



Stabilization of ferric arsenate sludge with mechanochemically prepared FeS₂/Fe composites

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Abstract: FeS₂/Fe composites were mechanochemically prepared with iron powder and pyrite for the stabilization of ferrite arsenate sludge (FAS). The effects of preparation parameters on stabilization performance were investigated. The results show that the optimum conditions are FeS₂/Fe molar ratio of 5:5, milling time of 2 h, ball-to-material mass ratio of 15:1 and milling with stainless steel ball. Then, the composites were characterized by XRD, SEM, FTIR, etc. The physicochemical properties of FeS₂/Fe mixture change dramatically, which is responsible for its excellent performance. Finally, the stabilization process of FAS was optimized. When the FAS is mixed with composites at mass ratio of 4:1 and milled for 30 min, the As leaching concentration of FAS can be reduced from 639.15 to 4.74 mg/L with the stabilization ratio of 99.2%.

Key words: arsenic; ferric arsenate sludge; stabilization; mechanical milling; FeS₂/Fe composites

1 Introduction

Except for its occurrence in the form of realgar (As₄S₄) and orpiment (As₂S₃), arsenic is frequently associated with non-ferrous metals (copper, lead, zinc, etc) in nature [1]. With mining and smelting of these non-ferrous metals, arsenic enters into the environment, posing a serious threat to human health, such as skin cancer, kidney cancer and death [2,3]. In the process of non-ferrous smelting, arsenic-containing waste acid and wastewater are two of the important ways for the release of arsenic into the environment. In general, the arsenic-containing waste acid and wastewater are treated with lime and ferric salt, which produces plenty of ferric arsenate sludge (FAS) [4]. Because arsenic in FAS exists in the form of unstable ferric arsenate, the sludge is extremely toxic and the arsenic migrates to the environment easily [5,6]. The safe disposal of FAS has become an urgent need in non-ferrous industry.

Due to the high toxicity of arsenic, its market is shrinking and the application of arsenic products is

limited. Arsenic recovery from the arsenic-containing waste has little economic benefit. Thus, the solidification/stabilization becomes the main method for the treatment of arsenic-containing waste. The Law on the Prevention and Control of Environmental Pollution by Solid Waste (Revised Draft) issued by the Ministry of Ecology and Environment of China in July 2018 proposed “harmlessness is the premise of resources” and “minimize the landfill capacity of solid waste as much as possible”. Therefore, the harmless treatment with low capacity-increase will become a trend for the disposal of arsenic-containing waste. However, the current method used for the solidification of arsenic-containing waste needs to add a large amount of additives such as cement and lime, which leads to a high capacity-increase and a large landfill capacity [7,8]. This does not meet the requirements of the Law on the Prevention and Control of Environmental Pollution by Solid Waste (Revised Draft). Under the current situation, therefore, solidification assisted by the chemical stabilization will become the most feasible method for the treatment of hazardous waste with high toxicity such as FAS.

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Zero valent iron (ZVI) is widely used in the treatment of heavy metals and organic pollutants [9–11]. Due to its strong affinity and high selectivity to arsenic, it has also been used for the remediation of arsenic-contaminated groundwater and soil [12–14]. However, ZVI and ZVI-based materials have defects, such as a narrow active pH range and easy formation of passivation film to reduce the activity. To solve these problems, sulfur element, which easily reacts with iron and form iron sulfide, is commonly used to modify ZVI [15–17]. The enhanced activity of ZVI after sulfidation modification includes a catalytic effect ascribed to the iron sulfides formed on the surface [18], more efficient charge transfer mediated by the sulfides [19–21], and increased depassivation of iron surface [22]. Pyrite is a common by-product during the beneficiation of non-ferrous metal ores [23]. Natural pyrite is often associated with arsenic and has a certain purification effect on arsenic. After the adsorption of arsenic, arsenic-containing pyrite or arsenic sulfide is formed [24]. Based on the advantages of ZVI, sulfidizing ZVI and pyrite in pollution control, FeS₂/Fe composites prepared by iron powder and pyrite were proposed to stabilize FAS.

Mechanical milling can give rise to physical and chemical reactions, accompanied by the formation of new surface and crystalline disorder, which can greatly increase the reactivity of the material [25]. Therefore, FeS₂/Fe composites were prepared by mechanical milling using pyrite and iron powder in this study. The preparation parameters of composites by mechanical milling were optimized firstly. Then, the influence of mechanical milling on the physicochemical properties of composites was analyzed. Finally, the composites were used to stabilize FAS and the effect of stabilization was investigated. This work can provide a practical, inexpensive and efficient treatment method for the stabilization of FAS in practical engineering.

2 Experimental

2.1 Materials

The FAS used in the experiment was prepared with crude sodium arsenate (collected from an antimony smelting company in Hunan Province, China) and FeSO₄·7H₂O (AR, Sinopharm Group Chemical Reagent Co., Ltd.) in laboratory. Firstly, the high-concentration arsenic solution and ferrous sulfate solution were prepared with crude sodium arsenate and FeSO₄·7H₂O, respectively. The pH of these solutions was then adjusted to 4.0 using dilute H₂SO₄. Afterwards, the two kinds of solutions were mixed according to Fe/As molar ratio of 1.5:1. The mixed solution was heated, stirred and reacted with air intake. After reacting for 2 h, it was cooled down

to room temperature. The precipitate (FAS) was collected after the reacted solution was filtered and washed. Finally, the FAS was dried at 60 °C for the subsequent experiments.

The FAS was digested by aqua regia. The concentration of each element in the digestion solution was measured by inductively coupled plasma optical emission spectrometry (ICP-OES). As given in Table 1, the contents of As and Fe in FAS reached 31.8 and 19.6 wt.%, and minor elements such as Na and S were also detected. The phase composition of FAS characterized by XRD patterns is shown in Fig. 1. It is suggested that the FAS is amorphous. The arsenic in the FAS can be easily dissolved because the leaching toxicity of As determined by the TCLP reached 639.15 mg/L.

Table 1 Main element contents of FAS (wt.%)

As	Fe	Na	Ca	P	S	Sb
31.8	19.6	5.01	0.017	0.14	0.16	0.10

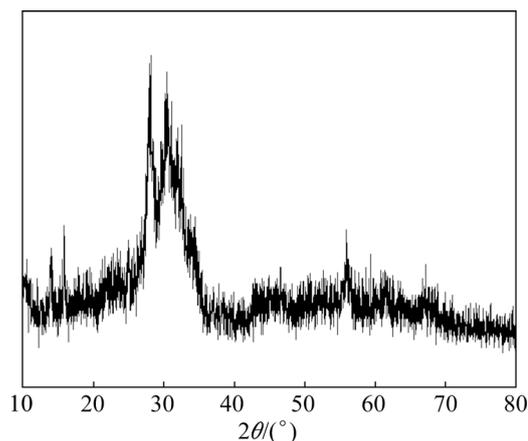


Fig. 1 XRD pattern of FAS

2.2 Experimental procedure

The process diagram of the experiments is shown in Fig. 2. A certain amount of pyrite and iron powder was weighed under a certain ball-to-material mass ratio (B/M), a certain FeS₂/Fe molar ratio ($n(\text{FeS}_2:\text{Fe})$), and a fixed mass of stainless steel balls (400 g). Then, the pyrite, iron powder and stainless steel balls were loaded into a stainless pot (500 mL). The preparation of FeS₂/Fe composites was performed in a planetary ball mill (QM-QX4, Nanjing, China) with a speed of 400 r/min. After a period of ball milling, the FeS₂/Fe composites were obtained. In order to optimize the preparation parameters of FeS₂/Fe composites, such as FeS₂/Fe molar ratio, milling time, B/M and milling medium, the as-prepared FeS₂/Fe composites were mixed with FAS under a fixed mass ratio of 1:10. Thereafter, the mixture was subjected to grinding in planetary ball mill with a

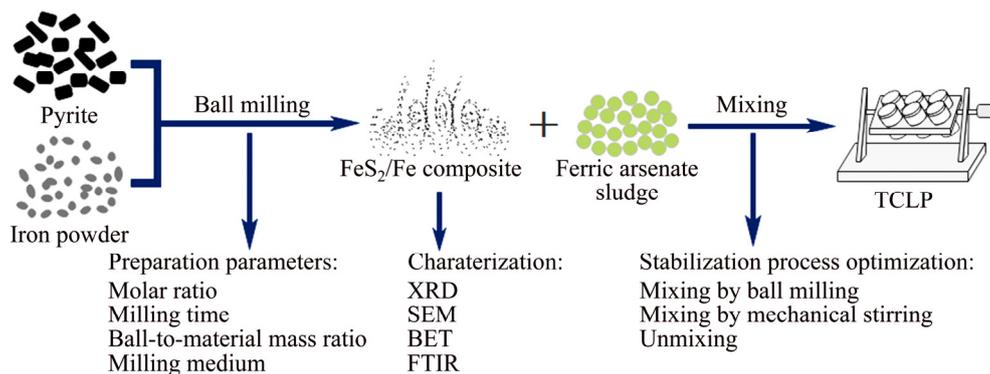


Fig. 2 Schematic diagram of experimental process

B/M of 20:1 for 1 h. Finally, the ground mixture was tested by TCLP, and the leaching concentration and stabilization ratio of As were selected as the indexes to estimate and optimize the preparation parameters of FeS₂/Fe composites.

To stabilize the FAS with FeS₂/Fe composites, the mixing methods of FAS and FeS₂/Fe composites should also be optimized. Therefore, two mixing methods (mixing by ball milling and mechanical stirring) and direct leaching without mixing were investigated. In ball milling process, the effect of mass ratio (FAS to FeS₂/Fe composites) and milling time was studied under a fixed B/M of 20:1. In mechanical stirring process, the FAS and FeS₂/Fe composites were mixed in a cement mortar mixer (JJ-5, Jiangsu Province, China), and the effect of mass ratio and mixing time was also investigated. The leaching concentration and stabilization ratio of As were also used to assess the mixing methods.

2.3 Analysis

2.3.1 Leaching concentration and stabilization ratio of As

The leaching concentration of FAS and treated sludge was determined by TCLP according to the procedure described in our previous studies [26–28]. The stabilization ratio of As is calculated according to the following equation:

$$\varphi = \frac{C_0 - C_1}{C_0} \times 100\% \quad (1)$$

where φ (%) is the stabilization ratio of As; C_0 and C_1 (mg/L) are the leaching concentrations of As in FAS and treated sludge, respectively.

2.3.2 Characterization

The micromorphology was analyzed by SEM (Nano SEM 230, FEI Company). The surface area was determined by nitrogen adsorption–desorption isotherms (Autosorb1, Quantachrome Corporation). The crystallographic composition of samples was characterized by X-ray diffraction (XRD, D/max 2550 VB+ 18 kW) with Cu K α radiation at a scanning rate of

10 (°)/min from 10° to 80°. Fourier transform infrared spectra were measured by FTIR spectrometer (Nicolet IS10, NICOLET).

3 Results and discussion

3.1 Preparation of FeS₂/Fe composites with ball milling

3.1.1 Effect of FeS₂/Fe molar ratio

Considerable research efforts have already demonstrated the fact that both pyrite and iron powder can react with arsenic [29–31], which means that the composites prepared at different FeS₂/Fe molar ratios will have different effects on arsenic stabilization. To investigate the effect of FeS₂/Fe molar ratio, the pyrite and iron powder with different $n(\text{FeS}_2:\text{Fe})$ were ball-milled with stainless steel balls at a fixed B/M of 20:1 for 2 h. As shown in Fig. 3, with the increase of molar ratio, the leaching concentration of As for the FAS decreases at first and subsequently increases. Accordingly, the stabilization ratio increases first and then slowly decreases. When $n(\text{FeS}_2:\text{Fe})$ is 0:10, the leaching concentration of As can be reduced from 639.1 to 80.7 mg/L. However, the leaching concentration of As

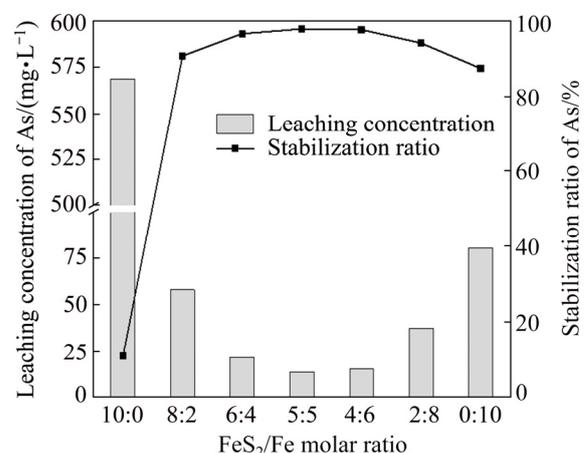


Fig. 3 Effect of FeS₂/Fe molar ratio on As stabilization performance of composites

can only be reduced to 568.8 mg/L by the ball-milled pyrite ($n(\text{FeS}_2:\text{Fe})=10:0$). Compared to $n(\text{FeS}_2:\text{Fe})$ of 10:0 and 0:10, the composites prepared under other molar ratios show a satisfactory stabilization performance of As for the FAS. The leaching concentration and stabilization ratio of As reach the valley value of 13.7 mg/L and the peak value of 97.8%, respectively, when $n(\text{FeS}_2:\text{Fe})$ is 5:5. Thus, $n(\text{FeS}_2:\text{Fe})$ of 5:5 should be selected as the optimal molar ratio.

3.1.2 Effect of milling time

Mechanical process can greatly change the particle size of samples [32]. In this process, large particles are broken into small size firstly. As the ball milling process continues, the pulverized fine particles reunite, resulting in the increase of particle size. Figure 4 presents the effect of milling time on As stabilization performance of composites prepared at B/M of 20:1, $n(\text{FeS}_2:\text{Fe})$ of 5:5 and milling medium of stainless steel ball. When milling time varies from 0.5 to 4 h, the leaching concentration of As for the FAS after stabilization decreases and then increases, whereas the variation trend of stabilization ratio is reversed. The composites ball-milled for 2 h possess a much better stabilization performance with As leaching concentration of 11.4 mg/L and stabilization ratio of 98.2%. Therefore, 2 h is considered as the optimal milling time.

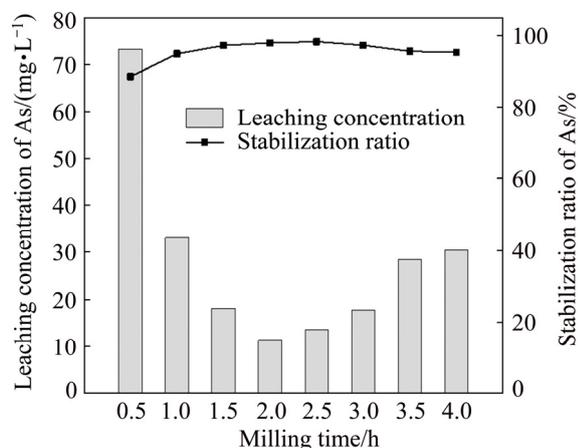


Fig. 4 Effect of milling time on As stabilization performance of composites

3.1.3 Effect of B/M

Previous research has established that the larger the B/M, the more the collisions and the greater the energy density, leading to highly-effective reaction [33]. To investigate the effect of B/M, FeS_2/Fe composites were prepared at different B/M with $n(\text{FeS}_2:\text{Fe})$ of 5:5, milling time of 2 h and milling medium of stainless steel ball. Figure 5 shows its stabilization performance towards As in FAS. As the B/M increases from 5:1 to 8:1, the leaching concentration decreases rapidly from 147.3 to 17.8 mg/L, and the stabilization ratio increases from

76.9% to 97.2%. Both the leaching concentration and stabilization ratio of As fluctuate slightly when the B/M varied from 8:1 to 20:1. After the FAS is stabilized with the composites prepared at B/M of 15:1, the leaching concentration and stabilization ratio of As reach 8.64 mg/L and 98.6%, respectively. This improved stabilization performance may be caused by the increase of energy density and the collision probability of ball and material due to the augment of B/M. However, when B/M increases to a certain value, the collision probability of ball and material becomes equilibrated, resulting in the fluctuation of leaching concentration and stabilization ratio. Thus, 15:1 is chosen as the optimal B/M.

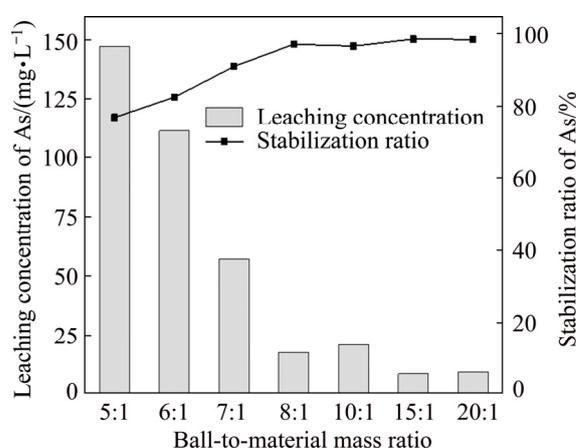


Fig. 5 Effect of ball-to-material mass ratio on As stabilization performance of composites

3.1.4 Effect of milling medium

During the milling process, milling medium may affect the morphology and characteristics of the milling product, and thus influences the performance of materials. To seek for the best milling medium, FeS_2/Fe composites were prepared with corundum or stainless steel ball under $n(\text{FeS}_2:\text{Fe})$ of 5:5, milling time of 2 h and B/M of 15:1. The stabilization performance of composites is given in Table 2. When stainless steel ball was used to prepare composites, the leaching concentration and stabilization ratio are 8.96 mg/L and 98.59%, respectively. Similar results can be obtained when the FAS was treated with composites prepared by corundum ball. The similar results indicate that the milling medium has no significant effect on stabilization performance of composites. Based on the results above,

Table 2 Effect of milling medium on As stabilization performance of composites

Milling medium	Leaching concentration/ (mg·L ⁻¹)	Stabilization ratio/%
Corundum ball	8.95	98.59
Stainless steel ball	8.64	98.65

stainless steel ball is chosen as the milling medium for subsequent experiments.

In summary, the optimum preparation parameters of FeS_2/Fe composites are $n(\text{FeS}_2:\text{Fe})$ of 5:5, milling time of 2 h, B/M of 15:1 and the milling medium of stainless steel ball. The composites prepared under this condition possess the best stabilization performance towards As in FAS. The As leaching concentration can be reduced from 639.15 to 8.64 mg/L.

3.1.5 Characterization of FeS_2/Fe composites

Pyrite, iron powder and the mixture of them were milled respectively for 2 h with a fixed B/M of 15:1 and $n(\text{FeS}_2:\text{Fe})$ of 5:5, and the results of XRD analysis are shown in Fig. 6. No other diffraction peak can be observed on the XRD patterns of milled iron powder ($n(\text{FeS}_2:\text{Fe})=0:10$) and pyrite ($n(\text{FeS}_2:\text{Fe})=10:0$) except for the diffraction peaks of Fe and FeS_2 , respectively. Diffraction peaks of Fe can only be observed at $2\theta=44.7^\circ$ and 64.9° , while many diffraction peaks of FeS_2 are found. On the XRD pattern of FeS_2/Fe composites, no new diffraction peaks can be observed except for the peaks of Fe and FeS_2 , indicating that no chemical reaction happens or amorphous substance is generated during the milling process. Moreover, the intensity of diffraction peaks for the ball-milled mixture is obviously weaker than that of the milled iron powder or pyrite, indicating that the non-crystallizing degree and activity of composites are enhanced after ball milling. Thus, the FeS_2/Fe composites are easier to react with the arsenic in FAS.

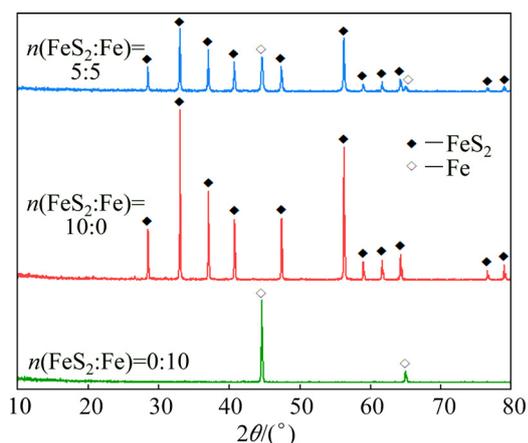


Fig. 6 XRD patterns of iron powder, pyrite and FeS_2/Fe mixtures after milling

Figure 7 presents SEM images of the raw mixture of pyrite and iron powder and the as-prepared composites (milling time of 2 h, $n(\text{FeS}_2:\text{Fe})$ of 5:5 and B/M of 15:1). It can be seen that there is an enormous alteration in the micromorphology of samples. The raw mixture in Fig. 7(a) possesses a smooth surface and a bulk structure with diameter of 10–20 μm . After the mixture of pyrite

and iron powder is ball-milled for 2 h (Fig. 7(b)), the bulk structure is broken into small pieces with approximately 3–6 μm in size and many tiny amorphous particles. And the tiny amorphous particles adhere to the surface of small pieces. Hence, the activity of mixture is greatly enhanced, suggesting that the composites are more effective for the stabilization of FAS. By considering the ductility of iron powder and fragility of pyrite, the large particles in Fig. 7(b) are considered as ground iron powder and the tiny amorphous particles are considered as pyrite.

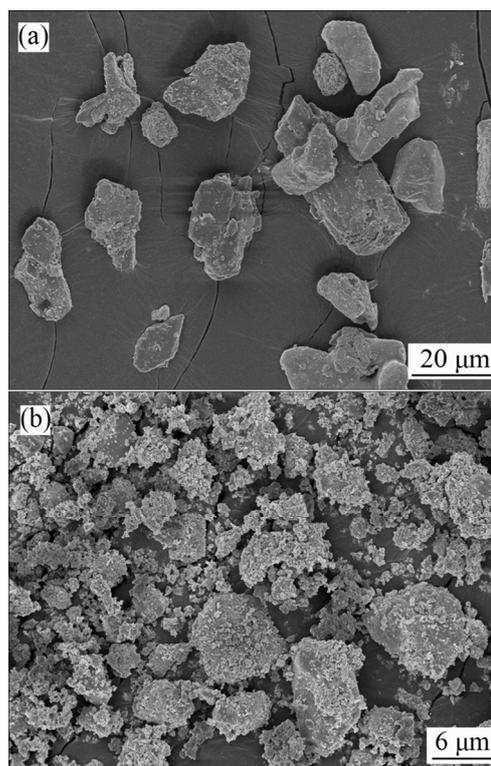


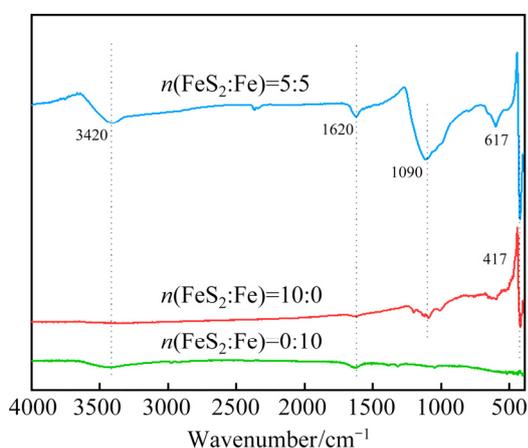
Fig. 7 SEM images of pyrite and iron powder mixtures (a) and FeS_2/Fe composites (b)

Table 3 gives the specific surface area and pore diameter of raw mixture and composites. The results demonstrate that mechanical milling significantly enhances the specific surface area of mixture. The specific surface area of raw mixture is 1.1157 m^2/g , whereas that of composites prepared under milling time of 2 h rises to 42.2948 m^2/g which is 40 times that of the raw mixture. The pore diameter of samples reduces from 75.83 nm to 52.34 nm after being milled for 2 h. The pore volume of samples rises from 0.02 to 0.054 cm^3/g after 2 h of ball milling. Overall, compared to the raw mixture of pyrite and iron powder, the composites decrease in pore diameter, but increase in the specific surface area and pore volume. These changes enable the composites to fully contact with FAS, making the stabilization process more efficient.

Table 3 Specific surface area and pore diameter of raw mixture and composites ($n(\text{FeS}_2:\text{Fe})$ of 5:5 and B/M of 15:1)

Milling time/h	Specific surface area/($\text{m}^2 \cdot \text{g}^{-1}$)	Pore diameter/nm	Pore volume/($\text{cm}^3 \cdot \text{g}^{-1}$)
0	1.1557	75.83	0.002
2	42.2948	52.34	0.054

The FTIR spectra of pyrite, iron powder and FeS_2/Fe mixture milled for 2 h with a fixed B/M of 15:1 and $n(\text{FeS}_2:\text{Fe})$ of 5:5 are shown in Fig. 8. The band at 3420 and 1620 cm^{-1} are assigned to O—H stretching vibration in water [34]. The vibration band at 417 cm^{-1} is attributed to S—S stretching [35]. The band at 617 cm^{-1} corresponds to the SO_4^{2-} stretching and the band at 1090 cm^{-1} belongs to the Fe—OH stretching [36,37]. It can be seen that the milled iron powder only shows the characteristic peak of hydroxyl in water. Besides the peaks of hydroxyl in water, the milled pyrite shows the characteristic peak of S—S bond and a weak Fe—OH bond. The composites show strong peaks of SO_4^{2-} and Fe—OH bonds, indicating that the reaction between pyrite and iron powder occurs. Researches indicated that SO_4^{2-} and Fe—OH bonds can react with arsenate [38,39], which might be the reason why the composites show a good stabilization performance for the FAS.

**Fig. 8** FTIR spectra of iron, pyrite, and FeS_2/Fe mixtures after milling

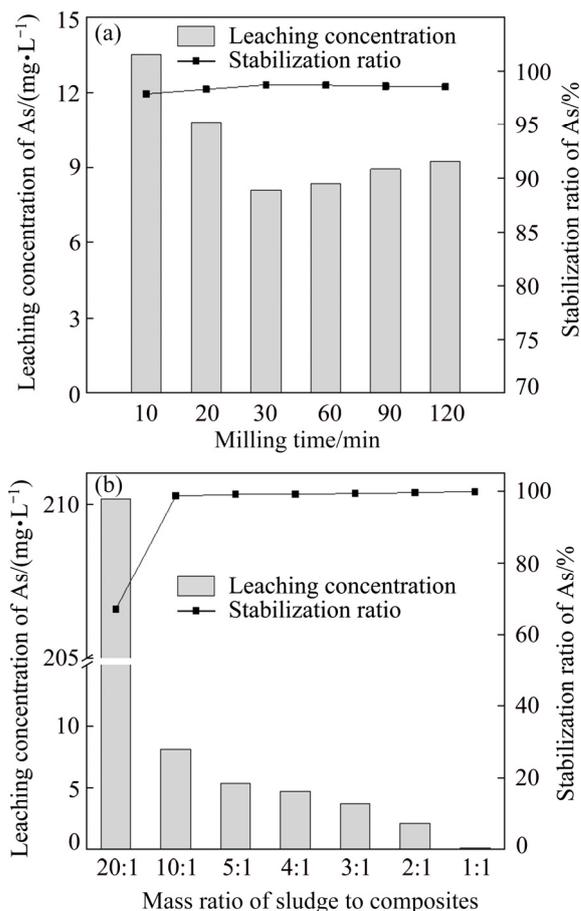
In conclusion, the physicochemical properties of the composites change significantly during the mechanochemical preparation. The mechanical milling enhances the non-crystallizing degree and activity of composites. The morphologies of composites change from the larger particles into rough fine particles with many nano-particles adhered to their surface. Hence, the specific surface area and pore volume increase. Additionally, SO_4^{2-} and Fe—OH bonds, which can react with arsenate, are produced after mechanical milling.

These changes in physicochemical properties enhance the stabilization performance of composites to FAS.

3.2 Optimization of stabilization process

3.2.1 Mixing by ball milling

The composites and FAS with different mass ratios are mixed by ball milling for different milling time, and the effects of milling time and mass ratio on As stabilization performance of composites are shown in Fig. 9. As can be seen from Fig. 9(a), milling time has slightly influence on leaching concentration and stabilization ratio of As. When milling time varies from 10 to 30 min, the leaching concentration of As decreases from 13.52 to 8.12 mg/L. By prolonging the milling time, the leaching concentration increases slowly to 9.25 mg/L. Nevertheless, the stabilization ratio hardly changes with the variation of milling time. In the milling time ranges investigated, the As leaching concentration fluctuates in the range of 8–15 mg/L while the stabilization ratios exceed 97% consistently. In this study, 30 min of milling time is chosen.

**Fig. 9** Effect of milling time (a) and mass ratio (b) on stabilization performance of FAS

Most often, stabilization ratio has a linear correlation with the dosage of composites. However, in engineering application, costs and stabilization

performance must be considered comprehensively. Therefore, Fig. 9(b) presents the effect of sludge-to-composites mass ratio on leaching concentration and stabilization ratio of As. The leaching concentration decreases continuously with the increase of mass ratio. When the mass ratio is 10:1, the leaching concentration decreases to 8.12 mg/L, which is much lower than 639.15 mg/L of its background. Further increasing the mass ratio to 4:1, the leaching concentration of As decreases to 4.74 mg/L, which is below the limit (5 mg/L) of hazardous waste identification. As for the stabilization ratio of As, it always exceeds 98% when the mass ratio surpasses 10:1. Therefore, suitable mass ratio should be selected according to the requirements of actual application.

3.2.2 Mixing by mechanical stirring

In the case of mechanical stirring, the effects of stirring time and sludge-to-composites mass on leaching concentration and stabilization ratio of As are shown in Fig. 10. It can be seen from Fig. 10(a) that stirring time has a slight impact on stabilization efficiency. In the entire range of stirring time, the As leaching concentration fluctuates in the range of 10–15 mg/L. When composites are mixed with sludge by mechanical

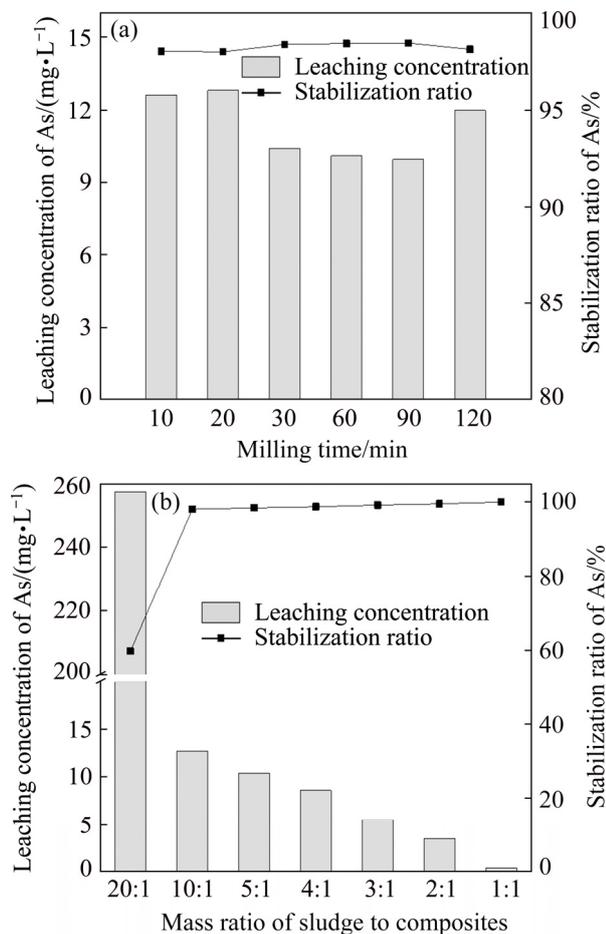


Fig. 10 Effect of stirring time (a) and mass ratio (b) on stabilization performance of FAS

stirring for 90 min, the leaching concentration reaches the valley value of 9.94 mg/L and the stabilization ratio of As reaches 98.4%. Hence, 90 min of stirring time is chosen for the subsequent experiment.

Figure 10(b) shows that leaching concentration continuously declines with the increase of mass ratio. When mass ratio is 20:1, the leaching concentration decreases to 257.35 mg/L and the stabilization ratio of As is 44.2%. As mass ratio increases to 10:1, the leaching concentration decreases sharply to 12.66 mg/L with a stabilization ratio of 98.1%. Only when the mass ratio increases to 2:1, the leaching concentration is lower than 5 mg/L. Thus, if the stabilized sludge needs to be treated as general waste, the mass ratio needs to exceed 2:1.

3.2.3 Unmixing

In addition to mixing by ball milling and mechanical stirring, unmixing was also investigated, in which the leaching toxicity test is directly carried out as soon as the FAS and composites are weighed. The effect of mass ratio on As stabilization performance is shown in Fig. 11. It can be seen that the composites still have a certain stabilization effect on FAS without mixing process. When mass ratio is 20:1, the leaching concentration decreases from 639.15 to 272.34 mg/L and the stabilization ratio is 57.4%. The leaching concentration is 2.49 mg/L and the stabilization ratio is 99.6% when mass ratio is 1:1. It indicates that the stabilization process mainly happens in the leaching toxicity test rather than the mixing process (ball milling or mechanical stirring).

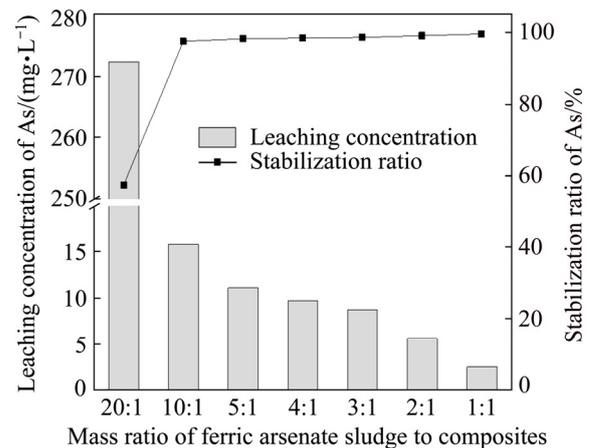


Fig. 11 Effect of mass ratio on stabilization of FAS

3.2.4 Comparison of stabilization methods

The As leaching concentration is compared when the sludge was stabilized by the composites with different stabilization methods (mixing by ball milling, mixing by mechanical stirring and unmixing). As shown in Fig. 12, the process that the FAS and composites are mixed by ball milling is more effective than other two processes under the same mass ratio. The As leaching

concentration of sludge stabilized with method of ball milling can be lower than 5 mg/L when the sludge-to-composites mass ratio is 4:1. However, only when the sludge-to-composites mass ratio reaches 2:1 and 1:1, the leaching concentration of As for sludge stabilized with mechanical stirring and unmixing can be lower than 5 mg/L. Therefore, mixing by ball milling is selected as the best stabilization method. After 30 min of milling time, the As leaching concentration of FAS, which is mixed with composites with a mass ratio of 4:1, can be decreased from 639.15 to 4.74 mg/L and the stabilization ratio of As reaches 99.2%.

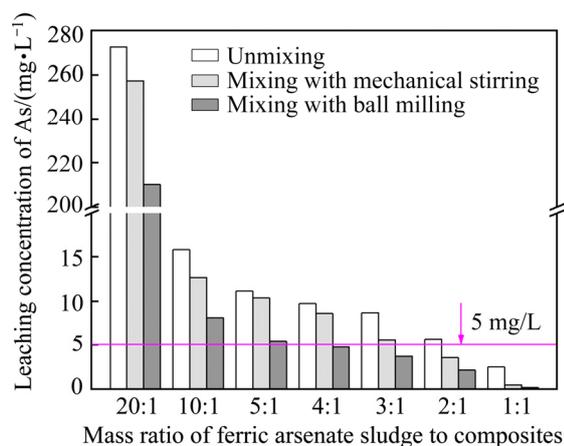


Fig. 12 Comparison of stabilization efficiency of FAS with different mixing methods

4 Conclusions

(1) In order to stabilize FAS, FeS₂/Fe composites were mechanochemically prepared using pyrite and iron powder as raw materials. The parameters, such as FeS₂/Fe molar ratio, milling time and ball-to-material mass ratio, have significant effects on the performance of composites for the stabilization of FAS, whereas the milling medium hardly affects the performance of composites. The optimum parameters of FeS₂/Fe composites are $n(\text{FeS}_2:\text{Fe})$ of 5:5, milling time of 2 h, B/M of 15:1 and milling medium of stainless steel ball.

(2) Mechanical milling enhances non-crystallizing degree and activity of composites, changes the morphology of pyrite and iron powder mixture, and improves the specific surface area and pore volume. In addition, the SO₄²⁻ and Fe—OH bonds are observed after mechanical milling. These changes in the physicochemical properties of composites might result in excellent performance for the stabilization of FAS.

(3) When the composites and FAS are mixed by ball milling with mass ratio of 1:4 for 30 min, the stabilization of As in FAS is efficient. Under these conditions, the leaching concentration of As for FAS can be reduced from 639.15 to 4.74 mg/L.

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采用机械化学制备 FeS₂/Fe 复合材料以稳定砷酸铁渣

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摘要: 以铁粉和黄铁矿为原料, 采用机械球磨制备 FeS₂/Fe 复合材料, 以稳定砷酸铁渣。考察制备工艺参数对复合材料稳定性能的影响, 确定复合材料最佳制备条件为: 黄铁矿/铁粉摩尔比 5:5、球磨时间 2 h、球料比 15:1、不锈钢球磨介质。采用 X 射线衍射仪、扫描电镜、傅里叶红外光谱仪等对复合材料进行表征。结果显示, 复合材料优异的性能主要归功于球磨过程中 FeS₂/Fe 混合物理化学性质的显著变化。对砷酸铁渣的稳定化工艺进行了优化。当砷酸铁渣与复合材料在质量比 4:1 的条件下球磨混合 30 min 时, 砷酸铁渣中砷的浸出浓度可由 639.15 mg/L 降至 4.74 mg/L, 砷的稳定率达 99.2%。

关键词: 砷; 砷酸铁渣; 稳定化; 机械球磨; FeS₂/Fe 复合材料

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