

Electronic Supplementary Information

Simultaneous realization of Hg²⁺ sensing, magnetic resonance imaging and upconversion luminescence *in vitro* and *in vivo* bioimaging based on hollow mesoporous silica coating UCNPs and ruthenium complex

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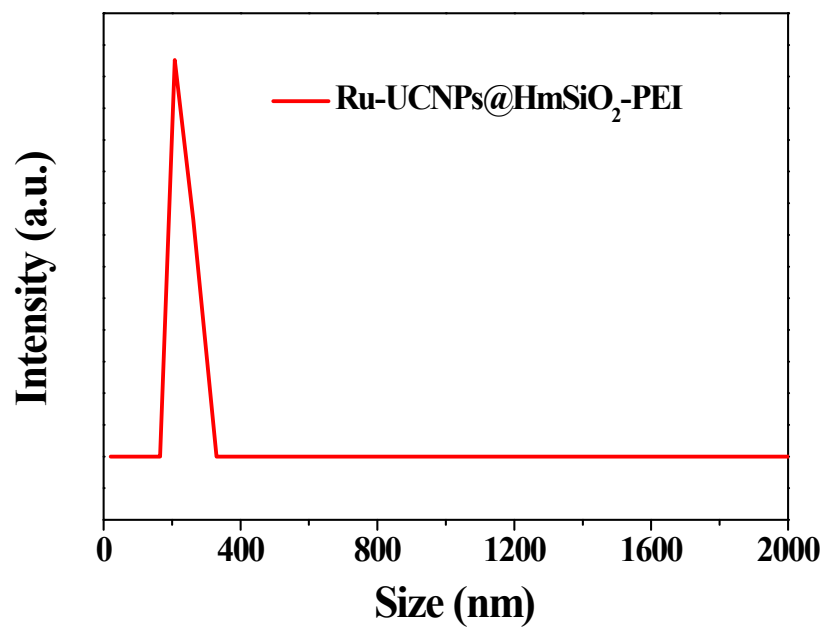


Fig. S1. Dynamic light scattering (DLS) of Ru-UCNPs@HmSiO₂-PEI in water.

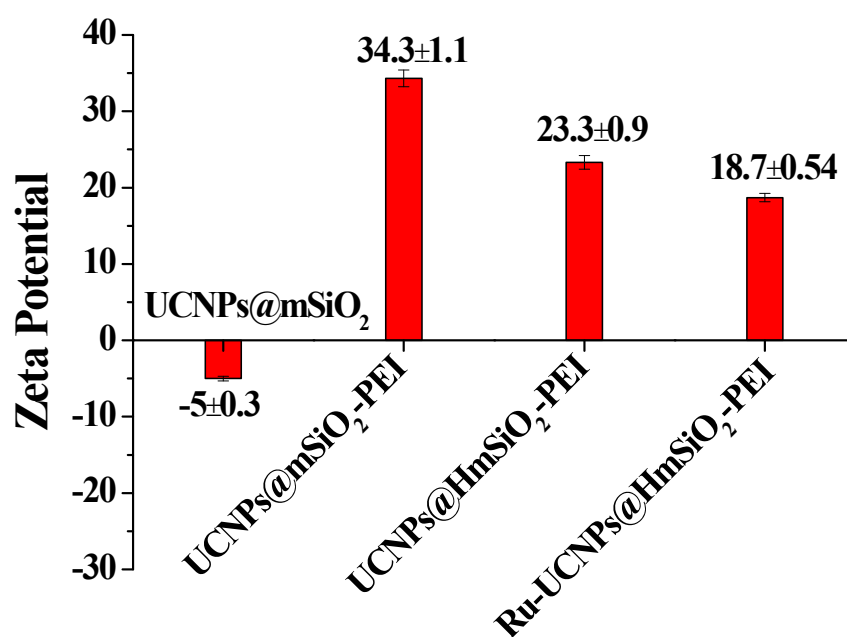


Fig. S2. The zeta potential of UCNPs@mSiO₂, UCNPs@mSiO₂-PEI, UCNPs@HmSiO₂-PEI, and Ru-UCNPs@HmSiO₂-PEI.

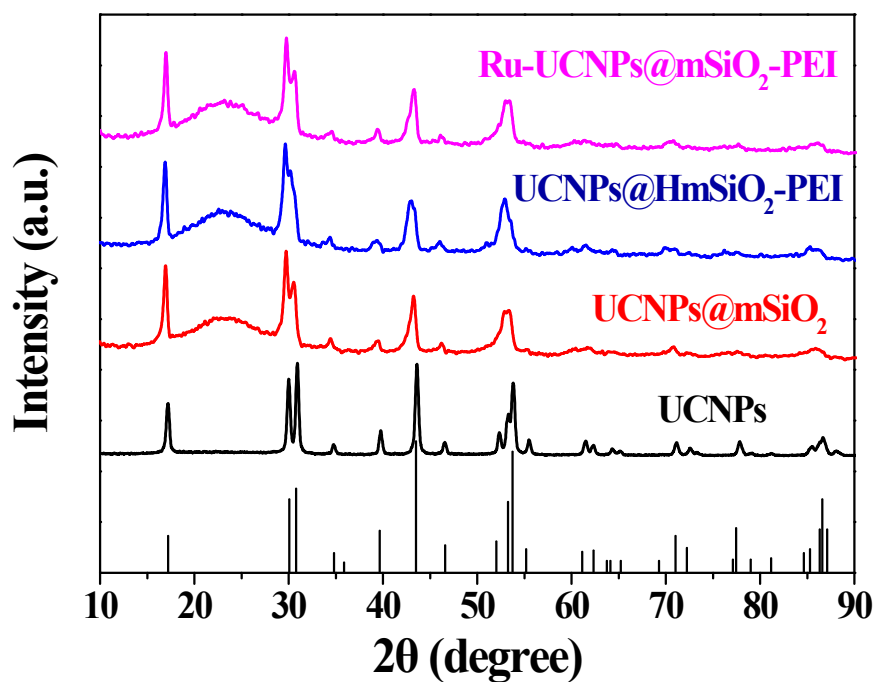


Fig. S3. The XRD patterns of UCNPs, UCNPs@mSiO₂, UCNPs@HmSiO₂-PEI, Ru-UCNPs@HmSiO₂-PEI, and the standard card of β -NaYF₄ (JCPDS: 16-0334).

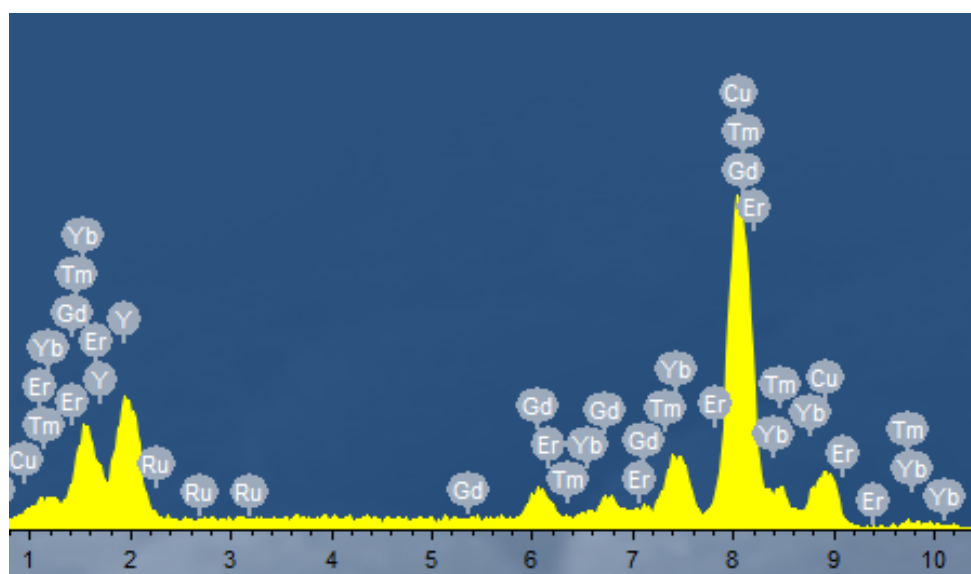


Fig. S4. Energy dispersive X-ray (EDX) spectrum of Ru-UCNPs@HmSiO₂-PEI.

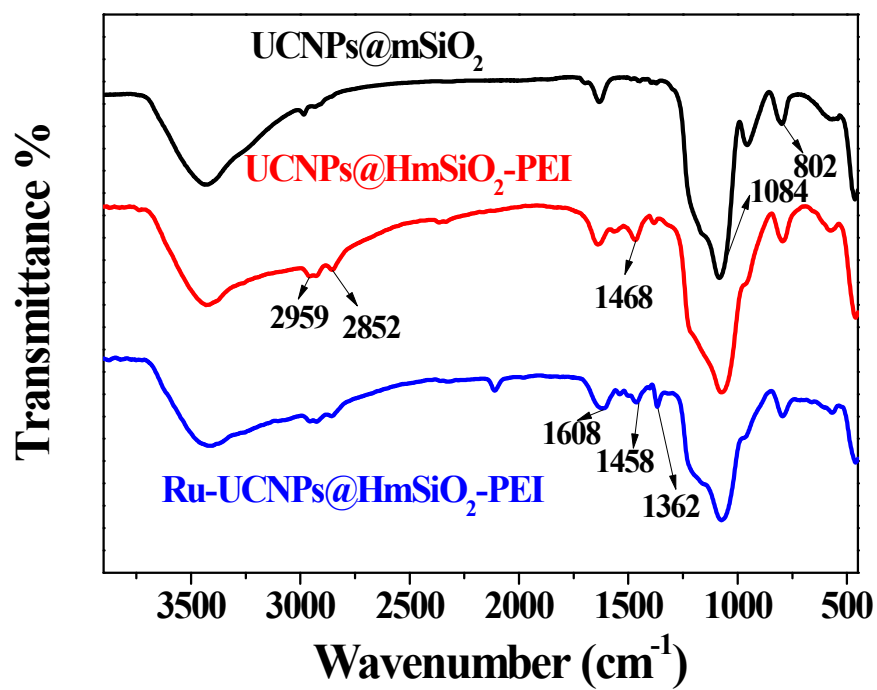


Fig. S5. FT-IR spectra of the UCNPs@mSiO₂, UCNPs@HmSiO₂-PEI, and Ru-UCNPs@HmSiO₂-PEI.

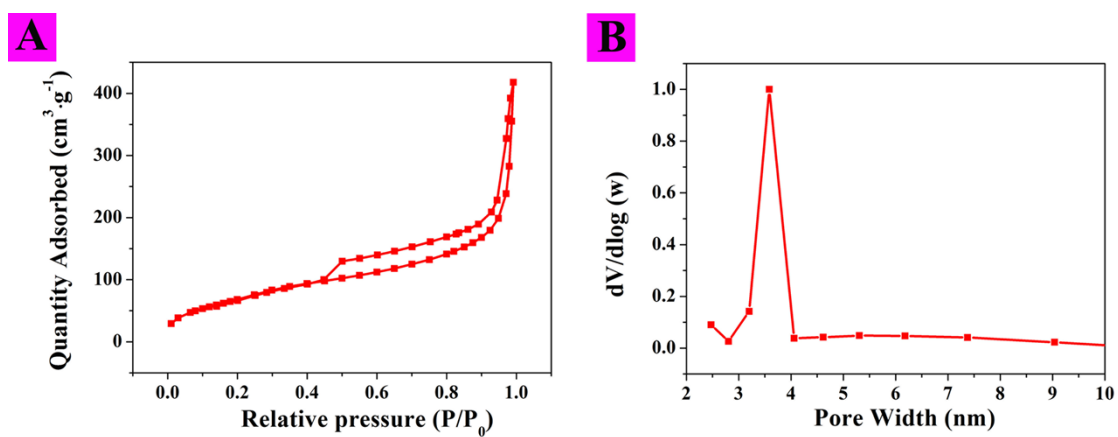


Fig. S6. (A) N_2 adsorption-desorption isotherm of Ru-UCNP@HmSiO₂-PEI; (B) The pore size distribution of Ru-UCNPs@HmSiO₂-PEI.

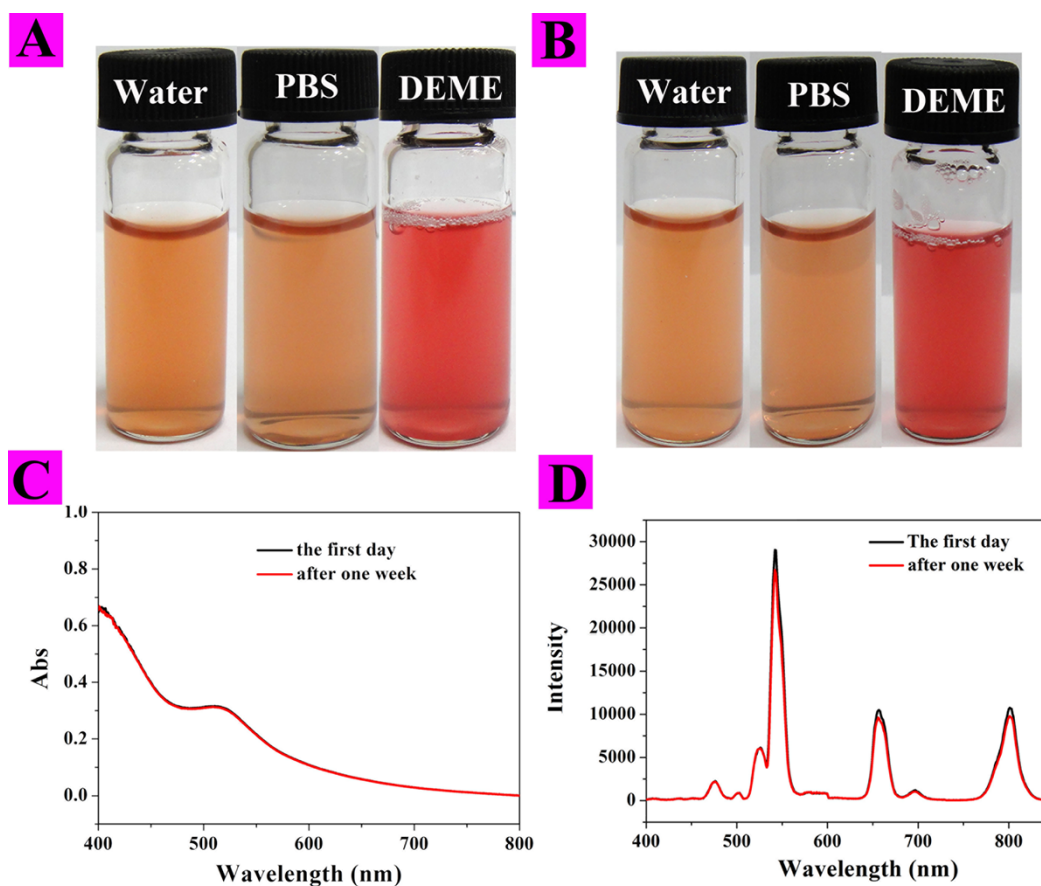


Fig. S7. (A) The photos of Ru-UCNPs@HmSiO₂-PEI in water, PBS and DMEM culture solution; (B) The photos of Ru-UCNPs@HmSiO₂-PEI placed in water, PBS and DMEM culture solution after one week; (C) UV-Vis absorption spectra of Ru-UCNPs@HmSiO₂-PEI in PBS solution on first day and after one week; (D) UCL spectra of Ru-UCNPs@HmSiO₂-PEI in PBS solution on first day and after one week.

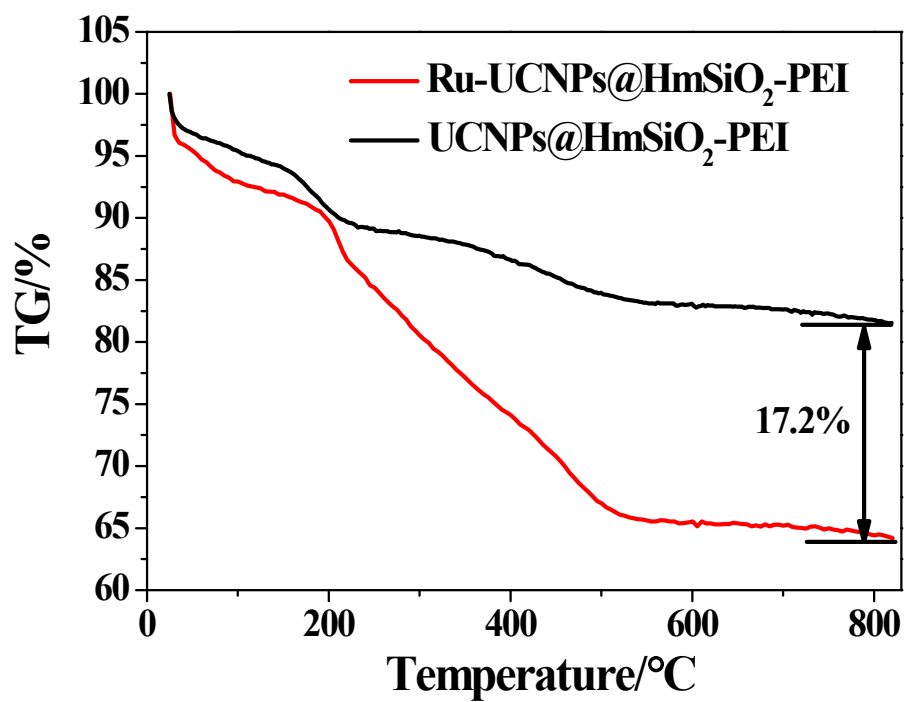


Fig. S8. Thermogravimetry (TG) curves of UCNPs@HmSiO₂-PEI and Ru-UCNPs@HmSiO₂-PEI.

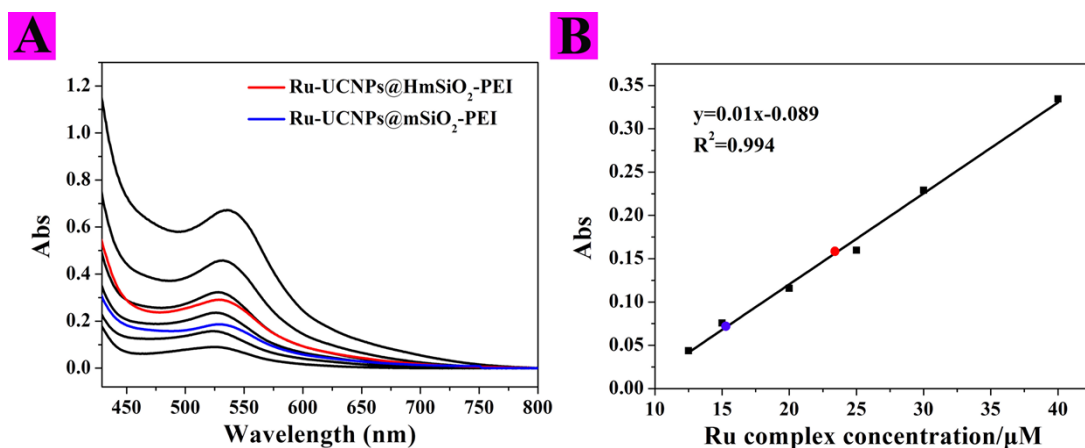


Fig. S9. The Ru complex concentrations of Ru-UCNPs@HmSiO₂-PEI and Ru-UCNPs@mSiO₂-PEI were calculated by using the detailed titration spectra. (A) UV/Vis absorption spectra of Ru complex with different concentrations. (B) The absorption intensity at 532 nm as a function of Ru complex concentration. The Ru complex contents of Ru-UCNPs@HmSiO₂-PEI and Ru-UCNPs@mSiO₂-PEI were determined as 23.4 μM (15.7 wt%) and 15.0 μM (10.1 wt%), respectively. The concentration of Ru-UCNPs@HmSiO₂-PEI and Ru-UCNPs@mSiO₂-PEI are both 0.15 mg·mL⁻¹.

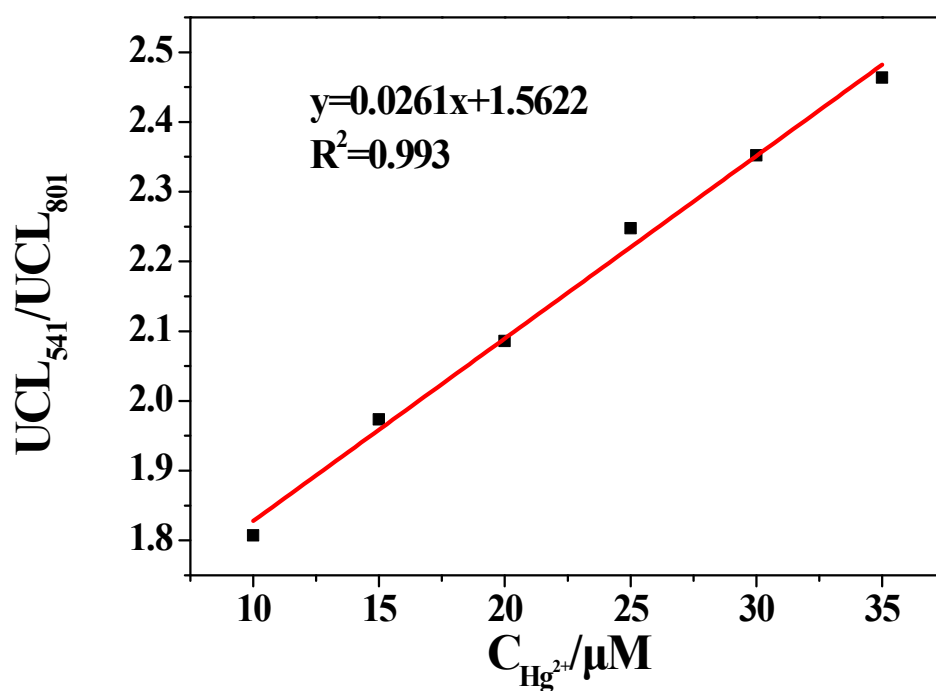


Fig. S10. The sensitivity test of Ru-UCNPs@HmSiO₂-PEI towards Hg²⁺ by using upconversion luminescence emission technique. The limit of detection limit (LOD) was given by the equation $\text{LOD} = 3S_0/S$; where 3 is the factor at the 99% confidence level, S_0 the standard deviation of the blank measurements ($n = 10$, $S_0 = 0.001392$), and S is the slope of the calibration curve. The limit of detection (LOD) was determined to be 0.16 μM .

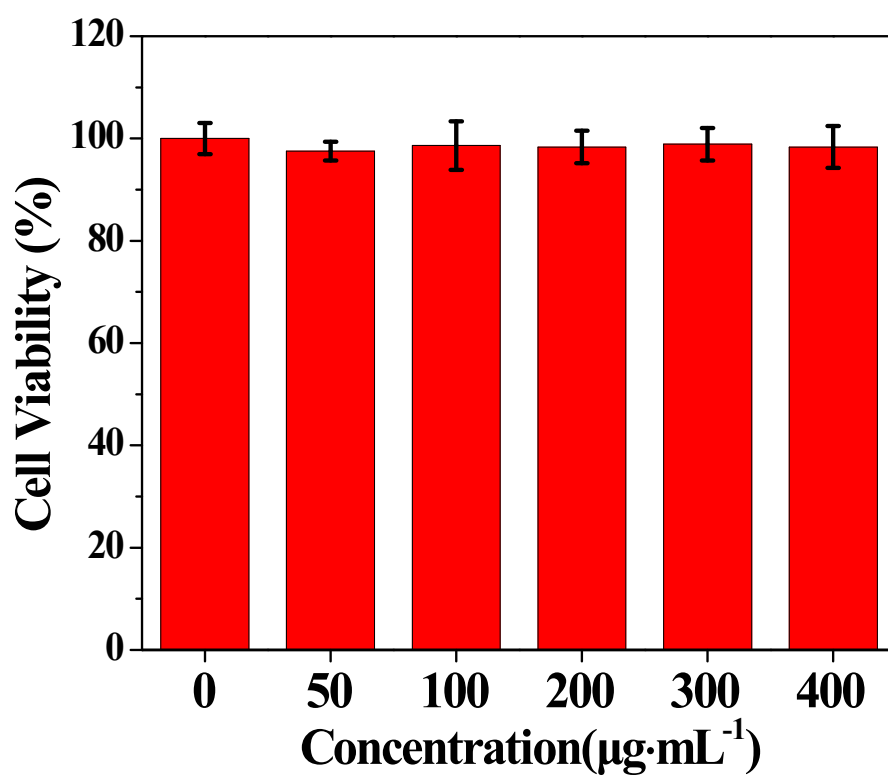


Fig. S11. *In vitro* cell viabilities of HeLa cells incubated with Ru-UCNPs@HmSiO₂-PEI at different concentrations (0, 50, 100, 200, 300, 400 µg·mL⁻¹) for 24 h.