

Systematic evaluation of biotoxicity of Pb-based perovskite materials and perovskite solar cells

Yue Zhu,^{‡a} Yingying Kang,^{‡a} He Huang,^{*a} Dicai Zhuang,^a Mohan Li,^a Zihao Ling,^a Ke Peng,^{*b} Lanlan Zhai^a and Chao Zou^{*a}

^a College of Chemistry and Materials Engineering, Wenzhou University, Wenzhou, 325000 P. R. China.

^b Zhejiang Engineering Research Center for Tissue Repair Materials, Wenzhou Institute, University of Chinese Academy of Sciences, Wenzhou, Zhejiang 325000, P.R. China.

[‡] These authors contribute equally to this work.

E-mail: huanghe@wzu.edu.cn, pengke@ucas.ac.cn, zouchao@wzu.edu.cn

Materials

The water used in this experiment was all secondary water specified in GB/T 6682. All materials used in the experiments were obtained commercially and used without further purification, which include: PbI₂ (99.99%) and FAI (99.99%) were purchased from Xi 'an polymer Light photoelectric technology Co., LTD, Pb standard solution (GSB 04-1742-2004) were purchased from National Nonferrous metals and electronic materials analysis and testing center.

Solubility of perovskite materials

There are two methods for the test of stability of perovskite materials. (1) At room temperature, weighing 23.5mg (0.137mmol) FAI was dissolved in 100mL pure water and ultrasonic stirring was performed. Then, 63 mg PbI₂ (0.137mmol) was weighed and placed in the FAI solution and 100mL pure water respectively, standing for 10min to observe the dissolution, and then the two cups of solution were ultrasonically stirred for 10min to observe the dissolution of the solution. (2) At room temperature, 34.4 mg FAI and 92 mg PbI₂ were weighed in test tubes and mixed

evenly at 100°C to obtain 0.2 mmol FAPbI₃ perovskite material, dissolved into suspension with appropriate amount of water and transferred to 500mL beaker. The solubility of FAPbI₃ perovskite was calculated by gradually mixing with water (a small number of times), stirring while adding, until the perovskite material was completely dissolved.

Solubility of PSCs

At room temperature, choice 5 pieces perovskite device with 20 mm×15 mm size, place them in 200mL beaker, gradually add water, leave for half an hour after each addition of water, do not stir, observe its solubility.

Planting of Arabidopsis

Appropriate amount of Arabidopsis seeds was added to a centrifuge tube, 1 mL of sterile water was added, and vernalized at 4 ° C for 3 days. Ten small pots were prepared and 50 g of soil was added in every pots. Numbered 1-10, among of them, No. 1 and No. 2 were used as the control group. The rest were dissolved in perovskite materials of different concentration gradients and perovskite devices of different quantities, respectively. The materials and soil were mixed evenly, and 20 Arabidopsis seeds were seeded in wet soil with toothpicks in each pot. Water regularly, under natural growth conditions, observe the germination and growth of Arabidopsis every 2-3 days, take photos and record the sprouting rate.

Planting of radish seedlings

Perovskite materials and devices with different concentration gradients were taken into the pot with 50 g moist soil, numbered 1-10, and 10 radish seedlings with the same growth were taken and transplanted into the soil, one in each group. Water regularly, under natural growth conditions, observe the growth of radish seedlings every 2-3 days.

Cell culture

PbI₂, FAI and FAPbI₃ with different concentration 0.625 μmol/L, 2.5 μmol/L and 10 μmol/L were prepared. A certain amount of mouse bone marrow stem cells were

purchased and divide them into 10 parts after differentiation and cultivation, including one control group and nine experimental group, where different amounts of PbI_2 , FAI and FAPbI_3 materials were added respectively. Then, the cells were dispersed in culture dishes for incubation 24 hours. The survival rate of ten groups of cells was tested by CCK-8 kit, and the cell growth state was observed under the microscope.

Breeding of zebrafish

Preparing several zebrafish AB (1-2 months old /1-1.5cm) and feeding with similar growth conditions. Taking 10 clean 500 mL beakers and add 400 mL water to each one, number 1-10, number 1 as control group and directly cultivate 6 zebrafish. Add perovskite materials with different concentration gradient and perovskite devices in the other beakers. Adding 6 zebrafish into each beaker and stirring every day to inject oxygen. Every three days a little feed was added, and the activity of the zebrafish was observed and photographed.

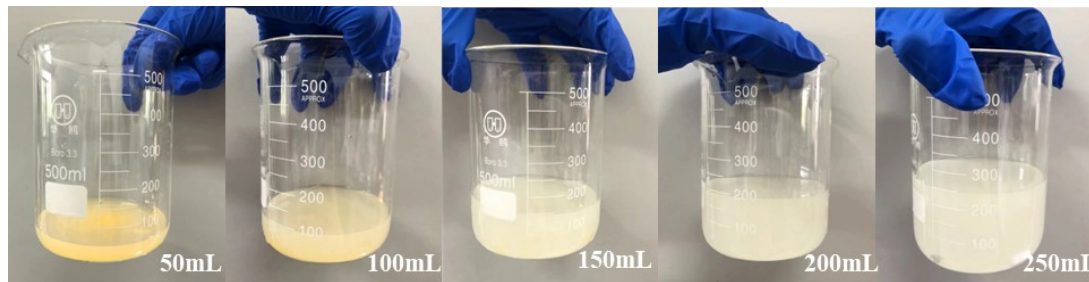


Fig. S1 the solubility process of FAPbI_3 in water

Table S1 the basis for determining the concentration of FAPbI_3 perovskite material

	Weight of FAPbI_3 in 50g soil	Equivalent of n (FAPbI_3)	Equivalent of PSCs
Equivalent of Pb in 1 PSCs (5 mg/kg)	0.75 mg	0.001 mmol	1 piece
Maximum allowable Pb value (250 mg/kg)	37.5 mg	0.05 mmol	50 pieces

Table S2 the group setting for investigating the phytotoxicity effect of perovskite materials and PSCs devices

Group	Materials	Quantity
1	Control	0
2	FAI	0.1mmol
3	PbI ₂	0.1mmol
4	FAPbI ₃	0.05 mmol
5	FAPbI ₃	0.1 mmol
6	FAPbI ₃	0.2 mmol
7	PSCs	5 pieces
8	PSCs	10 pieces
9	PSCs	15 pieces
10	Encapsulated PSCs	10 pieces

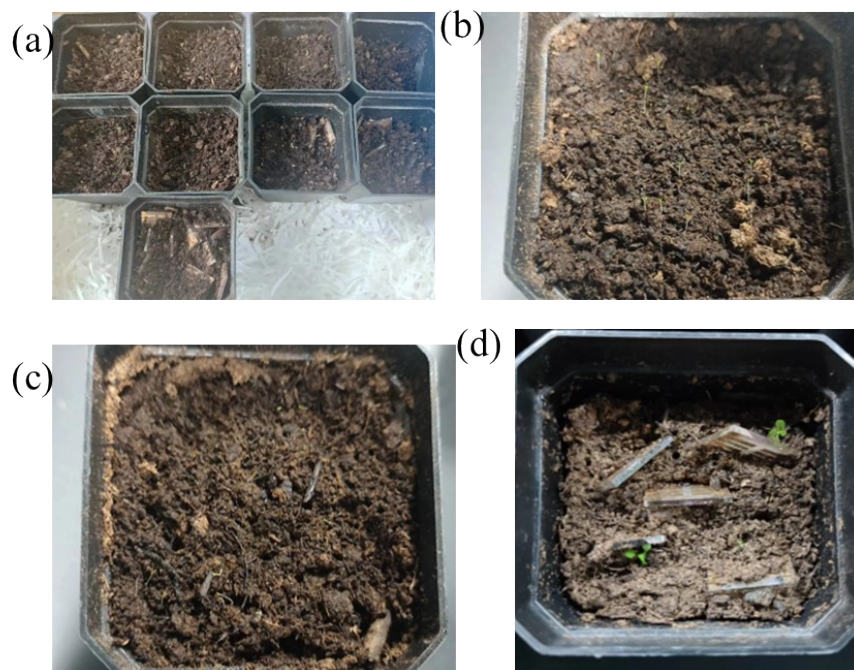


Fig. S2 the sprouting of Arabidopsis on the fifth day, a) all groups, b) control group, c) 0.05mmol FAPbI₃ group, d) 5 PSC devices group

Table S3 the sprouting of Arabidopsis with different time

	5th Day	6th Day	7th Day	8th D	9th Day	10th Day	11t h Day	12th Day
control	0	10	11	11	11	9	9	9
0.1 mmolPbI₂	0	3	3	2	1	0	0	0
0.1mmolFAI	0	1	1	3	3	3	2	2
0.05 mmolFAPbI₃	0	7	7	7	7	2	0	0
0.1mmolFAPbI₃	0	1	1	1	0	0	0	0
0.2mmolFAPbI₃	0	0	0	0	0	0	0	0
5 PSCs	0	9	10	9	8	8	8	6
10 PSCs	0	9	9	9	8	8	8	8
15 PSCs	0	7	7	8	8	8	7	3

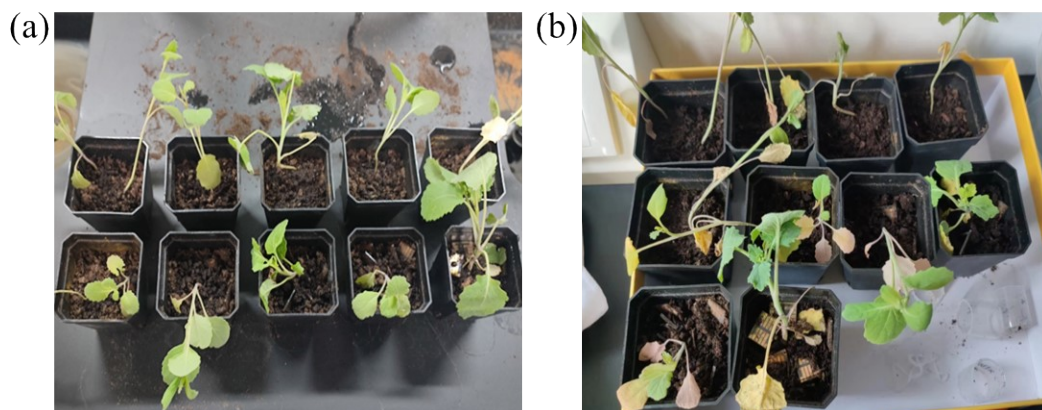


Fig. S3 the growth of morphology of radish seedling a) before and b) after culture 15 days in soil with different condition

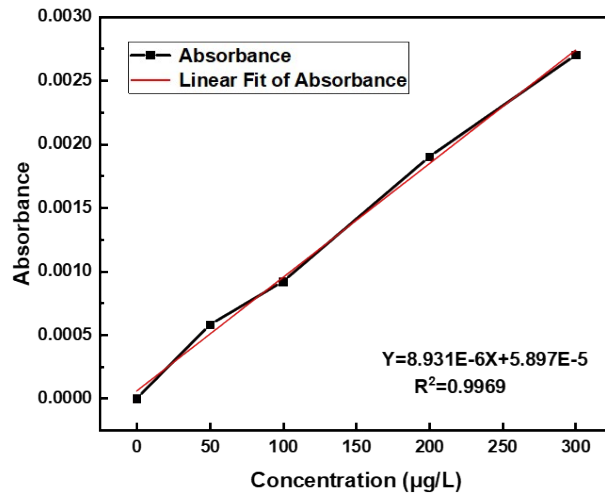


Fig. S4 the fitting standard curve for Pb concentration test with F-AAS

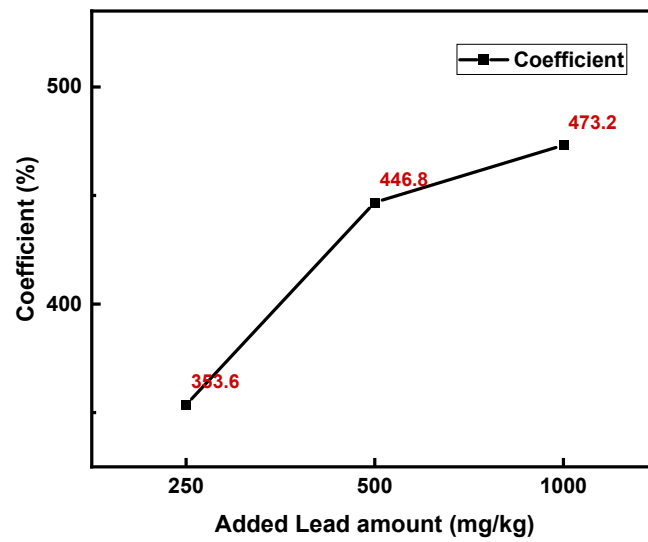


Fig. S5 the Pb absorption coefficient of radish seedling in soil with different $FAPbI_3$ concentration

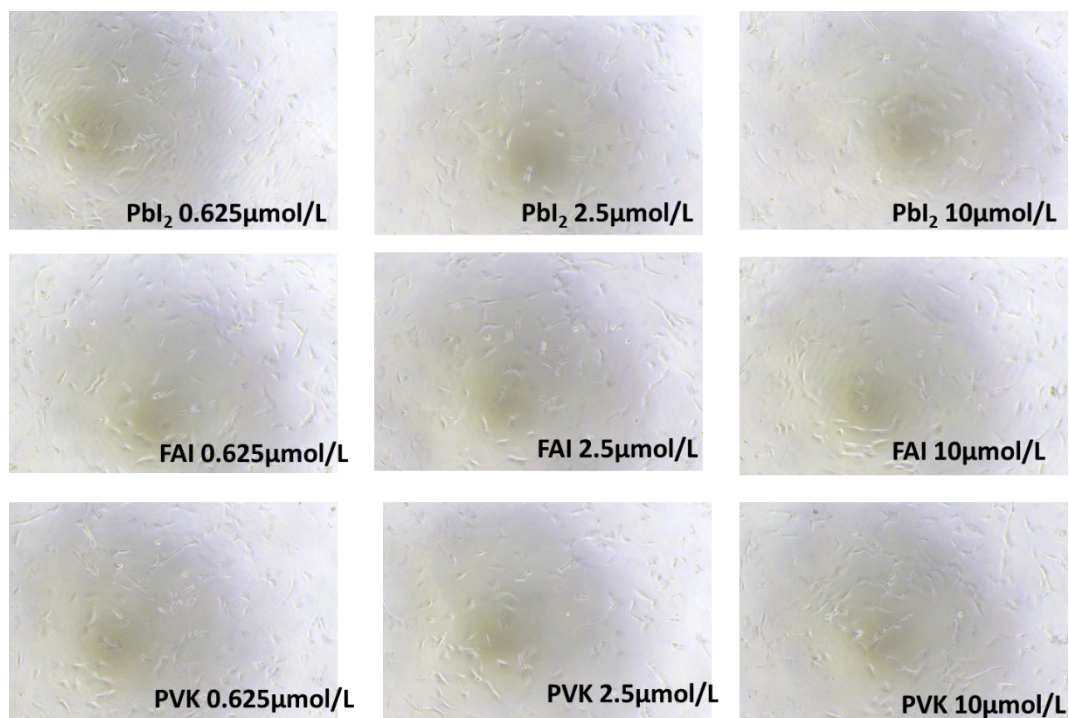


Fig. S6 the incipient cell state with adding different concentrations of PbI_2 , FAI and PVK materials in first day

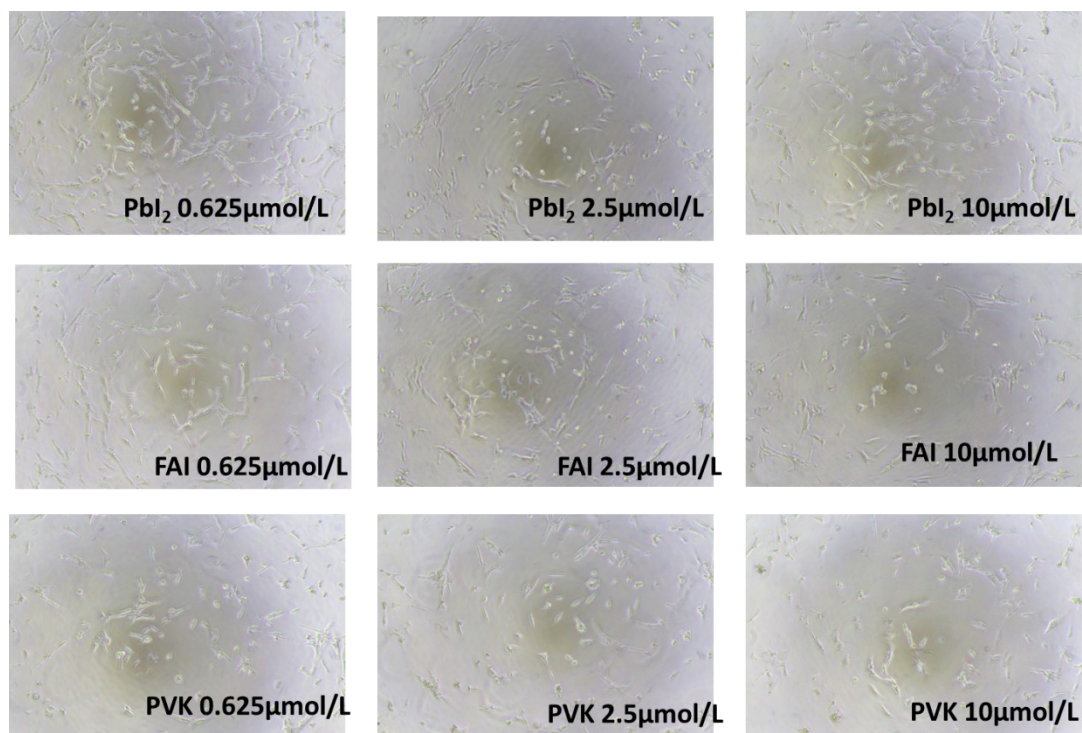


Fig. S7 the cell state with adding different condition after incubated for 24 hours

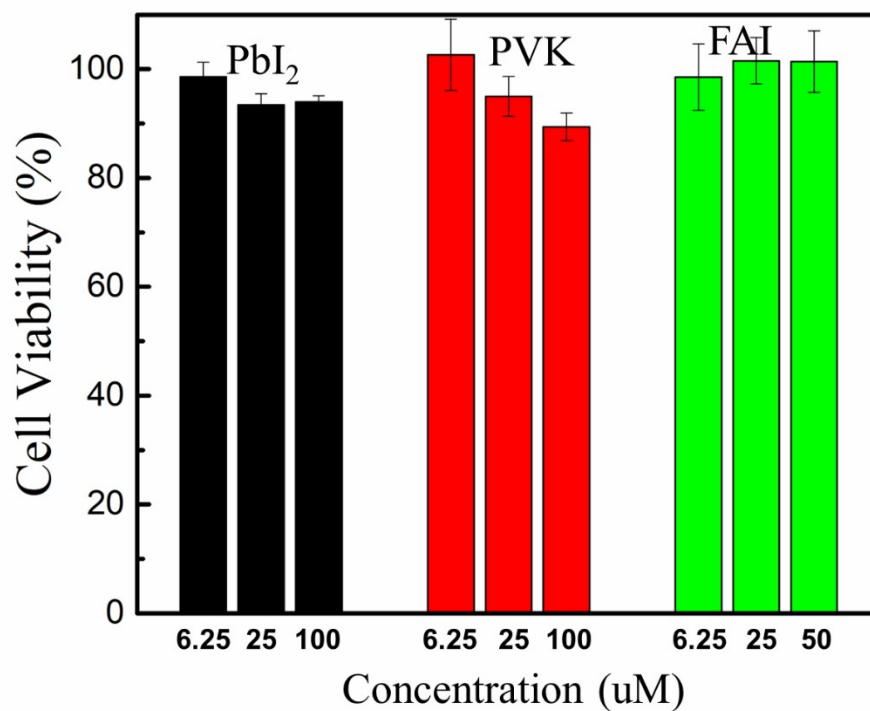


Fig. S8 rat bone marrow mesenchymal stem cells (BMSC) viability cultured for 1 day with different conditions

Table S4 the group setting for investigating the animal toxicity effect of perovskite materials and PSCs devices

Group	Materials	Quantity
1	control	0
2	FAI	2.5 $\mu\text{mol/L}$
3	PbI ₂	0.625 $\mu\text{mol/L}$
4	PbI ₂	2.5 $\mu\text{mol/L}$
5	PbI ₂	5.0 $\mu\text{mol/L}$
6	FAPbI ₃	0.625 $\mu\text{mol/L}$
7	FAPbI ₃	2.5 $\mu\text{mol/L}$
8	FAPbI ₃	5.0 $\mu\text{mol/L}$
9	FAPbI ₃	10.0 $\mu\text{mol/L}$
10	PSCs	0.5 pieces
11	PSCs	2 pieces

