the rejections of copper in the simulated groundwater by MEF using M-1 can reach more than 73%; the rejections of lead more than 82%; and the rejections of cadmium more than 91%.

Key words: Nanofiber membrane; Heavy metal removal; Groundwater; Filtration
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Groundwater pollution, often due to contaminant seepage from the disposal sites, is a big problem in many countries[1]. The elevated level of heavy metals in the groundwater poses a substantial risk to local resource users and to the natural environment potentially. Among current methods available for removing heavy metals from groundwater either is high in operating cost or is not effective in heavy metal removal, especially for groundwater polluted slightly. The increasingly restrictive regulations of allowable levels of heavy metal discharge and accelerated requirements for the remediation of contaminated sites make it necessary to develop new approaches and innovative techniques for heavy metal removal from groundwater. Filtration efficiency usually depends on the materials used for filters[2—3]. Therefore recent researches have focused on the application of novel nanofiber membrane materials in filtration. M—1 is obtained from chlorinated polyvinyl chloride by high-voltage electrospinning. Present work is mainly focused on filtration using M—1 to remove heavy metal cations (Cu^{2+}, Pb^{2+} and Cd^{2+}) from simulated groundwater.

1 Experiments

1.1 Materials

As shown in Fig. 1, electrospun fibers of M-1 are distributed randomly in the form of a nonwoven mat, forming a 3-dimensional network structure with multilayers. This kind of structure provides great physical barrier, resulting in it being used for filtering heavy metal-containing particles from aqueous medium.

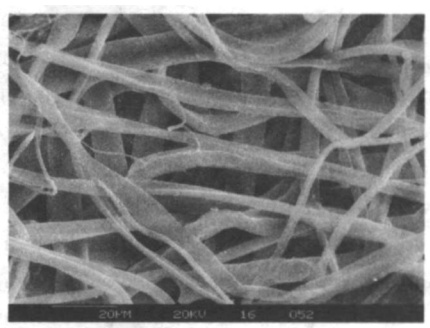

Fig. 1 SEM photographs of M—1 (1000×)

The Cu^{2+}/Pb^{2+}/Cd^{2+}-containing simulated groundwater is prepared by dissolving definite copper sulfate, cadmium chloride or lead acetate in the deion-

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ized water or the real uncontaminated groundwater from Daxing district, Beijing, China. The one from deionized water is named G-1 and that from real uncontaminated groundwater is G-2 in brief. Copper sulfate, cadmium chloride, lead acetate and sodium dodecyl benzene sulfonate (SDBS) are all analytical grade and purchased from Beijing Chemical Technology Co., China.

1.2 Experiments and analysis

The concentration of feed is varied from 3.0 to 5.5 mg/L under room temperature's conditions at an applied pressure of less than 0.5 MPa. The flow rates of feed are 30 L/h for all tests. An inductance coupling plasma spectrograph (ICP) is used to measure the Cu^{2+}/Pb^{2+}/Cd^{2+} concentration of the feed and permeate streams.

2 Results and discussion

2.1 Filtration for removal of Cu^{2+}

Since Cu^{2+}, Pb^{2+} and Cd^{2+} are all bivalent and most of their properties are similar, typical series of filtration experiments for Cu^{2+} removal are explored to find the best way to remove heavy metal cations from the groundwater using M-1.

Cu^{2+}-containing G-1 is directly filtered by monolayer and 12-layer M-1. Cu^{2+} concentrations of permeate fluctuate slightly around 5 mg/L, namely there is no evidence to indicate that direct filtration of G-1 is effective to remove metal ion. Membrane filtration maybe rejects the soil particulates and the heavy metals attached on them. A known quantity of soil or diatomite are dosed into Cu^{2+}-containing G-1 and stirred before G-1 is filtered by M-1 repeatedly for higher removal. Cu^{2+} removals of soil-addition run (26% ~ 37%) are much better than those of diatomite-addition run (2% ~ 5%). Micellar enhanced filtration (MEF) of Cu^{2+}-containing G-1 is not effective to remove Cu^{2+} at all with 6-layer M-1 and 5 mmol/L SDBS which is higher than the critical micelles concentration 1.2 mmol/L[4].

To obtain optimal operational conditions for the most efficient MEF of G-2, SDBS concentrations are adopted as 1.5, 3, 5 and 10 mmol/L, respectively; filtration M-1 as 3-layer, 7-layer and 10-layer, respectively. The results show that the optimal operational conditions for MEF of Cu-containing G-2 are 10-layer filtration and SDBS concentration of 5 mmol/L, whose rejections of copper are more than 70%.

2.2 MEF of Pb^{2+}/Cd^{2+} — containing G-2

MEF with 10-layer M-1 and SDBS of 5 mmol/L are also conducted to remove Pb^{2+} and Cd^{2+} from the Pb^{2+}/Cd^{2+}-containing G-2. As shown in Fig. 2, the rejections of lead in the groundwater solution can reach more than 82% and the rejections of cadmium in the groundwater solution are more than 91%.

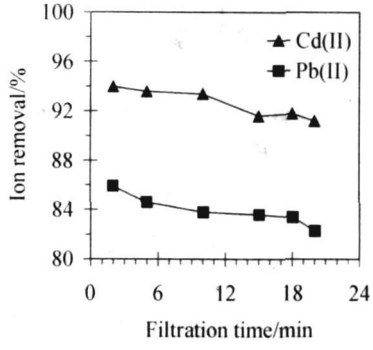

Fig. 2 Removals as a function of time in MEF of Pb^{2+}/Cd^{2+}-containing G-2

3 Conclusions

Due to the 3-dimensional network structure with multilayers, M-1 are successfully used as filtration membrane to remove heavy metal from groundwater. MEF is more effective to remove heavy metal cations from groundwater than direct filtration, soil-addition filtration and diatomite-addition filtration. The optimal experimental conditions of MEF are 10-layer filtration and SDBS concentration of 5 mmol/L. The rejections of copper in the simulated groundwater by MEF can reach more than 73%; the rejections of lead, more than 82%; and the rejections of cadmium, more than 91%.

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Tab. 1 The Scheme of factorial experimental and results of tests

Factors		N	P	C_m	T	Results
Test No.			Levels			CPS**
1		1 (3.9)*	1 (4.3)	1 (1.08)	1 (1250℃)	1302
2		1	2 (3.8)	2 (0.99)	2 (1300℃)	1436
3		1	3 (3.3)	3 (0.89)	3 (1350℃)	1610
4		2 (3.0)	1	2	3	1258
5		2	2	3	1	1334
6		2	3	1	2	1286
7		3 (2.0)	1	3	2	782
8		3	2	1	3	952
9		3	3	2	1	1199
Average CPS of tests at same level	K_1	1449	1114	1180	1275	
	K_2	1293	1241	1295	1168	
	K_3	975	1362	1242	1273	
Extreme deviation	R	474	248	115	107	

Note: ① * Figures in parentheses are values of modulus and sintering temperatures responding to the respective level.
② ** CPS of 0.376 nm peak of C_4A_3S

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用废铝渣制备膨胀和自应力硫铝酸盐水泥的研究

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摘 要: 通过正交试验设计, 研究了用废铝渣替代铝矾土制备硫铝酸盐水泥熟料, 调整石膏掺量制备膨胀和自应力水泥。研究结果表明: ①用废铝渣替代铝矾土制备硫铝酸盐水泥熟料是可行的; ②最佳熟料煅烧条件为 N= 3.9, P= 2.8, C_m= 0.99和煅烧温度 T_b= 1350 ℃; ③制备的水泥物理性能符合膨胀和自应力水泥国家标准。

关键词: 废铝渣; 膨胀和自应力水泥; 硫铝酸盐水泥熟料; 正交设计
中图分类号: TQ172.746

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新型纳米纤维膜对地下水中重金属的过滤去除研究

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摘 要: 采用扫描电镜表征了氯化聚氯乙烯静电纺丝纳米纤维膜的微观结构特征, 并进行了去除地下水中铜、铅、镉等重金属阳离子的过滤试验, 包括直接过滤、加土壤过滤、加硅藻土过滤和胶束强化过滤。结果表明, 最佳的过滤工艺是胶束强化过滤, 其最佳试验条件是 10层膜过滤和 5mmol/L的 SDBS浓度, 对铜、铅、镉的去除率分别超过 73%, 82%和 91%。

关键词: 纳米纤维膜; 重金属去除; 地下水; 过滤
中图分类号: X513