Electronic Supplementary Information (ESI)

Porous Silsesquioxane cage and Porphyrin Nanocomposites: Sensing and Adsorption for Heavy Metals and Anions

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Sample	BET Surface Area	Langmuir Surface Area	Micro ^a	Meso ^b
TPP	1.1975 m²/g	2.5705 m ² /g	-	1.7994 m²/g
TPPSQ	433.2777 m²/g	1,827.0442 m ² /g	97.6330 m²/g	335.6446 m²/g
TPPSQ-F ⁻ complex	26.2069 m²/g	151.0991 m²/g	-	28.3190 m²/g
TPPSQ-CN ⁻ complex	84.6379 m²/g	242.8706 m²/g	2.1786 m²/g	82.4593 m²/g
TPPSQ-Cu ²⁺ complex	327.4784 m²/g	751.6026 m²/g	84.2106 m²/g	243.2678 m²/g
TPPSQ-Hg ²⁺ complex	201.4521 m²/g	513.9381 m²/g	36.5220 m²/g	164.9301 m²/g

Table S1. Porous textural properties of TPPSQ before and after the adsorption of analytes.

^at-Plot Micropore Area

^bt-Plot external surface area

Table S2. Details of pore textures of TPPSQ before and after the adsorption of analytes
caaaculated by t-plot method and NLDFT method.

Sample	Pore Volume (cm ³ /g)		% Mesopore	Pore Size (nm)		
	Total ^a	Micro ^b	Meso ^c	(volume)	Micropore ^d	Mesopor
						e
TPP	0.0216	-	~0.0216	~100	-	-
TPPSQ	0.6912	0.0497	0.6415	92.8	0.64,1.26	2.0-3.0
TPPSQ-F ⁻	0.0602			100	1.48	2 53 2 0
complex	0.0092	-	~0.0092 ~10	~100	1.40	2.33-2.9
TPPSQ-CN ⁻	0.2125	0.00008	0.2124	~100	1 42	2 5-3 0
complex	0.2123	0.00000	0.2124	100	1.72	2.3-3.0
TPPSQ-Cu ²⁺	0.4468	0.0445	0.4023	90	0 53 1 32	2 4-3 0
Complex	0.4400	0.0445	0.4023)0	0.55,1.52	2.4-3.0
TPPSQ-Hg ²⁺	0.3400	0.0101	0 3210	04.4	0.58.1.3	2530
Complex	0.5409	0.0191	0.3219	74.4	0.30,1.3	2.3-3.0

^aTotal pore volume

^bt-plot micropore volume

^cdifference of total pore volume and t-plot micropore volume

^d micropore size determined from the highest contribution (0-2 nm) from NLDFT model.



Figure S1. a) FTIR and powder XRD of TPPSQ; b) FTIR and powder XRD analysis of precursor TPP; c) FTIR of precursor SQ.



Figure S2. Thermal gravimetric analysis (TGA) of TPP under a) N₂ atmosphere and b) O₂ atmosphere.



Figure S3. Thermal gravimetric analysis (TGA) of TPPSQ under a) N₂ atmosphere and b) O₂ atmosphere.



Figure S4a. FESEM image of a dried sample of TPPSQ suspension (20 μ g·mL⁻¹) in THF medium



Figure S4b. Energy Dispersive X-ray Analysis of a dried sample of TPPSQ suspension (20 μ g·mL⁻¹) in acetonitrile medium.



Figure S5. Absorption spectra of the TPPSQ in different medium



Figure S6. Emission spectra of TPPSQ in different media (λ_{ex} = 420 nm, in acetonitrile λ_{ex} =415 nm)



Figure S7. a) Absorption spectra of precursor TPP molecule and synthesized TPPSQ polymer in THF medium; b) emission spectra of precursor TPP molecule and synthesized TPPSQ in THF medium (λ_{ex} = 420 nm).

Solvent	Absorption band (λ_n	Emission hand (nm)		
Solvent	Soret (B) Band	Q band		
THF	418, 449	529, 571, 615, 668	654, 717	
DMSO	420	521, 560, 600, 651	650, 715	
DMF	420, 441	529, 564, 604, 659	654, 717	
Toluene	421, 473	534, 570, 608,667	655, 719	
Acetonitrile	415, 441	530, 567, 606, 661	650, 716	

Table S3. Photophysical property of hybrid polymer TPPSQ in different medium



Figure S8. Epifluorescence microscopy of TPP at a) 470 nm; b) 460 nm; c) 530 nm and d) 350 nm.



Figure S9. Epifluorescence microscopy of the synthesized TPPSQ at a) 470 nm; b) 460 nm; c) 530 nm and d) 350 nm



Figure S10. Absorption spectra of TPPSQ in presence and absence of fluoride ion in different media showing the blue shift of Q band of TPPSQ in presence of fluoride ion.



Figure S11. Absorption spectra of TPPSQ in presence and absence of cyanide ion in different media.

Tetrahydrofuran (THF)



Figure S12. Absorption spectra of TPPSQ in THF medium in presence of various anions.



Figure S13. Absorption spectra of TPPSQ in DMF medium with different anion.



Figure S14. Absorption spectra of the TPPSQ suspension $(20 \,\mu g \cdot mL^{-1})$ in different media in the presence of a series of anions (8 x 10^{-4} M).



Figure S15. a) Kinetics of TPPSQ in presence of TBAPO₄ in different media; b) powder XRD analysis of TPPSQ-F⁻ Complex.



Figure S16. Limit of detection (LOD) and Limit of quantitation (LOQ) of TPPSQ for fluoride ion (F) detection in various solvents.



Figure S17. Association constant between TPPSQ and fluoride ion (F⁻) in different media



Figure S18. Limit of detection (LOD) and Limit of quantitation (LOQ) of TPPSQ for fluoride ion (F⁻) and Association constant between TPPSQ and fluoride ion (F⁻) in acetonitrile.

Kinetic constant (k) x 10 ⁻³ sec ⁻¹				
Solvent	F ⁻	CN ⁻	PO4 ³⁻	
Toluene	72.6	3.2	-	
Tetrahydrofuran (THF)	8.0	2.2	1.4	
Acetonitrile	2.1	0.9	0.4	
DMF	6.9	1.4	0.6	
DMSO	0.638	0.4	0.2	

Table S4. Kinetic constant of the reaction between TPPSQ and anions in different media.



Figure S19. Titration of TPPSQ (20 μ g·mL⁻¹) upon addition of F⁻ ion in different media ($\lambda_{ex} = 420$ nm, for acetonitrile medium $\lambda_{em} = 415$ nm).



Figure S20. Absorption spectra of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) before and after the addition of fluoride ion (8 x 10^{-4} M) in a) THF, b) aqueous THF, c) SMSO and d) aqueous DMSO.



Figure S21. Kinetics of TPPSQ in the presence of TBAF in aqueous DMF media.



Figure S22. Testing of fluoride sensing capacity of TPPSQ in the presence of other anions in different media ($\lambda_{ex} = 420$ nm, for acetonitrile medium $\lambda_{em} = 415$ nm).



Figure S23: a) Calibration graph of TBAF; b) Reusability of TPPSQ as fluoride adsorbent and c) Absorption spectra of the recycled TPPSQ ($20 \ \mu g \cdot mL^{-1}$) towards F⁻ (8 x 10^{-4} M) in THF medium.



Figure S24. Limit of detection (LOD) and Limit of quantitation (LOQ) of TPPSQ for cyanide ion (CN^{-}) detection in various solvents.



Figure S25. a) FTIR of TPPSQ-F⁻ complex, b) N_2 adsorption-desorption isotherm of TPPSQ-F⁻ complex, c) FTIR of TPPSQ-CN⁻ complex, d) N_2 adsorption-desorption isotherm of TPPSQ-CN⁻ complex.



Figure S26. a, b) FESEM images of dried sample of TPPSQ-F⁻ complex in THF medium indicating assembly of nano-sized spherical particles yielding micro-sized spherical objects, c) Percentage of elements in elemental mapping of TPPSQ-F⁻ complex in THF medium (Figure S 27), d) FESEM image of dried sample of TPPSQ-CN⁻ complex in THF medium.



Figure S27. Elemental mapping of a dried sample of TPPSQ-F⁻ complex.



Figure S28. Epifluorescence microscopy of TPPSQ-F⁻ complex at a) 470 nm; b) 460 nm; c) 530 nm and d) 350 nm



Figure S29a. Selectivity of TPPSQ suspension (20 μ g·mL⁻¹) towards different metal ions in different media under UV lamp (Photo taken after 3 hours of metal ion addition).



Figure S29b. Sensitivity of TPPSQ suspension (20 μ g·mL⁻¹) towards different metal ions in DMSO under UV lamp (Photo taken after 18 hours of metal ion addition).



Figure S30. a) Time dependent quenching of emission band of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of Hg²⁺ ion (6.6 x 10⁻³ mM) in THF medium ($\lambda_{ex} = 420 \text{ nm}$), b) quenching of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of varied concentration of Hg²⁺ ion in acetonitrile medium ($\lambda_{ex} = 415 \text{ nm}$), c) time dependent quenching of emission band of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of Cu²⁺ ion (6.6 x 10⁻³ mM) in acetonitrile medium ($\lambda_{ex} = 415 \text{ nm}$), d) quenching of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of Varied concentration of Cu²⁺ ion in acetonitrile medium. ($\lambda_{ex} = 415 \text{ nm}$)



Figure S31. Kinetics of TPPSQ (20 μ g·mL⁻¹) in presence of Hg²⁺ ion (6.6 x 10⁻² mM) in different media.



Figure S32. Limit of detection (LOD) and Limit of quantitation (LOQ) of TPPSQ for mercury ion (Hg^{2+}) detection in various solvents.



Figure S33. Association constant between TPPSQ and HgClO₄ in different media.



Figure S34. Study of Limit of detection (LOD) and Limit of quantitation (LOQ) of TPPSQ with mercury standard solution for ICP in DMF ($\lambda_{ex} = 420$ nm).



Figure S35. Time dependent quenching of emission band of TPPSQ in presence of 4ppm and 8 ppm Hg²⁺ ion in THF ($\lambda_{ex} = 420$ nm).



Figure S36. Testing of mercury ion (Hg²⁺) sensing capacity of TPPSQ in the presence of other cations ($\lambda_{ex} = 420 \text{ nm}$).



Figure S37. Limit of detection (LOD) and Limit of quantitation (LOQ) of TPPSQ for copper ion (Cu^{2+}) detection in various solvents.



Figure S38. Titration of TPPSQ (20 μ g·mL⁻¹) upon addition of Cu²⁺ion in different media ($\lambda_{ex} = 420$ nm, in acetonitrile medium ($\lambda_{ex} = 415$ nm).

Kinetic studies of TPPSQ with different cations in different media

The kinetics of Cu^{2+} ion (6.6 x 10⁻² mM) adsorption on TPPSQ (20 µg·mL⁻¹) have been studied in different media (Figure S40 a). From the kinetic graph it has been observed that TPPSQ was much more reactive towards Cu^{2+} ion in acetonitrile medium in comparison to other media. Moreover, from the kinetic constants calculated from kinetic graphs in acetonitrile medium, it is evident that the reaction rate of TPPSQ with Hg²⁺ and Cu²⁺ is comparable in acetonitrile medium (Figure S41 b, Table S4). However, in THF and DMF media, the reaction rate of TPPSQ with Hg²⁺ is much faster in comparison to Cu²⁺ (Figure S41a, c). In fact, in THF medium the polymer is almost unresponsive towards Cu^{2+} in between the kinetic study timeframe. The kinetics of Cu^{2+} ion adsorption on TPPSQ in aqueous acetonitrile media have also been studied (Figure S40 b). The calculated kinetic constants indicated that the quenching rate of emission band of TPPSQ slowed down in aqueous acetonitrile in comparison to pure acetonitrile medium (Table S4). Kinetic studies of TPPSQ with Zn^{2+} ion revealed that the polymer was almost nonreactive towards Zn^{2+} ion in THF and DMF media. However, TPPSQ is responsive towards Zn^{2+} ion in acetonitrile media though the reaction rate is much slower in comparison to Hg^{2+} or Cu^{2+} ion (Figure S41). Similarly, Kinetic studies of TPPSQ was significantly responsive towards Fe^{2+} ion in acetonitrile media though the reaction rate was slower in comparison to Hg^{2+} or Cu^{2+} but much faster than Zn^{2+} ion (Figure S39 b and S41). After the addition of Fe^{2+} ion (6.6 x 10^{-2} mM) to the TPPSQ suspension (20 µg·mL⁻¹) in acetonitrile medium, the emission band of TPPSQ majorly quenched within 2 hours (Figure S39 and Figure S49).



Figure S39. a) Time dependent quenching of emission band of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of Fe²⁺ ion (6.6 x 10⁻² mM) in acetonitrile medium ($\lambda_{ex} = 415 \text{ nm}$); b) Kinetic study of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of Fe²⁺ ion (6.6 x 10⁻² mM) in different media.



Figure S40. a) Kinetics of TPPSQ (20 μ g·mL⁻¹) in presence of Cu²⁺ ion (6.6 x 10⁻² mM) in different media. b) Kinetic study of TPPSQ in aqueous acetonitrile medium in presence of Cu²⁺ ion ($\lambda_{ex} = 415$ nm).



Figure S41. a-c) Comparison of the kinetic data of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) with various metal ions (6.6 x $10^{-2} \ mM$) in different media; d) kinetic study of TPPSQ ($20 \ \mu g \cdot mL^{-1}$) in presence of Zn²⁺ ion (6.6 x $10^{-2} \ mM$) in different media.



Figure S42. a) FTIR of TPPSQ-Cu²⁺ complex; b) powder XRD analysis of TPPSQ-Cu²⁺ complex; c) N_2 adsorption-desorption isotherm of TPPSQ-Cu²⁺ complex; d) pore size distribution of TPPSQ-Cu²⁺ Complex.

Morphological characterisation of Cu- adsorbed and Zn-adsorbed TPPSQ polymer:

FESEM images of a Cu^{2+} -adsorbed TPPSQ polymer from acetonitrile medium revealed the presence of distinct nanosized spherical particles (Figure S43 b) along with self-assembled microsized particles (Figure S44). EDX analysis of the dried sample of Cu-adsorbed TPPSQ confirmed the presence of Cu along with the presence of C, N, O and Si which indicated the intactness of TPPSQ after the Cu²⁺ adsorption in acetonitrile medium (Figure S44). FESEM analysis of dried dispersion of Zn²⁺-adsorbed TPPSQ in acetonitrile medium indicated the presence of densely packed microsized spherical aggregates which are composed of nanosized particles (Figure S45 a,b). EDX analysis of a dried sample of Zn-adsorbed material also confirmed the presence of Zn (Figure S45 c).



Figure S43. FESEM image of a) TPPSQ-Hg²⁺ complex, b) TPPSQ-Cu²⁺ complex.



Figure S44. Elemental mapping of a dried sample of Cu^{2+} adsorbed TPPSQ.



Figure S45. Energy dispersive X-ray analysis of a dried sample of Zn^{2+} - adsorbed TPPSQ.



Figure S46. Epifluorescence microscopy of TPPSQ-Hg complex at a) 470 nm; b) 460 nm; c) 530 nm and d) 350 nm

Table S5. Kinetic constant of the reaction between TPPSQ and cations in different medi
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Kinetic constant (k) x 10^{-3} sec ⁻¹				
Solvent	Hg ²⁺	Cu ²⁺		
Tetrahydrofuran (THF)	234.5	-		
Acetonitrile	3.6	3.3		
DMF	0.6	_		
Acetonitrile/water 10:1	_	1.4		
Acetonitrile/water 5:1	_	0.5		
DMSO/water 1:2	1.8	_		
DMSO/water 1:7	8.3	-		
DMF/water 10:1	8.7	-		
DMF/ water 5:1	9.2	_		
DMF/water 2:1	9.7	_		



Figure S47. Fluorescence emission spectra of precursor TPP in presence of metal ions and anions in various medium ($\lambda_{ex} = 420$ nm, in acetonitrile medium ($\lambda_{ex} = 415$ nm).



Figure S48: Calibration curve of a) mercury and b) copper for the study of time dependent adsorption capability of TPPSQ; c) b) Adsorption efficacy of TPPSQ (10 mg) in acetonitrile medium with Hg^{2+} (50 ppm) and Cu^{2+} (50 ppm) ion.



Figure S49: Calibration curve of mercury to measure the Hg^{2+} adsorption efficacy of TPPSQ polymer in acetonitrile medium (Figure 8b).



Figure S50: Responsiveness of the recycled TPPSQ ($20 \ \mu g \cdot mL^{-1}$) towards Hg^{2+} (6.6 x $10^{-2} \ mM$) in THF medium ($\lambda_{ex} = 420 \ nm$).



Figure 51: a) Calibration curve of mercury; b) Reusability of TPPSQ as mercury(II) adsorbent after washing with 2M HCl for 3 hours. For each cycle 25 mg of TPPSQ was kept in contact of 50 ppm mercury in acetonitrile medium for 30 minutes; c) Reusability of TPPSQ as mercury(II) adsoebent after washing with 2M HCl for 3 hours. For each cycle 25 mg of TPPSQ was kept in contact of 50 ppm mercury in acetonitrile medium for 60 minutes. If TPPSQ is in contact with mercury for 60 minutes, then 2M HCl could not wash the polymer efficiently.

 Table S6: Comparison between dual probe fluoride and mercury sensor:

References	LOD of F ⁻	LOD of Hg ²⁺
This work	0.057 ppm-2.94 ppm (solvent dependent)	0.24-0.74 ppm (for HgClO ₄ salt)
		0.22 ppb (Standard mercury sample for ICP-MS)
Su & co-workers (reference 1)	Probe 1: 1.8 10 ⁻⁷ M and Probe 2: 1.7 10 ⁻⁷ M	Probe 1: 3.0 10 ⁻⁸ M and Probe 2: 4.9 10 ⁻⁸ M
P. Banerjee & co-workers (reference 2)	6.6 x 10 ⁻⁶ M	Did not mention
Cui-Hua Zhao et al (reference 3)	Not mentioned	72.7 nM
Reference 4	$1.5 \ \mu mol \ dm^{-3}$	$2.7 \ \mu mol \ dm^{-3}$
Reference 5	5.17 x 10 ⁻⁸ M (~1.0 ppb)	5.4 x 10 ⁻⁹ M (~1.1 ppb)
Reference 6	-	1.0 X10 ⁻⁶ -7.0 X10 ⁻⁷ M
S. Bhattyacharya et al (Reference 7)	Probe1:0.6ppb(acetonitrile),0.43ppm(DMF-water 9:1)	Probe 1: 0.4 ppb in acetonitrile, 3 ppb in aq. Acetonitrile
	Probe 2: 0.9 ppb (acetonitrile), 0.14 ppm (DMF-water 8:2)	Probe 2: 2.3 ppb in acetonitrile, 1 ppb in aqueous acetonitrile

A) Comparison with other dual probe fluoride and mercury sensor

Su and co-workers reported two novel thioxanthone-based derivatives which possess thiosemicarbazone as binding site for the dual-channel detection of Hg^{2+} and F^- ion. Upon treatment with Hg^{2+} and F^- separately, the probes fluorescence emission of the probes turned-off. The detection limit of the probes for Hg^{2+} ion were estimated as 3.0 10^{-8} M and 4.9 10^{-8} M, respectively. On the other hand, for fluoride ion, the LOD were were calculated as $1.8 \ 10^{-7}$ M and 1.7×10^{-7} M.¹

P. Banerjee and co-workers reported a dual responsive efficient new Schiff base sensing probe for selective sensing of F⁻and Hg²⁺ion. The LOD for fluoride ion has been determined via fluorescence titration and calculated as 6.6 x 10^{-6} M. It has been reported that on addition of Hg²⁺ ion to the sensing probe-F⁻ solution, observable optical changes was observed. However, the LOD for Hg²⁺ has not been mentioned.²

Cui-Hua Zhao and co-workers reported a bifunctional fluorescent probe posessing Hg^{2+} -responsive dithioacetal group and a F⁻-responsive boryl group for selective detection of Hg^{2+} ion and F⁻ ion. The detection limit for Hg^{2+} was reported as 72.7 nM whereas the detection limit of fluoride ion was not mentioned.³

A bifunctional aroylhydrazone chemosensor probe has been reported for the selective detection of Hg2+ and F⁻ ion. The detection limit of F⁻ ion and Hg²⁺ ion have been reported as 1.5 μ mol dm⁻³ and 2.7 μ mol dm⁻³.⁴

A novel fluorescein-rhodamine based dual fluorescent probe has been reported for the selective detection of F⁻ and Hg²⁺ ion. The calculated LOD of the probe are 5.17 x 10⁻⁸ M (~1.0 ppb) and 5.4 x 10⁻⁹ M (~1.1 ppb), respectively for F⁻ and Hg²⁺ in aqueous medium.⁵

Two dual responsive chemosensors based on photochromic dithienylcyclopentene have been reported for selective detection of F^- and Hg^{2+} ion in acetonitrile medium. The detection limits for Hg^{2+} ion have been reported as 1.0 X10⁻⁶ M and 7.0 x 10⁻⁷ M.⁶

S. Bhattyacharya and co-workers reported two rhodamine based dual responsive fluorescent probes for selective detection of Hg^{2+} and F^{-} ion. The detection limit for F^{-} was estimated as 0.6 ppb and 0.9 ppb for 1 and 2, respectively in acetonitrile medium. In aqueous DMF media (DMF–water 9:1), Probe 1 showed the detection limit of F^{-} ion was determined as 0.43 ppm. In a 8 : 2 DMF–water mixture, the probe 2 showed a detection limit of F^{-} ion as 0.14 ppm. The detection limits of Hg^{2+} ion were measured as 0.4 and 2.3 ppb in acetonitrile medium. In aqueous acetonitrile medium, the detection limits for Hg^{2+} ion were reported as 3 and 1 ppb for probe 1 and 2, respectively.⁷

B) Comparison with Fluoride sensors

In the previous report from our lab, we reported two fluorescent polymer composed of silsesquioxane cage-based anthracene (An-PSQ) and pyrene (Py-PSQ) as fluoride sensor. Whereas the detection limit of An-PSQ was calculated as 1.14 M-1.35 M in different medium, due to slow response of Py-PSQ, the detection limit was not calculated for Py-PSQ. Ly et al reported a hydrophilic luminescent polymer composed of amino-functionalized polyhedral oligomeric silsesquioxane (AE-POSS) and perylene diimides (PDIs) for fluoride ion detection in aqueous medium. The limit of detection for fluoride ion was reported 16.2 ppb.⁸ Our group has reported an anthracene-conjugated octameric silsesquioxane (AnSQ) fluorescent probe for fluoride sensing with a detection limit of 1.65-9.57 ppb in different media. However, the UV-vis titration of AnSQ with fluoride ion indicated the detection limit was 0.452 ppm. Another report from our group mentioned about the efficacy of the pyrene functionalized silsesquioxane cages (PySQ) as fluoride with a detection limit of 1.61 ppb. Xu et al reported synthesis of three octapyrene-modified POSS molecules by condensation reactions between pyrenecarboxylic acid (C₀-Py, C₁-Py, C₃-Py) and amino-substituted POSS. Among them, POSS-(C₁-Py)₈ displayed specific selectivity to the F⁻ ion with a detection limit of lower than 5×10^{-5} M.⁹ Shen and Gu et al reported a trimethyldiphenylsilyl ether recognition group containing organic fluorophore as fluoride sensor. The lowest limit of fluoride ion detection was reported as 1.16×10^{-6} M.¹⁰ Li and Shen et al reported a fluorescent probe containing two pyrene moiety connected by -O-Si-Si-O or O-Si-O linkage. This probe is highly sensitive towards fluoride ion due to fluoride anion induced Si–O bond cleavage with a detection limit in the micromolar range.¹¹

C) Comparison with Mercury (II) sensors

Wang and co-workers reported the synthesis of a novel selenone-functionalized POSS (POSS-Se) as a turn-on mercury sensor with detection limit of (LOD) of 8.48 ppb.¹² Gokulnth et al reported synthesis of a new class of carbazole based macrocycles. One of the synthesized macrocycle which contain a furan moiety is highly sensitive towards mercury with a detection limit 100 nM.¹³ Wu et al reported a novel amphiphilic acrylamide-based polymer with porphyrin pendants for the selective detection of Hg²⁺ ion with a detection limit of 50 nM.¹⁴

The above discussion indicates that the sensing efficacy of our synthesized polymer is comparable with other dual sensing fluorescent probe for fluoride as well as mercury sensing. According to World Health Organization guideline, the optimum fluoride ion (F^-) concentration is 1.5 ppm. Below this level can cause osteoporosis and dental caries and excessive amount can cause serious health problem. In this perspective, the calculated LOD and LOQ value of TPPSQ for fluoride ion in different media (LOD = 0.057-2.94 ppm and LOQ = 0.19-9.8 ppm) confirmed the efficacy of the TPPSQ as fluoride sensor. The Hg²⁺ sensing capacity of TPPSQ in aqueous media (LOD = 0.74 ppm) made it a potential candidate at mercury sensor in realistic field like waste water treatment. Moreover, the experimental results showed that our synthesized polymer TPPSQ is an excellent reusable adsorbent and sensor which makes our polymer more advantageous over the other dual fluorescent probes discussed (Figures S32, S50-51).

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