Preparation and application of iron-based composite materials for the removal of antimony from aqueous solution*

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Abstract: The pollution - antimony (Sb) species in Natural Waters has drawn more then More attention due To their high cumulative toxicity then carcinogenicity . In recentyears , It ? highly in demand to Develop efficient and Economical Technologies to Address the increasing Pollution of Antimony all over World . iron-based composite materials (e . G . Fe ^{0}, Fe3 0 4 , and femno$_x$) Have become a hotspot the in the field of antimony Treatment based On their various Advantages, including High adsorptioncapacity, easy separation and recycling, Safety and environmental friendliness, etc . This article summarizes This Preparation, modification and application The Iron - basedcomposite Materials based on zero-valent Iron , ferric oxide and iron Bimetallic oxide For , removal of Sb ( ]|) and Sb (V) in Water. The adsorption mechanisms of Sb (M) and Sb (V) by Different iron-based composite materials are emphatically discussed. The effects in temperature, PH and Co-existing ions On Sb adsorption of iron-basedComposite materials are also investigated , Find this Optimal adsorption condition . Finally , some primary issues Antimony removal are proposed and this outlook of key developing Trends on the Antimony removal by iron-based Composite materials are presented .

Keywords: Iron - based composite material ! Modification ; Antimony ; Adsorption mechanism; influencing factor

Contents

1. Introduction

2. The removal - Sb by zero-valent iron based composite materials

2.1 The physical modification to nano-fe

2.2 The loading modification to nano-fe

2.3 The stabilization modification of nano-fe

3. The removal - Sb by ferric oxide based composite materials

3.1 The composite materials based on Magnetic

Fe 3 0 4

3.2 The composite materials based on ferric oxide

Hydrate

4. The removal - Sb by Iron bimetallic oxide based composite Materials

4.1 Iron then manganese oxides

4.2 Other iron bimetallic oxides

5. Conclusion

1. Introduction

as an important and non-renewable strategic metal , Antimony and its Composite in flame retardant , alloy , ceramic , pigments and synthetic fibres, areas has been widely applied . but , antimony to human body with high Cumulative toxicity and carcinogenicity , The toxicity order of different valence antimony is : SBW >Sb (n) >sb(v),where Sb (n) has the toxicity of " Sb"(V"") 1   times [3]. to protect the human body. healthy , The United States and the European Union make antimony a priority control pollutant , United States to specify that the amount of antimony in drinking water is not greater than 6 ^ g/l, all EU's

is not   to 5 PG / L .

The source of antimony contaminants in China is more extensive , government controls on antimony also very strict " Living Drinking water hygienic standard (GB57494006) to specify the antimony content limit is 5 pg /Lmunicipal Wastewater Treatment Plant pollution Object emission standard (Solicit comments Draft) emission limits for total antimony to 5   pg/L . because China is the world's antimony reserves and antimony ore production the largest country , Therefore, our country is suffering from the mining of antimony ore to bring the Environmental Pollution . other , with our printing and dyeing, flame retardants and semiconductors Rapid development of industries , The use of antimony is increasing every year , into a The step increases the environmental risks and hazards associated with antimony contaminants .

in the natural environment , antimony is mainly in three-price (Sb (n)) and five-price (Sb(V)) form exists [m]. Sb (n)) can be natural waters or Its sediments Fe (OH) 3, Mn0 2 adsorption oxidation to Sb (V), So in the oxidation state , the Sb main (Sb(OH)$_6$-(- Sb(V)) form presence [8], Restore status under Sb(OH) 3, Sb(OH) 2 $^+$ and Sb ((OH) 4 form save in . normal body of water , antimony concentration minimum , in   . 1 ppb The following , But the investigation found that the antimony content in some contaminated water was severe exceeded , even reached ppm level , has been a serious threat to humanity health . For example , on 2 14 ~2 16 Year survey found in Chinathe highest antimony content in waters near Hunan Tin mine is 22 98   pg/L , average of 386   pg/l , Antimony in the nearby drinking water source contains amount to 47.6 ~ 6 pg/ L, has been severely higher than China drinking water label standard [6 7]; and both Guizhou and Guangxi Liujiang , Gansu Tai Shek River , Shaanxi Western Han Shui and Sichuan Jialing River basin due to via antimony mine , At present , has found multiple signs of antimony exceeding ., Some exceed hundreds of times [8] [9]; Antimony contamination problems in some foreign regions , as in snow --5 residential ground water near an abandoned antimony mine Sb content Up to 126 pg/ L , far exceed EU standards [M]; US-Allah scar antimony concentration in a river near an antimony mine 72   PG /L, Next tour 8 km The detection of antimony at the level is still high . All. at the same time , questionnaire in some areas of nephritis , hepatitis , The incidence of pneumonia and cancer and The excessive intake of antimony has a significant connection [4]. so , World wide The problem of antimony contamination in is getting worse . , developing cost-effective antimony pollution the processing technology has significant significance .

There are a number of ways to remove antimony in water bodies at present , Research and use mostly have : electrochemical method , Chemical Precipitation Method ,Microbial processing method , , etc. [M], where the adsorption is for its efficient economy , Operations Simple are widely used for benefits such as . the adsorption method for antimony removal can be divided into biological adsorption , Carbon material adsorption and metal oxygen Object adsorption etc [E3, 14]. where the iron-based composite has a ratio table area large , Strong surface reactivity , Cheap and easy , structure and functionality can be Benefits of Predictive strong , Ease of separation and recovery , and more and more are being developed investigate the removal of antimony . 0-valent iron in iron-based composites you can use the

Sb (v) revert to Sb (m), To form A SB (0 H) 3 precipitate solid present antimony removal ; Fe-mn oxides can oxidize Sb(m) To SB (v), to reduce the toxicity of antimony by using its own adsorption characteristics of the real present antimony removal . however , iron-based composites also exist _ Insufficient : such as iron matrix composites in the water body easy to reunite , Poor dispersion ; Ticki composite materials are extremely susceptible to oxidation under

aerobic conditions , easy under acidic conditions corrode , Active ; These adverse factors seriously affect iron-based composites Adsorption capacity of antimony , restrict its application in the actual project . because this , to enter _ Step improve the removal effect of ferrous composites on antimony , the - aspect can be modified with starch ,CMC , gelatin, and so on ~ Stabilizer to Iron Base composite controls , to make it have good oxidation resistance and Corrosion-resistant ; On the other hand , the will base composites with carbon-based materials or Other metal oxides combined [M], to add composite particles scatter; ; can also be based on the nature of antimony in different forms of water , on iron Base composite surface decoration , introduce a specific adsorption or People chemical stability strong functional groups , To enhance the adsorption activity and suction Attach Ability , reduces the occurrence of a reunion .

This article summarizes the domestic and foreign iron-based composite materials in the removal of water from the Research advances in different forms of antimony contaminants , highlights na 0-valent Iron composite ,, iron oxide composite and iron-based double gold the preparation or improvement of three kinds of iron-matrix composite materials for oxides and their modification to sb(m) and SB (v) processing Effect , analyzes a variety of iron-based adsorption mechanism of composite materials on different forms of antimony in water , adsorption conditions and apply to, Finally, the problems existing in the current research and The application are pointed out . ,predicts iron-matrix composites removal of water Development prospects and development direction of antimony contaminants .

2. removal of antimony by 0-valent Iron composites

Nano 0-valent Iron (Fe   ) is water pollution treatment at home and abroad in recent years Field development of new nano-environment functional Materials , its raw material to source wide , high reactive activity , Low processing cost , can be restored by , micro-power Solution , adsorption , A variety of actions such as sedimentation to remove organic or inorganic contaminants in water dye , Special at lead , Arsenic , Chrome , Zinc , copper and other heavy metal sewage treatment side masks have a greater advantage , thus getting extensive research and application [M]. with increased pollutant antimony in the environment , Many scholars start to Fe^0 removal of antimony in water by [E5 '] . such as Dai etc [E7] use liquid phase Restore nanometer level Fe^0 and used with Sb (m) and Sb (V) Removal . Research Discovery Nano Fe^0 best to adsorb antimony contaminants pH to 4, in min the removal rate of antimony in water has reached 90%, describes Nano Fe [0] has a high removal capability for antimony . but no 0 Valence Iron itself has _ fixed defect , such as antioxidant weak , easy to blunt to adsorbed antimony and other metal ions susceptible to natural organic compounds and others altogether deposit ions , in aqueous solution Easy reunion , Not easy to detach wait , because this to overcome Fe^0 Limitations , To improve Fe [0] adsorption of antimony can , Many scholars on Nano Fe^0 improved , includes a pair of Fe [0] in line load or stabilizer stabilizer , for surface preprocessing , and with the help of External magnetic field , physical methods such as ultrasound [M] .

2.1 Nano Fe [0] The physical method of improves

the physical and chemical effects of the magnetic field and electrochemical effects can speed up the water in a movement of some ions , flocculation of fortified bodies ,adsorption, etc. , and enables separation of magnetic and non-magnetic substances , benefit pollutant , adsorbent, and separate regeneration of water body . Research discovery using nano Fe^0 Adsorption Water with antimony , the presence of a magnetic field can accelerate Fe^0 Electronic delivery of the surface , To defer Fe^0 Surface passivation film formation , To promote Fe^0 Corrosion , thereby Increase Fe^0 to Sb removal rate [M].

Li , and so on [M] The studies the effect of an applied magnetic field on a Fe [0] powder to water solution Sb(V) sorption effect , The experiments were tested with different magnetic field intensity Fe^0 powder to Sb (V) sorption capability , results found Fe^0 powder to Sb (V)) the adsorption law of the is more consistent with pseudo-first-level adsorption dynamic equation . on inlet Sb(V) concentration of 5~40mg /L , external magnetic field to make Fe^0 to Sb(V) The adsorption rate constants for are increased by 5 ~7 Times , Fe [0] to Sb (V) The ability to remove is determined by the 1 mg/ g mentioning High to ? 2 mg / G . in the presence of an applied magnetic field , so /-,NO,; -,Cl:' C 0 3^{2-}, Si 0 3^{2-} and humic substances to Fe^0 Adsorption Sb (V) The impact of is also greatly reduced .

Xu , and so on [122] using commercially available nano 0-valent iron in a weak magnetic field of to use for Sb(m) remove . the study was tested separately in the different nano Fe^0 Add amount ,Fe ( ) n) Add Quantity , Sb (m) initial concentration , blending rate and PH weak magnetic field has no pair Sb (m) for removal rate and effect of removal . The results of the Experiment show that in the case of weak magnetic fields, Sb (m) The removal rate of is under different conditions shows varying degrees of improvement (as shown 1 shows). in particular on add Fe (n) "" under this influence factor , When there is a weak magnetic field Sb (the) removal rate for m"" is no weak magnetic field when the 6 ~8 double about . phase off analysis shows , plus weak magnetic field to promote nano Fe^0 Corrosion reaction , Postpone surface passivation , To promote the Sb (m) Remove the rate . xps test show Sb (the removal mechanism for (m) is mainly Sb (m) First oxidized in a constantly stirring aqueous solution to Sb (V),then adsorbed to the Fe^0 a formed after corrosion and oxidation on iron oxides to remove .

2.2 Nano Fe ^{0} Improved Load method for

Activated Carbon , Carbon based materials such as graphene and zeolite , kaolinite , Synthetic resins etc ,? has a large surface area and strong Mechanical Strength , with rich pore structure and good dispersibility , 0 nm Fe load can be effectively improved on these materials Fe^0 , , stability , improve its size and dispersion , reduce nano Fe^0"reunion " , To promote Fe^0 Migration in the environment ; another , a Some carriers themselves have strong adsorption capabilities , to further improve

diagram 1 nano with or without a weak magnetic field under different conditions Fe^0 to Sb (n) Removal Rate of comparison chart (ZVI The amount of dosing is0.1g/l, different levels of processing within each series are represented by the size of the Circle , such as circular Circle Greater Rep PH The greater the value , the longer theaging time, and so on ; where pH value is 3,5, 7, 9 ; initial Sb (H) concentration is 1,, 0 mg/l; Aging Time is 0, , 20 min ; Add Fe (n-) concentration 0 , 2 , 4, 6 mg/l ; Churn mix rate to , ,400 r/min ; The amount of isopropyl alcohol is 1 , 10,100 MM)

Fig. 1 Summary of rate constants for Sb (melon)sequestration by ZVI under Different treatment conditions with and without external weak magnetic field (the added ZVI of 0.1 g/l; PH of 3, 5, 7, and 9; Initial Sb (H) concentration of 1, 5, mg/l; Aging time of 0, Min; Added Fe (N)] of 0, 2, 4, 6 mg/l; Mixing rate of r/min; Added isopropanol of 1, 5, M. MM. The circle size represents the degree of treatment, the bigger the circle, the higher the PH and the longer time)

Fe^0 antimony removal capability for .

will nanometer Fe ^{0} loaded with a functional carbon na m -tube, Then add this composite adsorption material (Fe (0) ~ CNT) for in water 3 Dagger (1) and 8Dagger (¥) remove . on $^{[J}$ =5 ,, vs. single Pure, Fe^0 compared to carbon nanotubes ,Fe^0 - Carbon nanotube composites to Sb ((H) + Sb((V) show strong adsorption capability , its to The maximum adsorption capacity of both is reached mg /g. BET open fruit Show load Fe^0 after Fe (0) ~CNT specific surface area is 132 m ^{2}/ G , compared to the load-less carbon nanotubes (m^2 / G) have a reference to high . SEM,XRD The results show a large number of granular Fe^0 Negative on carbon nanotubes , effectively improves Nano Fe^0 stability . the Kinetic Adsorption experiment shows that ,Fe (0) ~CNT to Sb (H) and Sb (V) The adsorption process conforms to the pseudo two level kinetic model , its adsorption

rate constants are 0.0015 and 0.0011 mgkg * min). the desorption regeneration Experiment shows the use of 0 . 5 M Hydrochloric acid of as desorption solution Take off 5after , Fe （6）~ CNT to Sb (H) and Sb (V) Suction With ability to only decrease about 20%, indicates that the composite material in the actual antimony The has great potential for polluting wastewater treatment Applications .

kaolinite , bentonite , perlite etc ^{E6,} [25,26] Industrial or natural Minerals due to material from a wide range , cost-effective and has a larger table area and good adsorption performance , In the heavy metal adsorption also get wide application , thus more and more scholars are studying its treatment of antimony-containing wastewater work with ^{B6,} ? $^{]}$. saeidnia etc ^{M} uses the VISUAL Minteq 3. 1 Software simulation will Fe^0 load separately on kaolinite , Bentonite and perlite , and then use it for antimony ore waste water Place rationale , Examines the dosing and solution of adsorbed materials PH for antimony ore waste effects of water treatment . simulation results show antimony ore wastewater

pH by 1 to 2, in solution voted Ghana m Fe ^{0} The is concentrated by 7. 5 increase to 5 mg/L when , The removal rate of antimony quickly accelerated . forecast model Show load nano Fe ^{0} kaolinite after , bentonite , perlite three The maximum adsorption capacity of antimony for composites is 3. 9246 and

3. 1 mg / G . after an actual test in the lab on the basis of the requirements and conditions for establishing a forecast model , related data to prove the model predictive datais highly accurate , indicates kaolinite , bentonite , perlite, etc. as Nano Fe^0 carrier is more feasible .

compared to traditional zeolite , P The Zeolite has a three-dimensional 12 ring hole structure , show strong cation exchange characteristics and high adsorptionperformance , These features make P zeolite and Nano Fe^0 Easier to combine . Zhou etc $^{E5\ ]}$ with ultrasound p zeolite dispersed in FeCl3 Solution , Yes after the nitrogen protection access NaBH4 solution Get Fe^0-J zeolite composite adsorbent material . to use this composite in the nitrogen protection environment in aqueous solution Sb (H)Removal , results found , with simple na m Fe^0 compared to , This material is better displayed by Yu Ying's entry The dispersibility and stronger antimony removal capability of the . When the adsorption material is added to 1 g/L when ,Fe^0-J zeolite composite to Sb(H) adsorption The process is more in line with the pseudo level two kinetic equation , Balanced adsorption capacity up to No . 8 pm 0 L / G , its adsorption isotherm on antimony is more consistent with the Freundlich model , and iron in Sb (H) The restore and adsorption process for The plays a major role in . adsorptive product XPS analysis Results show Sb(H) restore reaction strong , final product Sb(0) accounts for up to 80%. EDX test shows p zeolite the nano Fe^0 on Sb(H) The Restore and adsorption activity of is more than the sticky attached to zeolite surface Fe^0 Stronger .

ion-exchange resins have high selectivity , Exchange Adsorption capacity large , adsorbed - Good advantages of desorption reversibility , So some researchers will be the ion Exchange resins with nano Fe^0 combines , Preparing composite adsorbent materials using on antimony removal & $^]$. such as akarsu etc in preparation nano Fe^0

Review and review

in the process of – strong anion exchange Resins (amberlite IRA 458 , to make the generated Fe ^{0} can load on the resin surface . will make ready [] ^{0}- to grease composite forSb (m) and Sb (V) Suction with Remove and not load Fe^0 amberlite IRA 458 compare . Preliminary adsorption sb(m) and Sb (v) The experiment shows that , A tree that is not loaded Grease only Sb (V) with) adsorption , and after the load Fe^0 - on the Grease bar Up to , sb (m) + sb ((v) has strong absorptive capacity . pH affect experiment proofFe ^{0} - adsorption of antimony on lipid materials by PH for affect smaller , its appropriate PH Extends . on pH value 3 ~ 10 when ,Fe ^{0} - to the lipid material to Sb (1) has a higher removal rate ; and in PH is 3~8 , Sb (V) has a higher removal rate . when sb()) and Sb (v) Initial concentration of tenmg/l, temperature is   c , PH =7 , the composites have the same removal rate as 90% around , and not load Fe ^{0} The resin for has a higher adsorption capacity than the previous 4 times , fully demonstrates the success of this load method .

is visible from the top , The uses the load to apply the nanometer Fe ^{0} and other surface area wide , Strong adsorption , Stable and dispersive good material material combination , can significantly improve iron matrix composites in antimony-containing wastewater dispersion and adsorption performance . but load process and carrier material adsorption of 0-valent Iron composites for , Degradation and aging performance all have a big impact , should therefore be based on the characteristics of different antimony-containing wastewater Select the load material and optimize the load process .

2.3 Nano Fe ^{0} Stabilizing the Stabilizer

through electrostatic repulsion and steric steric inhibition , in Fe ^{0} Preparation Procedure To add _ Stabilizer to effectively control Fe ^{0} the nucleation of length ,simultaneous stabilizer wrap in Fe ^{0} Surface . This stabilizing, iron-based Composites when treating antimony-containing wastewater , because of the stabilizer's wrappingmake Fe ^{0} particles are isolated from each other , weakened nano Fe ^{0} between particles Magnetic Attraction , Better overcomes the small size effect of the nanoparticlesshould be , phenomenon of surface electron effects and proximity effects .

The presence of a stabilizer causes the Fe^0 Antioxidant Enhancements , stability Increase plus . current , for nano Fe ^{0}

stabilizing stabilizer main Lake Powder , carboxy methyl cellulose sodium (CMC) and gelatin etc ~ ,,.

Zhao , and so on % in nanometer Fe ^{0} A proper amount of is introduced in the preparation process polyvinyl alcohol (PVA 424),, Hydrochloric acid and Glutaraldehyde solution formation package Inside Fe^{2+} small particles of the ions , and then use the Nabh $_4$ Ethanol Solution To restore , to make Nano Fe ^{0} -! Aldehyde-polyvinyl alcohol composite adsorbent material (Fe^0 ->VA). tested , This material has a size of 2. 04± 0. The mm , porosity is approximately 8% and has good porosity permeability , very suitable contact reaction to metal ions . SEM and XRD results show nanometer Fe^0 Evenly embedded in polyvinyl alcohol surface and interior , the facilitates the continuous availability of antimony in the composite and aqueous solution contact and reaction . other ,Fe^0 -> VA The compression strength of the reaches 7± 4.8 N , is perfect for use in a fluidized or immobilized bed . power study results show Fe ^{0} -> VA adsorbed material to Sb (1) and Sb (V) The adsorption process for is more in line with the pseudo two kinetic model . when original start Sb (m) and Sb(V) concentration 0 ~20 mg / L , adsorbed material cast plus 2 g / L , PH is 7.0, reaction temperature is C , Fe ^{0} - PVA to Sb(m) and Sb (V) The adsorption isotherm of the is more consistent with the Langmuir model , the Maximum adsorption capacity of the composite at this time to 6 . and 1., mg/ g, vs. General adsorption materials Stronger adsorption ability [64,35]. The effects of several coexisting ions in nature on the "" "" " antimony adsorption process from large to small as 0 4 $^{3-}$> P 0 4 $^{3-}$> SiO $_4$ ^{4} - > So $_4$ ^{2} - > NO $_3$ - > Cl -. because of the AsO $_4$ ^{3} - and P 0 4^3 $_-$ property with Sb (OH) 6 $^-$ and Sb (OH) 3 similar , because of the with the most significant removal of antimony . XPS and FTIR Test Display Fe ^{0} - PVA to Sb (1) and Sb (V) The adsorption of belongs to chemical adsorption , and the Sb (m)has stronger adsorption than Sb (V). Fe^0->VA High efficiency during adsorption (, the stability and low toxicity characteristics of the confirm the material The success of the material in antimony pollution treatment .

carboxy methyl cellulose sodium (CMC) is an environment friendly profile material , can degrade naturally , often used as dispersion of nanoparticles agent [B6']. withCMC to Nano Fe ^{0} for surface modification and cladding , can enhance nano Fe^0 static potential resistance between , To prepare a grain path smaller , more stable nano Fe^0 . Zhou Zhe M prepared na m CMC^Fe ^{0} Modified composite and study its absorption of antimony in water Attach effect . SEM and TEM images showing Nano Fe^0 wrapped inCMC^Fe^0 The interior or inlay of the particle on its surface . CMC^Fe^0 the particle is not a normal sphere , With an average diameter of nm around , than Pure Nano Fe^0particle diameter slightly increased , but CMC^ Fe. medium nanometer Fe^0 granular and simple Fe^0 particles compared to , Has a smaller particle size , only about to NMaround . antimony adsorption experiment shows , with antimony initial concentration Increase ,CMC ~Antimony adsorption capacity of ~Fe^0 + increase . when antimony firstinitial concentration is mg / L , CMC - Fe^0 to Sb (dish) and Sb (V) The adsorption capacity of is up to mg / G around , is significantly higher in the same condition not stabilized nano Fe^0 , at the same time CMC ^ Fe^0 stability , Performance for decentralization and resilience is also significantly changed goodness . same condition ,CMC ~Fe^0 to Sb (V) The removal rate for is better than Sb (1) . Long-time response ,CMC ^ Fe^0 for XPS and TEM results show , It is good to maintain granular structure and guarantee fixed antimony will not be released two times . at the same time CMC~ Fe^0 on suction the attachment gradually becomes loose and produces a partial lamellar structure and breaks the movie , Provides more active points for adsorption of heavy metal contaminants , Enhanced material removal .

Table 1 displays a variety of 0-valent iron composites under optimal conditions to water Sb(m) and Sb(V) adsorption effect . from the table can be find , different stabilizers or carrier or physical conditions to composite adsorbents The optimal adsorption conditions for the material and the adsorption capacity of antimony are significant. , so the 0-valent Iron Composite should be designed according to the characteristics of antimony-containing wastewater. So that it can be specific to remove the different water quality under the conditions of antimony-containing pollutants .

3. Iron oxide composite paving removal

Iron oxide composite adsorbent material because of low preparation cost , Adsorption powerful , particle spread evenly , is widely used for features such as ease of collection, "" to treat waste water contaminated with heavy metals or

organic pollutants ? ~ All . in heavy metal pollution treatment Area , iron oxide composites commonly used for removal Cr (w),Hg(n),n(N),Cu (N),Pb(n) $ heavily, & 2 ~ All , due to antimony contamination in recent years , More and more scholars To start improving iron oxide materials for removal of contaminants Antimony . Current application of more iron oxides in antimony pollution treatment the main to include magnetic Fe3 0 4 [@' + and hydrated ferric oxide all ,.

3.1 Magnetic Fe3 0 4 Composite

F & O4 Magnetic nanoparticles because of the simple preparation process , Cheap , Low Poison , with nanometer size effect , extremely high specific surface area and good suction With performance is widely considered [a. Research certificate when fego# particle size less than nm when , at ambient temperature performance ultra-smooth magnetic ^{M} , under directional control of external magnetic field , through a cleaning and desorption operation , can quickly detach the target from the multi-component environment . These features allow Many scholars to apply it to the treatment of antimony-containing wastewater . Shan etc [51] using commercially available magnetic nanoFe3 0 4 The material is used with Trace in water Sb(m) removal , at temperature   C , PH is

4. 1, Oscillation frequency is 160 R / min , Fe3 0 4 Add the amount of 0. 1 g/l when , Langmuir The model can better describe the nano Fe_3O_4 to Sb (1) thermodynamic process for adsorption , at this time Fe3 0 4 to Sb (1) for adsorption ability to reach . 9 mg / G , is much higher than graphite brightening (8.06 mg// g) , bentonite (0. mg /G) [153], Carbon nanotubes (0.33 mg/) commonly used adsorbents g) M . Experiment proven magnetic nano Fe3 0 4 exhibits strong adsorption affinity for antimony .

but Nano Fe3 0 4 also shows some missing in the application process Point , as corrosion and reunion in acidic environment , and then lose the nanometer materialMaterial Special Properties , make the adsorption and adsorption selectivity worse , because this to further enhance the nano Fe3 0 4 adsorption of pollutant antimony to ,,improve nano Fe3 0 4 vulnerability to deactivation and reunion , To original nano Fe3 0 4 material for modification . For example in Fe3 0 4 surface draw into stable functional groups , make it available with antimony contaminants special heterosexual affinity adsorption ; or Fe3 0 4 is loaded with some corrosion-resistant , than table area large and easily dispersed material , fully improve its dispersibility can wait ^{M} .

Shan is fully aware of the nano Fe3 0 4 Insufficient for after , using hematite to improve raw materials , through the heterogeneous nucleation Technology , will Fe 2 0 3coated in Fe 3 0 4 surface of , To produce a red iron ore modified magnetic nanomaterials (MNP @ hematite). to use this complex to be used for Sb (1) and compare to raw material . Dynamics Experiment Discovery MNP@ hematite adsorption of antimony compared to to conform to the pseudo-level dynamics model . Adsorption thermodynamics research shows MNP@ hematite adsorption on antimony reached . 7 mg / G , is original Fe3 0 4 antimony adsorption capacity about twice times ,Description Fe3 0 4 in Package 0 Fe2 3 to Sb (1) The adsorption affinity of the is further enhanced . modified MNP@ hematite Composite pair Sb (1) suction with stability significantly enhanced , 3 ~ ph value to remove antimony The effect is small and . on initial Sb(1) to ^ G / L , PH is 7, adsorption dose is 0.1 G / L , coexisting anion concentrations (P 0 $4^{3'}$ SiO_4^4 – , So $_4^2$ – , NO_3 – ,Cl – etc up to ten mM when ,MNP @ hematite The effect of the adsorbed antimony is almost unaffected . applies this compound to the adsorption removal of antimony in tap water , in tap water PH is 7.64 ,TOC to 0. mg / L , Total hardness is MB mg/l (to CaC 0 3 Meter) , Antimony Initial concentration is 194. 25± 0. 闚 / L , through MNP@ hematite The concentration of antimony in the tap water processed by changes to

1.96 ± 0.25 ^ G / L , fully compliant with national drinking water standards off rule (5 net / L, confirmed), MNP @ hematite Potential applicability of in actual antimonypollution treatment.

Graphite oxide (Go) is a commonly used heavy metal adsorbent. material , Yang Xiuzhen [will go for water Sb(m) adsorption removal , Discovery Go Because it is more hydrophilic , difficult and moisture after antimony adsorption from . so that for The sake of go separate from water , Yang Xiuzhen the nano Fe3 0 4 load on graphene oxide ,prepared Fe3 0 4 /go compound Material . Magnetic test show F&O4 /go with Super paramagnetic magnetism , Its ability to achieve rapid separation from liquid phase under magnetic field , in Magnetic The field disappears and quickly disperse to the liquid phase . on adsorption Sb (m) experiment , temperature increase is beneficial to F&O4/ go to Sb (m)

adsorption , the kind of coexistence ion concentrations are determined by the 0 grows to mg / L , F & O4 / Go to Sb (m) The adsorption effect of is almost unaffected ring , removal rate all in 97% above . adsorption kinetics and thermodynamics research investigate show F & O4 / Go to Sb (m) The adsorption of conforms to pseudo-level Mechanical Model , Its adsorption isotherm conforms to Langmuir model . when 298 K ,Fe_3O_4/ go to Sb(M) Maximum adsorption capacity up9mg/ . Adsorption thermodynamic parameters as and AG Displays F &O4 /go to Sb (m) The adsorption reaction is the absorption and entropy increase of the procedure . adsorption XPS results show Fe_3O_4 / Go the antimony on the surface is Sb_2O5 in the form of , Description Sb (m) occurs during the adsorption process Redox reaction . Select 0. 1 MD / L for EDTA is regenerated agent ,F & O4 / Go has a regeneration rate of up to 99%, shows a good Recycle sex .

then Yang Xiuzhen [M] The first uses the direct evaporation method to prepare the quartz sand /F& O4 complex , then load oxidized graphene in this composite quartz sand / Fe_3O_4/go(qfgo) composite material . at pH to 3 ~ 9 ,qfgo to Sb ("")) adsorption effect more than good , 298 K , Its adsorption capacity is approximately 2. + mg/ g . to full impersonation qfgo dynamic process of treating actual antimony-containing wastewater , on Sb (m) column adsorption experiment for , results show Thomas andYoon- Nelson model better describes qfgo adsorption column pair Sb

(m) adsorption process .

B Dagger to wait [First use in -situ coprecipitation method Fe_3O_4 Negative on halloysite nanotubes (hnts) in , prepared Hnts/Fe_3O_4, Then the silane coupling agent is grafted to the hnts/ fego by the condensation reaction # surface (,) Surface Group modified , for m- hnts/Fe_3O_4 Composite . Use this material for antimony-containing wastewater into the line initial adsorption , finds 3- piperazine propyl methyl dimethyl siloxane alkanes (KH 408 type silane coupling agent) decorated by m ~ hnts / Fe_3O_4material to a separate Sb (V) Has the strongest absorptive capacity . But when Sb(V) and Cr (W) exists when , aniline methyl three ethyl siloxane (KH -42 type) decorated byKH 42~ hnts /

Fego # to Sb (V) The has the strongest absorptive capacity , also for Cr (W) for removal efficiency is also higher . using KH42~hnts/fe 3O4 Remove Sb (V) on, find PH =2when antimony adsorption is best , its to Sb (V) The adsorption isotherm for is more consistent with the Langmuir model . on pH = 2, temperature is 303 K, no Cr (W) , , KH42- Hnts/fe3o4 to Sb (V) adsorption) capacity 30.49 mg/g, and when Cr(W) concentration is . 0 mg/l , its adsorption capacity for antimony amount to 53.06 mg/g ,Description Cr (w) The presence of facilitates the KH42-hnts/fe_3O_4 to Sb (V) adsorption . atr-ftir and XPS The results of the display , when Cr (w) and Sb (V) exists at the same time when , section Cr (w) The is first adsorbed to the KH 42- hnts/fe 3 O 4 surface of , binding to functional groups on the surface of the material , and then the waterfree states Sb(V) combination in KH 42-hnts/fe3 O 4 Surface build Cr(W) -)-Sb(V) complex , Implementation Sb(V) Rapid remove .

Li , and so on [B7] simultaneous use of tetraethyl silane and N-octyl Tri-B Siloxane to Magnetic nano feso# to be wrapped and immobilized thereby prepare to C8~ Fe_3O_4@ SiO_2 Composite and used in water trace Sb (m) and Sb (V ( ) remove . Research found in the water to add a to the "" heptane ammonium carbamate (APDC) to promote C8 ~fe3o4 @SiO_2 to Sb (m) and Sb (V) specific removal of . on pH value 4.5 ~6 when , C 8 -fe_3O_4@SiO_2 main removal Sb (m); and PH The value is 2~3 , Sb (m) andSb (V) will all be gone other than , This behavior is Sb (m) and Sb (V) separation or specificity of Removal provides an effective way to . when apdc concentration mg/l , Sb (m) and Sb (V) adsorption of PH The value is 5 and 2 , C 8~ Fe_3O_4 @ SiO_2 to water Sb (m) and (Sb (V) , Large adsorption capacity 3. 5 and 2. 3 mg/g.

research shows that in Nano - Fe ; O4 Add some gold during the preparation process generic elements such as Zn,Co ,Cu,Ce can control Fe_3O_4 particle size growth ,further decrease Fe_3O_4 's granularity , Increase surface adsorption active point , to help enhance Fe; O4 adsorption of heavy metals Force M. Qi etc [ ] use solvent hot-synthesis method Ce (m) Doping to nanometer Fe_3O_4 , prepared as Ce^m ~ Fe 3 O 4 Composite . BET results show with original Ce / (Ce /[, +] + () Fe) % mole increase big ,its surface area increases gradually , when the mole ratio is 0.5 , Ce^m - Fe_3O_4 the specific surface area of the is 152. 2 m^2/g, [], no plus Ce(m) on feso* surface area 2 m^2/g) ,4 times many . will Ce^m- Fe ; O4 is used for Sb (m) and Sb (V) Removal , Dynamic Experiment display Show Ce^m ~Fe_3O_4 to Sb (m) and Sb (V)

The adsorption process for isconform to Elovich and pseudo two level dynamics model . with material $Ce \wedge Ce + Fe$) mole ratio from 0 grow to $0.5, Ce^m\text{-}fe_3O_4$ to Sb (m) and Sb (V) The maximum adsorption capacity of the is separated by the 4. , and mg/g , grow to ? and ,, mg/g . Thermal

The analysis indicates that , Langmuir The model can better fit the Ce^m - Fe ; O 4 to Sb (m) and Sb (V) Thermodynamic adsorption process for . when $Ce \wedge Ce + Fe$) ratio to 0.5 , Ce^m - Fe $_3$ O $_4$ to Sb (m) and Sb (V) Compute) adsorption capacity up to 224. and 188.07 mg/g, The shows the ultra strong adsorption properties of the material on antimony . $Ce^m\text{-}\wedge$ [] O 4 in the adsorption and desorption loop 2 after , its removal of antimony efficiency is still high , Show strong stability and reuse .

Qi not only Ce (m) doped into nano F & O 4, also puts the Cu doping into nanometer F & O 4, prepared copper-doped magnetic iron base material material (cu-dopedFe$_3$O $_4$) [1] All . cu-doped Fe $_3$ O $_4$ to Sb (m) and Sb ( ) adsorption kinetics and thermodynamic processes for (v) , Elovich model and Langmuir model . on pH =7 time , mixedNano after miscellaneous copper cu-joped Fe$_3$O $_4$ to Sb(m) and Sb (V) The ability to adsorb the from the original . mg/g and 7. on mg/g grow to + mg/g and , mg/g, Its adsorption rate also has to significantly accelerate . adsorption mechanism research (Chart 2) indicates that the doping Cu Cu - [1]-) oxidation of antimony contaminants by active sites and stronger adsorption than Fe^m -).

Table 2 lists different magnetic nano Fe 3 O 4 class composites in under different conditions to Sb(m) + Sb((V) Maximum adsorption capacity value . can be seen from the table to the nanometer Fe; O 4 The main improvement method for is with load , surface Modification and doping other metal elements , and do not improved with method Fe; O 4 The adsorption performance of the on the pollutant antimony and the most
Good adsorption conditions are significantly different , to select the Fego # Excellent for Improved methods , should be determined according to the actual needs of antimony-containing wastewater . 3. 2 hydrated ferric oxide composites

hydrated ferric oxide (HFO : hydrated ferric oxide) is – species nanometer hydroxyl oxide , can naturally form , has a higher ratio than table area and reactive activity ,Common heavy metal ions in water and organic Pollutant has strong adsorption ability [650] . so , Some scholars Research HFO treating antimony-Containing wastewater , Mitsunobu etc use synthetic water and needle iron ores and naturally formed water three adsorbents to iron oxide to Sb(V) for adsorption removal , knot Fruit found three adsorbents to Sb ((V) has special adsorption , no under water environment pH, the influence of the coexistence ion concentration and other factors , confirms HFO potential application in the area of antimony pollution treatment .

Qi , and so on M using iron ore to Sb (m) and Sb (V) Mixed The is adsorbed by a solution to investigate the competitive adsorption mechanism for both .. experimentstudy different Fe /Sb ratio and different PH Water mine to Sb(m) and Sb( ) The adsorption effect V . results found with Fe/Sb greater than large , Sb(m) The removal rate of the is increasing , and the Sb (m) oxide generated Sb(v) the residual concentration in the water also gradually decreases . when you Sb(m) and Sb (v) when is in common ,Sb (v) to Sb (m) The adsorption of has little effect on , but Sb (m) in PH The value is 4 ~10 The suppresses the iron ore to the Sb (V) adsorption of , To prove that

SB (m) The has a stronger bond with the iron ore than the SB (v).

antimony and arsenic belong to the same kin element , With similar chemical properties , in many The case of arsenic and antimony contaminants is common. , so Qi , and so on All explores the As(m),a$_s$(v),b(m) and SB (v) Four kinds of The competition mechanism of metal ions in the process of iron ore adsorption . Research on Current iron adsorption A $_s$ (m) The procedure for is affected by the SB (m) is more affected than sb (v) has a large effect , and A $_s$ (m) to iron ore adsorption SB (v) suppresses the SB(m) has strong inhibitory effects . when four kinds of gold all exist , The adsorption thermodynamics of four kinds of ions by an iron ore mine procedure more compliantFreundlich

adsorption model ; A four-type adsorption capability of metal ions subject to pH affect greater , on pH <4 , its ability to adsorb four ions is SB (m) > a$_s$ (v) «SB (v) > As (m), and when PH >5 when , Its absorptive capacity becomes Sb (m) >A$_S$(m) > a $_s$(v) > SB (v) . overall ,sb (m() the strongest binding to a pyrite , which is good for toxic antimony removal of contaminants .

Needle iron ore (a ~ FeO (-OH)) is another of hydrated ferric oxide form ,Leuz , and so on [i for the analysis of the needle iron to the The Sb " (m) and Sb(v) adsorption mechanism for , tests different PH , Aerobic and non-adsorption of two ions in the reaction time period . results show that ph value 3 ~ ,, iron ore pair sb(m) Adsorption removal effect all strong , and PH = 7 when ,Sb (v) removal best . exafs (Extend X X-ray absorption fine structure , Extended X-ray absorption Fine structure) The analysis test shows SB's main go except the principle is sb (m) and SB) (v) combined with a needle iron ore formed within layer complexes . needle iron mine to sb(v The thermodynamic adsorption process for) is more consistent than the Langmuir model , its in PH = 3 when to sb (v) for Maximum adsorption capacity mg / G ; under aerobic conditions , Adsorption Poly set on needle iron surface sb(m() due to increased electronic intensity and The catalysis of the iron ore is easily 0 2 oxidation to SB (v) , from for more virulent sb(m) remove .

Simple HFO The has certain special adsorption capabilities on antimony ,

But hydrated iron oxide _ granular Finer , is often loosely used in water , is not a form flocculation , easy to disperse , is also not easy to keep away from the ^{M} , These missingPoints to increase the cost of antimony HFO + , Restricted HFO on actual apply in . and HFO fixed on the surface area is large and rough many the particle carrier of the hole is an important way to solve the problem , now common carrier has quartz sand , Activated carbon , resin etc [6566]. Koh Kwang Eyebrow etc [67] using quartz sand load hydrated ferric oxide preparation HFO - Stone UK Sand composites , and in water SB (m) adsorption of . XRD show that the main component of the surface of the material is the mixture of the needle iron ore with hematite fit , FTIR indicates a large number of on its surface Fe - O and Fe - OH adsorption active bit , provides a guarantee for the removal of antimony contaminants . HFO- quartz sand pair SB (m) The adsorption kinetics process is more in line with the pseudo two level Dynamics model , Its adsorption thermodynamic process is more in line with the Langmuir Model . temperature to   c when , this material to sb (m) Adsorption capacity amount to 2. 0 mg/g. Interference experiment show NO_3^-,Cl$^-$, O $_4^{2-}$ anion Pairs HFO - antimony adsorption capacity of quartz sand almost no shadow ring , this is inferred from the three-layer surface coordination model sb(m) adsorption on A layer , strongly adsorbed ions , the shows that the material is adsorbed antimony , with strong anti-interference ability .

Miuyangyang [apply' $ ' use anion exchange resins respectively (D201) and Fang Shi Sha (RCs) load HFO, making Fe (m)- to Grease (HFO45201, As shown in figure 3shows) and Fe (m)- Square Solution Stone (Ioccs) Two kinds of composites and explore two materials to

Sb (V) Adsorption effect . Experiment results show pH value 3~9 time , Two materials to Sb (V) The has the ability to adsorb with PH increase of the value To decrease . at the same temperature ,HFO~ D201 to Sb (V) most Large adsorption capacity is higher than Ioccs, such as 303 K on hfod ~201 and Ioccs the antimony adsorption capacity of IS " 9 and " "" 9 mg/g , but HFO ~ D 201 to Sb (V) The adsorption process of the is strongly affected by solution ions the degree and other coexistence ions have a greater impact . column adsorption experiment shows Ioccs penetration point (4000 BV) Yes HFO- D201 ($ BV) , 6 Times about , To further prove that Ioccs when antimony is adsorbed anti-jamming ability , in practical application , Ioccs to Sb (V) The is also more effective than hfod -:01 works better .

Chmielewsk # , and so on [$ use sol - glue nano-level FeO (OH) load on oblique zeolite tuff prepared with FeO (OH) -oolite type composites , and study its adsorption process with The ability of antimony wastewater . semtdx,XRD test show load on The Iron base component of the surface or internal pores of the zeolite is mainly needle iron., Water

iron ore and hematite . Use this composite for Sb (m) adsorption found FeO (OH) the decentralization of is significantly improved , its to

Sb (m) The adsorption thermodynamic data for is more in line with Langmuir Model . temperature is @ [*]　 C when ,FeO (OH)~zeolite to Sb(m) maximum adsorption capacity about 7.17 mg/g.

Biswas orange Waste soap Preparation gel

(SOW) , and then HFO is loaded on the saponification gel , Prepare for HFO- Adhesive composite material (Fe (m) loaded SOW). research investigate find Langmuir the Thermodynamic adsorption model can be better fitted Fe (oaded) 4 SOW to Sb (m) and Sb (V) adsorbed on threads , The maximum adsorption capacity of the composite to two metal ions is the no 136. and 144., mg/g. so$_4$ $^{2-}$,3 $_-$,CO.$_3$ $^{2-}$, Cl - coexisting ion pairs Fe (m) 4 oaded the antimony sorption of the SOW "" can affect small , shows that the new composite material has a Strong Special adsorption ability .

Table 3 summarizes the hydration of ferric oxide composites to pollutants in water Remove conditions and removal effects of antimony . is visible to the table , to hydrated oxidation The improved methods of the iron composite are focused on the load stabilizing side face , the antimony adsorption performance of composites modified by different carriers is poor opposite is large .

4. removal of antimony by ferrous metal oxide composites

Study on the removal of antimony contaminants by iron oxide composites indicates a strong adsorption function for contaminants antimony , but simple iron oxides have more disadvantages at the same time , So many scholars explore the Modify iron oxides . doping different gold in iron oxides generic elements are one of many modified methods , Using this method Prepared iron-based bimetallic oxides with iron oxides and newly added metal oxygen The benefits of both , the is thus increasingly valued . The iron-based bimetallic oxides that are currently used by in the antimony pollution treatment area are mainly Iron Manganese oxide , Iron copper oxide etc [&1].

4.1 Iron Manganese oxide composites

Research shows that [&2 , a.] Strong ability to oxidize manganese oxides , for heavy Metals with special one sex characteristics , Special on oxidation and removal Sb(m) show strong capabilities [& 4.]$, therefore for further enhancements Adsorption ability of iron oxide materials on antimony contaminants , full combination Advantages of iron oxides and manganese oxides , Some scholars study the preparation of iron The manganese oxide and use it for treatment of antimony-containing wastewater .

Xu , and so on [& 6] using redox / A coprecipitation method for the preparation of Fe-MN composite oxides (fmbo) and compare fmbo ,feooh and MnO 2 to Sb (m) and Sb(V) Removal effect , analyzes its adsorption mechanism . Research Discovery ,fmbo on Sb(m) adsorption kinetics over compare to pseudo two level dynamics model , theAdsorption thermodynamic process is better than more consistent with Freundlich model . after calculation ,fmbo Adsorption Sb (m) The maximum capability of the IS 1. The mmol/g , far exceeds Feooh (0. mmol/g)) and MnO$_2$ (0. Bayi mmol/g) adsorption energy Force . ftir and xps Show , manganese oxide in Sb(m) oxidation to Sb (V) the process of plays a leading role while iron oxides suck

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