人工土壤渗滤对颗粒 COD 的吸附及堵塞*

孙宗健 丁爱中 滕彦国

(北京师范大学水科学研究院,教育部水沙重点实验室,北京 100875)

摘要 生活污水中颗粒 COD 占到总 COD 的 30 %～60 %,砂滤试验证实,非生物参与的单纯过滤仅能去除总 COD 的 20 %～35 %。人工土壤渗滤对颗粒 COD 的吸附是通过系统介质表层的快速接触-吸附完成的,通常 80 %以上吸附量集中在表层 20 cm 之内。对颗粒 COD 的吸附是人工土壤渗滤系统堵塞的主要原因,微生物增长量占到系统孔隙率的 3.7 %～5.3 %。通过对系统入渗及恢复试验,得到系统干湿交替运行的合适配搭,对人工土壤渗滤防堵塞和长期稳定运行提供了有益探索。

关键词 土壤渗滤 颗粒 COD 污水处理 吸附 堵塞

0 引言

在人工土壤渗滤等生态工程应用中,颗粒 COD 往往是造成系统堵塞的主要成分[1]。生活污水中颗粒 COD 含量一般比较高[2],这种情况下,如果让大部分颗粒 COD 进入生物处理系统,不仅微生物对其降解起来较困难,而且极易造成系统的堵塞[3]。因此,研究颗粒 COD 在生活污水中的比例、土壤渗滤对颗粒 COD 的去除以及由此造成的堵塞,对于污水生态处理系统非常重要。

事实上,人工土壤渗滤不仅可以有效地去除 SS,而且对颗粒 COD 也具有一定的去除效果。污水中大部分颗粒 COD 可被截留、吸附在渗滤介质的表面[4],剩余的可生物降解的部分颗粒 COD 也可以通过微生物降解得以部分去除[5]。

1 污水中颗粒 COD 的测定

根据颗粒 COD 的定义,测试过程中将其视为悬浮物,按照悬浮物的测定方法,将水样通过孔径为 0.45 μm的滤膜[6]。测定滤出液的 COD 浓度,将其视为溶解性 COD,用原水的 COD 浓度减去溶解性 COD 即为颗粒 COD 的浓度。

测定中使用抽滤装置(包括抽滤漏斗、抽滤瓶、真空泵)以及 CTL-12 型化学需氧量测定仪。

2 单纯利用粗砂过滤对颗粒 COD 的去除

试验选取了两种砂,一种是人工粉碎加工的石英砂,另一种是建筑砂(两种砂均经过160 ℃下烘烤2 h 的干热灭菌法处理)。

2.1 污水中颗粒 COD 的含量

试验的生活污水取自某下水管道主管道,污水中颗粒 COD 含量试验结果见表 1。

表 1 生活污水中颗粒 COD 含量

原水总 ρ(COD)/(mg·L⁻¹)	溶解性 ρ(COD)/(mg·L⁻¹)	颗粒 ρ(COD)/(mg·L⁻¹)	颗粒 COD 含量/%
764.2	235.1	529.1	69.2
303.6	190.1	113.5	37.4
366.0	188.1	147.9	47.0
478.6	320.2	158.4	33.1

由表 1 中数据可以看出,颗粒 COD 在生活污水中的含量随原水的浓度变化而变化,其含量一般在 30 %～60 %。

2.2 试验结果

试验结果见表 2。

表 2 单纯砂滤试验结果

项目	原水	建筑砂过滤	石英砂过滤	微孔过滤
ρ(COD)/(mg·L⁻¹)	303.6	240.4	197.6	190.2
总 COD 去除率/%		20.8	34.9	37.4
颗粒 COD 去除率/%		55.8	93.5	100

试验结果表明,砂滤对于颗粒 COD 具有很好的去除,主要颗粒直径为 0.1～0.3 mm的石英砂对颗粒 COD 的去除高达 93.5 %,而颗粒较粗的建筑砂对颗粒 COD 的去除也达到了 55.8 %。

由于试验进行前,对试验用砂进行了干热灭菌处理,而且试验过程中污水渗滤速度很快,建筑砂和石英砂的渗透速度分别为30.26和10.08 m/s。基本上可以认为渗滤过程几乎没有微生物对 COD 的降解去除作用发生,总 COD 的去除主要是由渗滤介质对颗粒

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COD 的过滤、吸附作用得到去除。建筑砂和石英砂对总 COD 的去除分别为 20.8 %和 34.9 %。因此,可以判定颗粒 COD 的去除不仅与原水中颗粒 COD 的含量有关,而且与渗滤介质的性质有关。渗滤介质的比表面积越大、孔隙直径越小,颗粒 COD 的去除效果也越好,同悬浮物的去除基本一致。

3 人工土壤渗滤吸附颗粒 COD 的试验

3.1 试验设计

试验选取了一种比较粗的石英砂作为人工土壤渗滤的填料介质,并添加石灰石、少量矿石和活性炭及营养物质等构成人工土壤渗滤的人工土壤层。

砂粒度分析结果见表 3,人工土壤结构示意图见图 1。

表 3 石英砂的粒度分析结果

粒径/mm	石英砂/ %
2～1.43	5.91
1.43～0.9	32.23
0.9～0.6	57.59
0.6～0.45	4.01
0.45～0.3	0.20
0.3～0.2	0.05
0.2～0.1	0.00
0.1～0.074	0.00
<0.074	0.00
不均匀系数 D_u	1.80

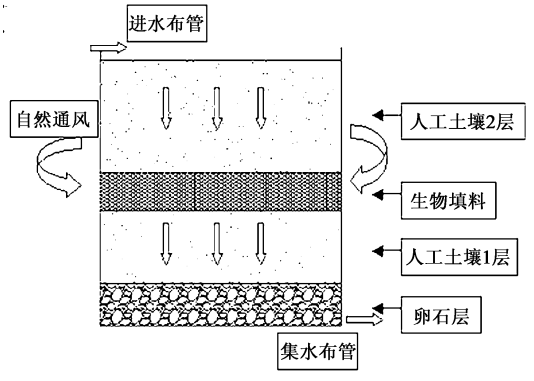


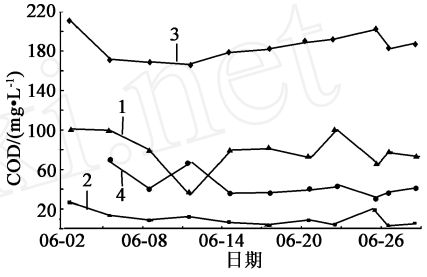
图 1 人工土壤结构示意

3.2 处理结果

系统进出水 COD 与颗粒 COD 浓度的变化见图 2。

从图 2 中可以看出,进水中颗粒 COD 占总 COD 的比例在 30 %～60 %,颗粒 COD 的浓度变化比较平稳。这是因为试验中,人工土壤渗滤池前设进水调节池,因此对颗粒 COD 的稳定起到了很好的调节作用。

从图 2 中可以看出,人工土壤渗滤工艺对颗粒 COD 有比较好的去除效果,通常在 50 %～90 %,最好可到 93.66 %虽然随着试验的进行和进水浓度的变化,处理效果有所起伏,但是基本出水都可以稳定地保持在50 mg/L之下,说明人工土壤渗滤工艺对颗粒 COD 的去除效果稳定有效,在进水冲击下也能保持较好的性能。



1 —进水颗粒 COD;2 —出水颗粒 COD;
3 —进水 COD;4 —出水 COD。

图 2 系统进水 COD 与颗粒 COD 浓度变化

因为试验设计的需要,为尽量减少停留时间,从而使人工土壤快渗对 COD 的整体去除率得到削弱,仅达 30 %。通过综合分析图 2,去除的 COD 中超过 60 %是通过对颗粒 COD 削减完成,但是依然有生物降解及其他反应发生。

4 颗粒物质的吸附与堵塞相关性

堵塞问题是所有渗滤系统所必须研究的,因为它不仅影响到系统的水力负荷,而且也影响到系统的寿命。造成系统介质孔隙堵塞的原因主要有:悬浮物截留、吸附堵塞,化学沉淀堵塞,系统填料崩解堵塞以及微生物的生长造成的堵塞等。对于哪种作用起主导作用,不同学者持不同看法[7]。

4.1 吸附去除

人工土壤渗滤技术,可以有效去除污水中颗粒 COD。主要机理为颗粒 COD 通过与人工土壤表层的快速吸附作用而得到去除,随着试验的进行,将在土壤表面形成积累,并由此可能产生堵塞。

试验中调整进水颗粒 COD 浓度,使其进水与理论计算进水假设浓度一致,得到试验数据见图 3。

图 3 中颗粒 COD 浓度在系统表层的20 cm内随深度增加而迅速递减,这表明大部分悬浮物将被截留在人工土壤与污水接触的浅表层,由于过滤所造成的堵塞将主要发生在表层20 cm以上;随着人工土壤深度的增加,污水渗滤过程发生的吸附逐渐变小。

人工土壤渗滤中对颗粒 COD 的去除主要是在填料表层完成的,污水中超过 80 %的颗粒 COD 都被截留和吸附在表层,随着污水量的增加,吸附物质将逐

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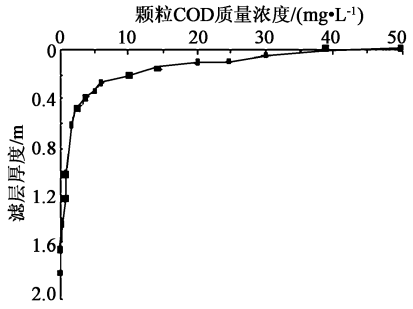

图 3 颗粒 COD 浓度随深度变化

渐的占据填料的空隙,最终导致堵塞。根据对堵塞系统的各个截面取样观察,堵塞基本都发生在表层,这也与图 3 的试验结果相吻合。

4.2 微生物生长量

系统中主要发生的微生物作用过程——好氧微生物降解。在连续运行的稳态生物处理系统中,一般同时进行着 3 个过程:(1) 有机物质的不断氧化分解(降解);(2) 微生物新细胞物质的不断合成;(3) 微生物老细胞物质的不断自身氧化衰亡。将这 3 个过程综合起来即可得出系统内新生长细胞物质的量,见表达式(1)。

$$\Delta S = aL_r - bS_a \quad (1)$$

式中 ΔS ——新生长的细胞物质,kg/d;

L_r ——所利用的营养物质,可以去除的 BOD_5 代替,kg/d;

S_a ——系统内原有的细胞物质,即微生物的量,kg;

a ——合成系数,即:合成的细胞物质/去除的 BOD_5;

b ——细胞自身氧化率或衰减系数,$1/d^{-1}$。

假设原水组分恒定,其所提供的营养物质为一定量。由于系统不存在污泥排放过程。因此,在达到平衡点后,可以认为微生物的增长量与微生物的衰减量相等,即 $\Delta S = 0$,微生物的总量保持不变。因此可以导出微生物的总量,见式(2)。

$$S_a = \frac{a}{b}L_r \quad (2)$$

计算结果表明:在系统稳定运行后,假设进水的 $\rho(BOD_5)$ 为200 mg/L,在填料表层20 cm范围内,微生物增长量所占孔隙体积分数为 3.7 %～5.3 %。

因此,人工土壤渗滤系统中单纯由于微生物生长所产生的堵塞问题并不严重,并不会造成明显的堵塞现象。

因此,微生物的生长一般不会导致系统内部产生堵塞。

5 系统堵塞及恢复

人工土壤渗滤系统由于对颗粒物的吸附造成逐渐堵塞,渗透速率将明显下降,甚至发生完全堵塞造成系统崩溃。

根据试验,测得人工土壤作为填料的系统污水进水的入渗速率递减曲线,通过完全落干试验测得系统入渗速率恢复曲线,如图 4。

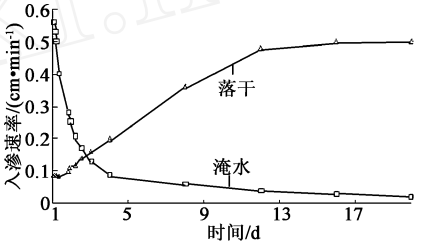

图 4 人工土壤入渗速率递减及恢复曲线

图 4 为试验得出的人工土壤入渗速率递减及恢复曲线。根据试验结果结合工程控制条件,系统取淹水3 h,落干3 h,可以取得良好的运行效果。

根据对渗滤过程吸附与堵塞机理的理解,系统采用干湿交替的方式即可对堵塞进行恢复,在淹水期,由于悬浮固体通过渗滤作用造成对表层的堵塞,使系统的入渗速率逐渐递减。落干期的作用之一就是使淹水期截留在表层的悬浮物固体得以氧化分解,渗滤池入渗性能逐渐恢复,使得系统可以长期稳定运行。

6 结论

人工土壤渗滤吸附作用造成系统有明显堵塞现象发生,但是采用淹水期与落干期交替运行方式,既保证了人工土壤快渗对污水中污染物质的快速吸附降解,又可有效解决由此造成的堵塞问题,保证系统的长期稳定运行。

人工土壤作为系统填料,不仅仅具有比表面积大,吸附能力强的优点,而且其合理的材料搭配和良好的微生物生境都为不同微生物种群的繁殖创造了条件,使得系统能保持稳定运行对吸附的颗粒物质及污水中的可降解物质都具有良好的去除效果。

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地中的氧和 NO_3^- 相当充分,因此,反硝化也能顺畅进行,反应速率也随之加快。在硝化与反硝化都能快速进行的条件下,总氮去除率得以迅速提高。

在气水比继续加大后,湿地后部溶解氧浓度得以升高,后部逐渐由厌氧环境向好氧环境转变,充分的好氧对反硝化不利,反硝化反应过程受阻。在前端充分硝化的基础上,硝态氮开始过量积累;另一方面,过大的曝气量易对湿地基质产生一定的冲刷,使已吸附于基质上的氮类物质被重新释放回湿地。而且曝气量过大容易使整个湿地系统处于好氧状态,破坏了湿地厌氧好氧交替进行的脱氮方式。因此总氮去除率开始出现下降。由图 4 可见,总氮去除率此时降低幅度达 13.4 %,由此说明硝化和反硝化任一反应过程受阻,湿地总氮去除率都会受到很大影响。

图 4 还反映了湿地出水硝态氮浓度随气水比的变化规律。硝态氮浓度开始时随气水比的增加而降低,在气水比为 6 时降到最低点,之后随气水比的增加而增加。呈现出与总氮去除率完全相反的变化规律。究其原因,开始时,氨氮硝化进行顺利,而且反应速率很快,硝酸盐浓度提高较快,但反硝化同样进行顺利,从图 4 中可见,总氮去除率变化曲线比氨氮去除率变化曲线要陡,说明反硝化反应速率比硝化反应速率快,因此硝化反应生成的硝态氮不会积累,而是很快参与到反硝化反应中被去除。所以硝态氮质量浓度开始从 8.1 mg/L降低到6.32 mg/L。在气水比继续增加的情况下,反硝化反应过程由于厌氧环境被破坏而受阻,硝化反应产生的硝态氮开始出现积累,一部分随出水而被带出,使出水中的硝态氮浓度开始升高。

3 结论

(1) 曝气会影响人工湿地内整体的溶解氧水平,在气水比 > 6 时,湿地出水溶解氧质量浓度基本维持在 0.73～0.8 mg/L。

(2) 在气水比为 6 时,人工湿地各污染物的去除率达到最大,COD 去除率为 85.6 %,TP 去除率为 70.9 %,TN 去除率为 83.1 %,NH_3-N 去除率为 84.2 %。出水 NO_3^--N 质量浓度最低,为6.32 mg/L。曝气能够很好地解决人工湿地脱氮效果不佳的问题。

(3) 曝气在一定程度上打破了人工湿地长期以来无动力的运行模式,使人工湿地处理效果具有明显的改善,尤其是湿地的脱氮效果。

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作者通信处 钟秋爽 210013 南京市虎踞北路 12 号综合楼南三楼
电话 (025) 83738129
E-mail zqs827@tom.com

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作者通信处 孙宗健 100875 北京师范大学水科学研究院
电话 (010) 62237824

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INTENSIVE PHOSPHORUS REMOVAL USING TP16 WITH HIGH CAPABILITY OF ACCUMULATING POLY-P ····· *Chen Liwei Cai Tianming Yin Honglan et al* (24)

Abstract Adopting SBR reactor , and using synthetic wastewater as material of reactor , it was researched the capability of PHB-accumulating and P-releasing under anaerobic condition , and that of PHB-decomposing and P-absorbing under aerobic condition using TP16. The result of experiment indicating :When cultured in acetic acid under aerobic conditions , TP16 could accumulate PHB. Ascending of PHB concentration in the strains was negatively correlated with descending of acetic acid concentration. While TP16 grew under anaerobic conditions , descending of acetic acid concentration in the supernatant was negatively correlated with ascending of PHB and P concentration.

Keywords biologic phosphate accumulation biological phosphate release absorbing acetic acid accumulating PHB

PROCESS OF FILTRATION AND DESALINATION FOR CIRCULATED COOLING WATER FROM THERMAL POWER PLANTS ····· *Yang Fengmin Zou Anhua Xing Yi et al* (26)

Abstract The circulated cooling water from a thermal power plant was treated by means of filtration and desalination , which could increase the concentration multiples of the circulated cooling water , also could reduce sewage water and fresh water supplement dosage , increasing water use rate in the power plants. The treatment process was comprised of the two filters , reverse osmosis desalination , and addition of chemical agents. After the processing , the reclaimed water could be used as supply water to the circulating cooling water.

Keywords circulated cooling water desalination continuous dynamic filters reverse osmosis

TREATMENT OF RAW BAMBOO FIBER WASTEWATER BY AIR-FLOATATION + A/O PROCESS ····· *Li Song Shan Shengdao Chen Bin et al* (29)

Abstract The wastewater of raw bamboo fiber with high concentration and low bio-degradability was treated by air-floatation + A/O process. The results showed that the removal rates of COD , SS , NH_4^+-N and colority reached 92 % , 95. 4 % , 64. 7 % and 90 % respectively , so the effluent met the wastewater discharge standard of industrial district. This process featured stable treatment effect , simple operation , as well as easy maintenance.

Keywords air-floatation A/O process raw bamboo fiber

PRACTICAL STUDIES ON THE TECHNOLOGY OF THE TOTAL WASTEWATER REGENERATION AND REUSE IN BAOTOU IRON AND STEEL CAMPARY ····· *Meng Yanxiao Hui Kegang Song Hua* (31)

Abstract It was studied on the choice of process flow and main parameters of total wastewater regeneration and reuse project in Baotou Iron and Steel Group ; it was also summarized the operating practice of the main facilities for this project. Which provided experience in the planning , design and construction of other similar projects.

Keywords iron and steel enterprise total wastewater regeneration and reuse

TREATMENT OF MUNICIPAL LANDFILL LEACHATE BY ANAEROBIC DIGESTION-SBR PROCESS ····· *Gao Feng Li Chen* (33)

Abstract Biological nitrogen and organic matter removal of municipal landfill leachate by ASBR-SBR system was investigated. The cycle length of both reactors was 12 h. Raw wastewater was fed to ASBR for anaerobic digestion. Four sorts HRT of ASBR from 28. 8 h to 72 h were tested. The result indicated that the COD removal achieved 41. 2 % and the effluent BOD_5/COD and BOD_5/NH_4^+-N ratio was 0. 41 and 4. 6 respectively when the HRT of ASBR was 36 h , it was in favor of aerobic biological treatment of organic matters and nitrogen. The effluent of ASBR whose HRT was 36 h was added to SBR for further treatment. And the effluent NH_4^+-N of SBR was about 11 mg/L , but the effluent COD concentration couldn't meet the discharging standard. The effluent COD could be lowered to less than 100 mg/L after coagulating sedimentation by PFS.

Keywords municipal landfill leachate anaerobic digestion ASBR SBR TN

THE TREATMENT OF LANDFILL LEACHATE BY COMBINATION OF TWO-PHASE ANAEROBIC AND OZONE ACTIVATED CARBON ····· *Huang Guoxin Huang Jiguo Jin Aifang* (36)

Abstract According to the properties of landfill leachate ,the combination process of two-phase anaerobic system ,which is composed of UBF acidification reatorand UASB mechanization reator ,and ozone activated carbon is used to treat landfill leachate. The results show that the optimum HRT of the UBF is 10. 3h ,the acidification phenomenon of the acidification phase is not occurring and the activity of the acid-producing bacteria being better ; the optimum sludge load of the UASB is 0. 122 g/(g·d) ,the function of resisting the changing load of the mechanization phase being better ;the two-phase anaerobic system can stably and high efficiently remove organics ,but the NH_3-N removal is not ideal ;the optimum dosage of activated carbon is 4.5×10^{-2} g/mL wastewater ;the optimum reaction time is 120 min ;the ozone activated carbon can handle organics better ,decolors prominently and has a defoaming function.

Keywords landfill leachate two-phase anaerobic ozone activated carbon

STUDY ON PARTICLE COD ADSORPTION AND CLOGGING IN CONSTRUCTED SOIL INFILTRATION ····· *Sun Zongjian Ding Aizhong Teng Yanguo* (39)

Abstract The percent of particle COD in total COD of domestic wastewater is between 30 %～60 % , of which only 20 %～35 % can be re-

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moved through sand infiltration test but no microbial influence. Adsorption of particle COD in constructed soil infiltration is completed by rapid contact adsorption , and above 80 % focuses on the surface layer within the depth of 20 cm. To seek the reason of clogging in the system , some experiments prove that clogging mostly results from the adsorption especially in surface layer , nevertheless microbial increment makes up 3. 7 %～5. 3 % in total porosity. And so a beneficial exploration is carried out on system restoration after clogging. Which makes sure that a suitable wet-dry cycle is a good way to solve the problem.

Keywords soil infiltration particle COD wastewater treatment adsorption clogging

INFLUENCE OF AERATING GAS-WATER RATIO ON TREATING EFFECT OF CONSTRUCTED WETLAND

Zhong Qiushuang Wang Shihe Sun Xiaowen et al (42)

Abstract The influence of different aerating gas-water ratio on treating effect of constructed wetland was discussed from dissolved oxygen. Seven kinds of gas-water ratios , 0 ,2 ,4 ,6 ,8 ,10 and 12 , were selected for test operation condition. The result showed that aeration could make the level of DO and treating effect improve obviously ,especially the removal rate of TN. Treating effect of wetlands was best when gas-water ratio was 6 , and removal rate of COD ,TP ,TN and NH_3-N was respectively up to 85. 6 % ,70. 9 % ,83. 1 % and 84. 2 % ,the concentration of NO_3^--N of the effluent was the lowest (6. 32 mg/L) .

Keywords constructed wetland aeration gas-water ratio DO treating effect

TREATMENT OF TOILET WASTEWATER FROM PARKS BY COIX CONSTRUCTED WETLAND

Li Yan Zhang Jian Li Weijiang et al (45)

Abstract Subsurface constructed wetland planted with Coix was used for the treatment of toilet wastewater from parks. The results showed that Coix grew well in constructed wetland. With a hydraulic loading rate of 8 cm/d and a hydraulic retention time of 1. 5 d , the average removal efficiencies of COD , NH_4-N^+ , TN and TP for constructed wetland were 56. 4 % , 53. 3 % , 49. 8 % and 73. 0 % , respectively. While for the system without Coix , the average removal efficiencies of COD , NH_4-N^+ , TN and TP were 46. 0 % , 50. 1 % , 49. 1 % and 68. 1 % , respectively. Coix can be applied to constructed wetland due to its possibility of pollutants removal as well as its higher economic benefit.

Keywords Coix constructed wetland toilet wastewater

NUMERICAL SIMULATION AND COAGULATION OF FLOW FIELD FOR FOLDED PLATE FLOCCULATOR

Zhang Bingbin Yang Kaiming Yang Xiaolin et al (47)

Abstract FLUENT analytic software was used to numerically simulate the flow field of different angles for a folded plate flocculator. Then it was compared the flow state of fluids in different folded plate flocculators , whose coagulation effects were analyzed according to the design conditions. Finally some measures were proposed for improving and enhancing the efficiency of the flocculator , which could guide the practical engineering design.

Keywords FLUENT folded plate flocculator numerical simulation

PREPARATION OF Fe-Mg-Al COMPOSITE FLOCCULANT FOR PRETREATMENT OF LANDFILL LEACHATE

Sang Yimin Gu Qingbao Sun Tichang et al (50)

Abstract In order to get optimal preparation conditions of Fe-Mg-Al composite flocculant (PFMAS) for pretreatment of landfill leachate , COD removals of landfill leachate were optimaized by jar test from concentration of raw $FeSO_4$,$MgSO_4$ and $Al_2(SO_4)_3$, mole ratio of three salts , aging temperature , aging time and dosage. The experimental results of a landfill leachate indicated that the optimal preparation conditions of PFMAS were as below: nFe(Ⅲ) ∶nMg(Ⅱ) ∶ nAl(Ⅲ) = 5 ∶0. 35 ∶0. 5 , aging temperature = 50 ℃ and aging time = 0. 5 h. After pretreatment by PFMAS , COD removal could reach over 60 %. PFMAS is a kind of inorganic macromolecular copolymer of Fe(Ⅲ) , Mg(Ⅱ) and Al(Ⅲ) , with long macromolecular chains and macrocosmic crystal structure.

Keywords landfill leachate inorganic polymer flocculant copolymer of Fe(Ⅲ) Mg(Ⅱ) and Al(Ⅲ) COD removal rate preparation optimization

THE STUDY ON THE INOCULA FOR BOD_5 DETERMINATION

Cui Jiansheng Wang Fang Wei Fusheng (54)

Abstract Three strains screened from the municipal wastewater were used to make the BOD_5 inocula for BOD_5 test. The best conditions for making the freeze dry power (BOD_5 inocula) were studied. The characteristics of the BOD_5 inocula were compared by test on soil leaching solution and commercial *Polyseed* of GGA 's and the actual wastewater 's BOD_5 determinition. The standard deviation of inocula , soil leaching solution and polyseed was 3. 60 ,8. 34 and 2. 87 mg/L respectively in GGA 's experiment , and 8. 5 ,33. 2 and 6. 0 mg/L in the test of actual wasterwater.

Keywords Biochemical Oxygen Demand BOD_5 inocula repeatability

EVALUATION AND IMPROVING ON THE METHODS OF MONITORING COD IN SEDIMENT-LADEN RIVER

He Zhijuan Xiao Xiangqun Mao Yuxia et al (57)

Abstract Based on the analysis of the characteristics of sediments in the Yellow River and the impacts of sediments on the water environments , this paper analyzed the primary problem which exists in monitoring COD in Yellow River with the prevenient and current monitoring methods. According to which , an improved method of monitoring COD was put forward. In this method , the concept of non-attenuation COD value of sediment was introduced and the computing formula of the value in lower reaches of the Yellow River was got by experimentation. The experiments

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