# Supporting Information

# for

# Modified guar gum/$SiO_2$: Development and application of a novel hybrid nanocomposite as flocculant for the treatment of wastewaters

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# Investigation of flocculation characteristics:

## Flocculation characteristics using synthetic wastewater:

The flocculation efficiency of GG, g-GG, g-GG/$SiO_2$ nanocomposites and commercial flocculants were carried out using settling test and jar test. To explain the flocculation mechanism and kinetics, two different synthetic effluents (Fe-ore and Mn-ore suspensions) were used. The flocculation characteristics were performed at different *pH* conditions (acidic, neutral and basic). Additionally the zeta potential of the suspensions (before and after treatment) was measured using Zetasizer Nano ZS (Malvern, UK). The floc size was determined by DLS analysis (Zeta Sizer Nano ZS, Malvern, UK). The details of the experimental procedure of jar and settling tests have been explained below.

## Settling/Column test method:

Column test was investigated using a 100 mL stopper graduated cylinder (height – 40 cm; inner diameter – 2 cm) and stopwatch. At first, the suspension at different *pH* conditions was taken in the cylinder and the flocculant solution was added into it. The cylinder was inverted 10 times for thorough mixing. Afterwards, the cylinder was set upright and the height of the interface between the supernatant water and settling flocs was measured at regular interval.

## Jar test method:

The efficiency of flocculation characteristic of the flocculant was carried out using jar test apparatus which comprises of a flocculator with electronically equipped paddle (Make: Gon Engineering Works, Dhanbad, India) and turbidity meter (Digital Nephelo-Turbidity Meter 132, Systronics, India). The 1 wt% aqueous suspensions (at various *pH*: prepared using 0.1 (N) HCl and 0.1 (N) NaOH) of Fe-ore and Mn-ore were taken in 1-L beaker and different flocculant doses were added. After that, flocculation study was carried out by stirring at 75 rpm for 2 minutes, followed by 3 minute stirring at 25 ppm. The flocs, which were formed during the study was allowed to settle for 15 min. Finally the supernatant liquid was withdrawn from a depth of 1 cm and its turbidity was measured using the turbidity meter.

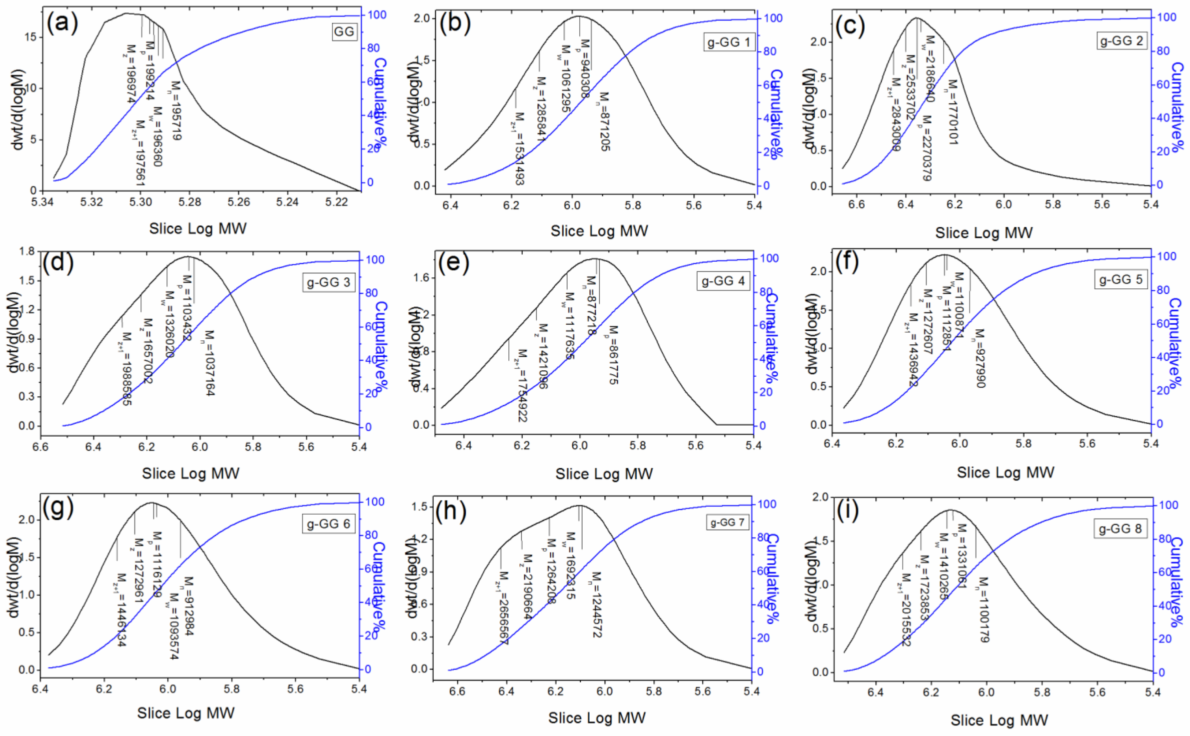

**Fig. S1**: GPC analysis result of (a) guar gum and (b-i) various graft copolymers.

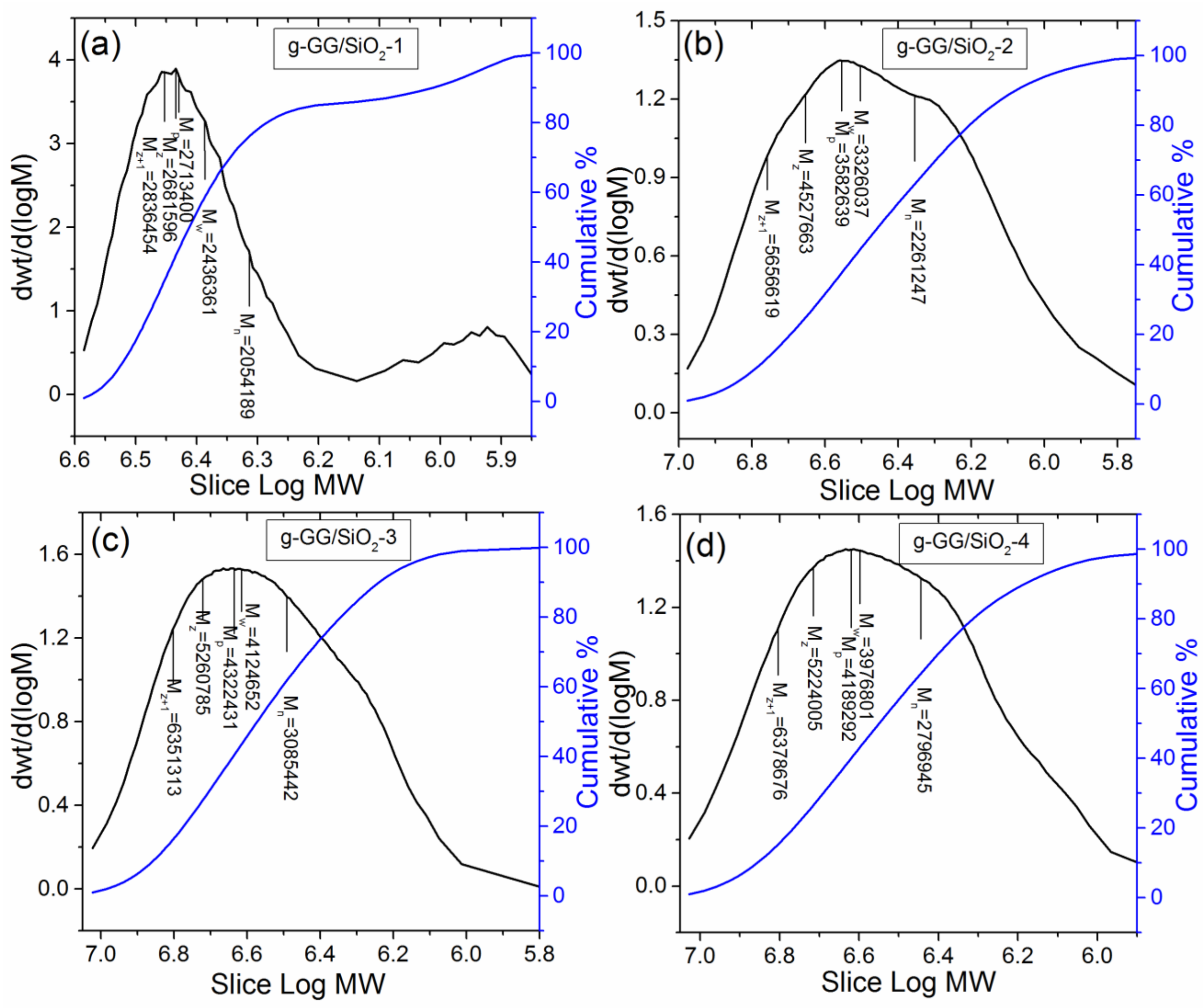


**Fig. S2**: GPC analysis result of (a) g-GG/$SiO_2$-1 (b) g-GG/$SiO_2$-2, (c) g-GG/$SiO_2$-3, and (d) g-GG/$SiO_2$-4 nanocomposites.

**Table S1:** Elemental analysis result.

| Sample | % C | % H | % N | % O |
|---|---|---|---|---|
| GG | 41.7 | 7.49 | 0.12 | 50.67 |
| g-GG 7 | 43. 8 | 8.12 | 9.52 | 38.53 |
| g-GG/$SiO_2$-3 | 40.65 | 7.16 | 8.86 | 41.28 |

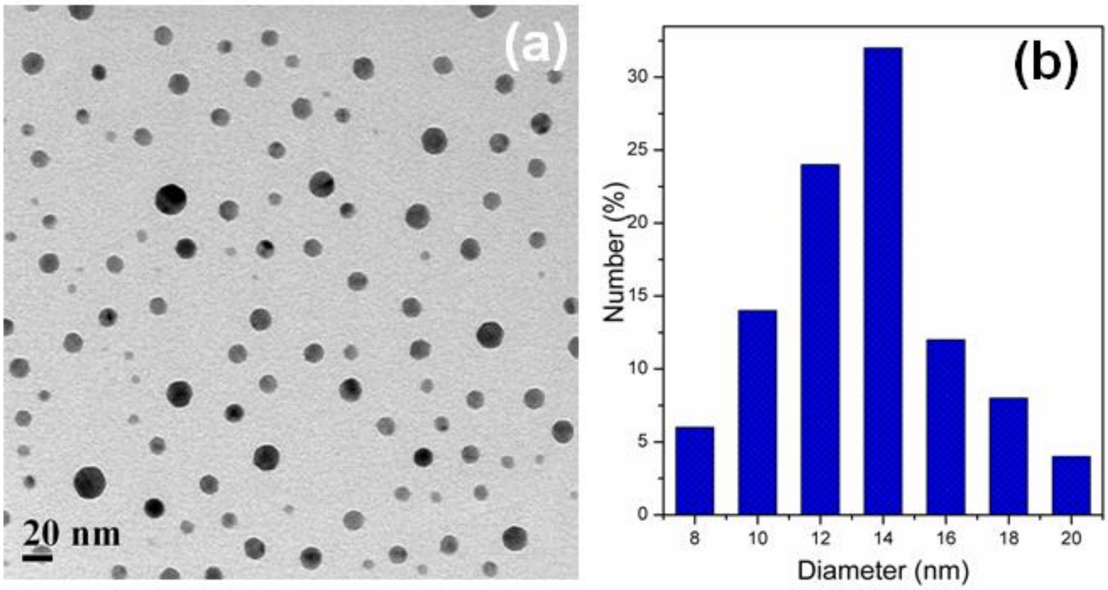


**Fig. S3**: (a) HR-TEM image and (b) histogram of g-GG/$SiO_2$-4 nanocomposite.

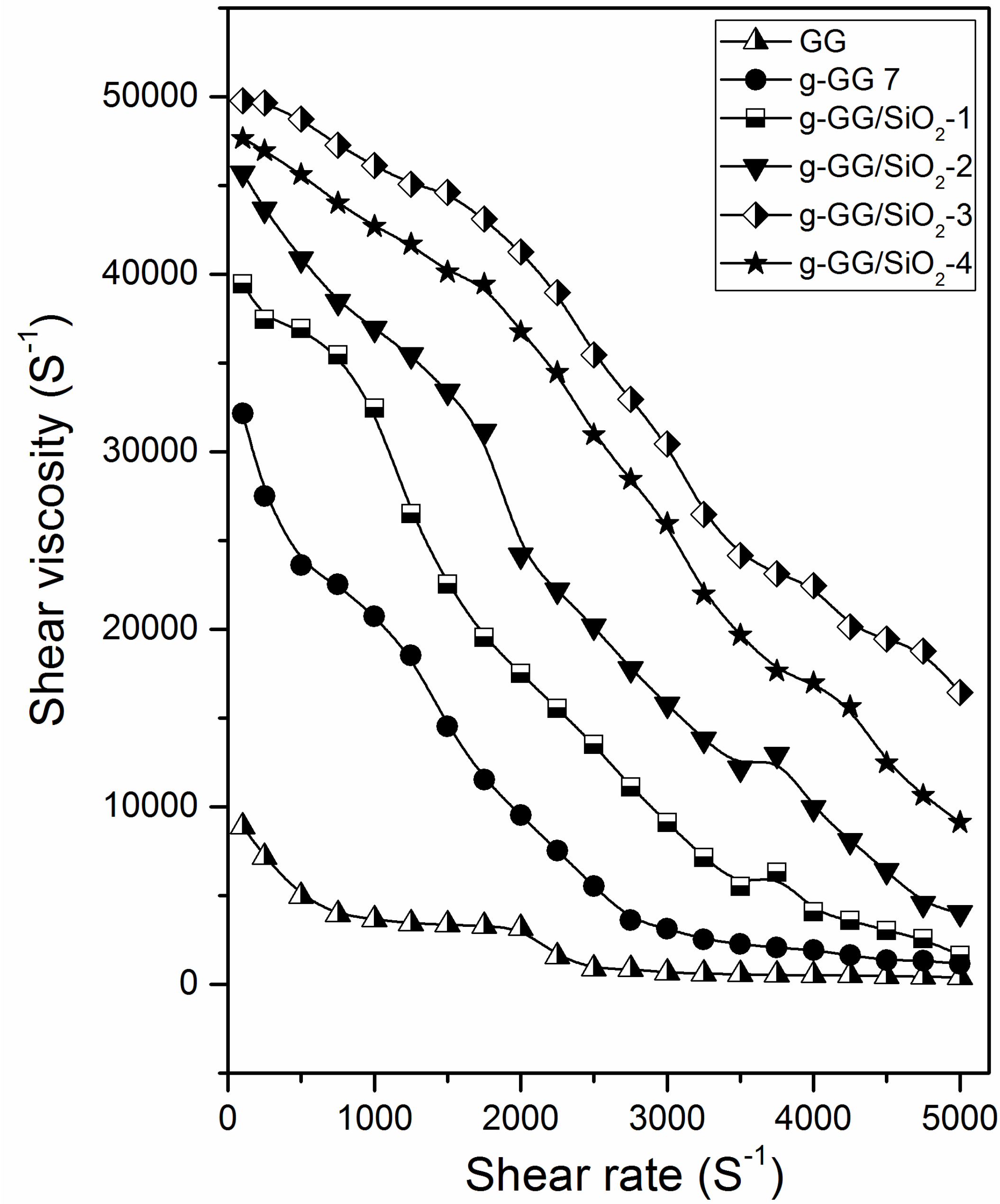


**Fig. S4:** Shear viscosity vs. shear rate of GG, g-GG7 and various nanocomposites.

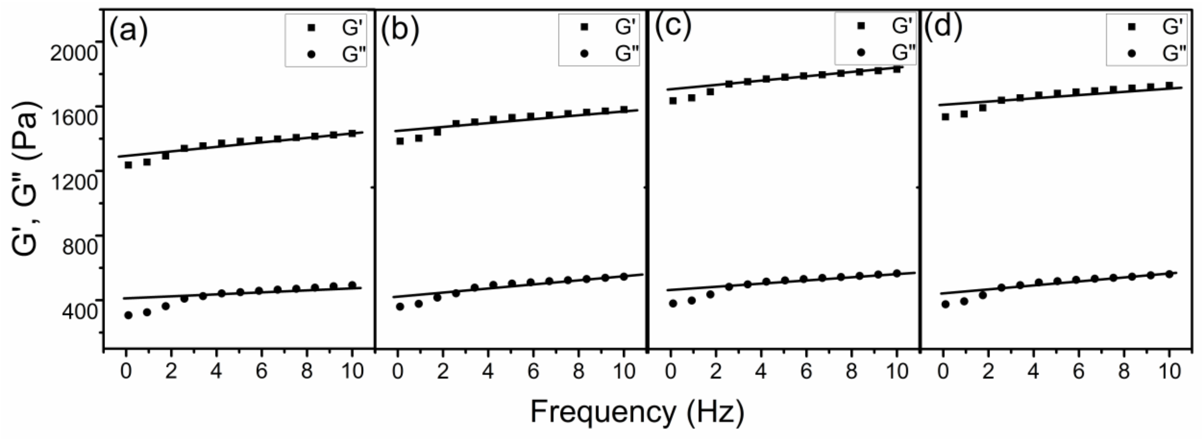


**Fig. S5:** G′ and G″ vs. frequency for (a) g-GG/$SiO_2$-1 (b) g-GG/$SiO_2$-2, (c) g-GG/$SiO_2$-3, and (d) g-GG/$SiO_2$-4 nanocomposites.

**Table S2**: Hydrodynamic radius of various flocculants; settling rate, average floc size and turbidity of Fe-ore/Mn-ore suspensions at different *pH* conditions.

| Polymer | $R_H$ | | | Settling rate (cm/sec) | | | Average floc size (nm) | | | Turbidity (NTU) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH 4 | pH 7 | pH 9 | pH 4 | pH 7 | pH 9 | pH 4 | pH 7 | pH 9 | pH 4 | pH 7 | pH 9 |
| *Fe-ore suspension* | | | | | | | | | | | | |
| GG | 6.2 | 5.7 | 7.9 | 0.22 | 0.21 | 0.19 | 545 | 404 | 654 | 54.0 | 61.0 | 59.0 |
| g-GG 7 | 19.4 | 16.9 | 28.3 | 1.01 | 0.96 | 1.36 | 925 | 779 | 1082 | 21.6 | 30.6 | 11.3 |
| g-GG/$SiO_2$- 3 | 30.8 | 26.9 | 39.4 | 1.75 | 1.62 | 2.46 | 1102 | 982 | 1265 | 15.5 | 25.7 | 7.3 |
| FL-419 | 21.3 | 13.9 | 27.9 | 0.74 | 0.70 | 0.94 | 858 | 698 | 912 | 25.9 | 35.7 | 16.1 |
| Fl-920 | 24.5 | 14.5 | 30.4 | 1.34 | 1.17 | 1.98 | 1026 | 886 | 1125 | 18.4 | 28.6 | 10.2 |
| *Mn-ore suspension* | | | | | | | | | | | | |
| GG | 6.2 | 5.65 | 7.9 | 0.19 | 0.17 | 0.20 | 424 | 316 | 528 | 70.0 | 66.9 | 65.4 |
| g-GG 7 | 19.4 | 16.9 | 28.3 | 0.82 | 0.67 | 1.07 | 758 | 651 | 877 | 26.2 | 33.3 | 17.4 |
| g-GG/$SiO_2$- 3 | 30.8 | 26.9 | 39.4 | 1.70 | 1.25 | 2.46 | 911 | 809 | 1082 | 20.2 | 27.2 | 11.2 |
| FL-419 | 21.3 | 13.9 | 27.9 | 0.65 | 0.50 | 0.72 | 642 | 553 | 721 | 32.3 | 38.9 | 22.0 |
| Fl-920 | 24.5 | 14.5 | 30.4 | 1.22 | 0.85 | 1.42 | 836 | 734 | 961 | 23.2 | 30.9 | 14.3 |

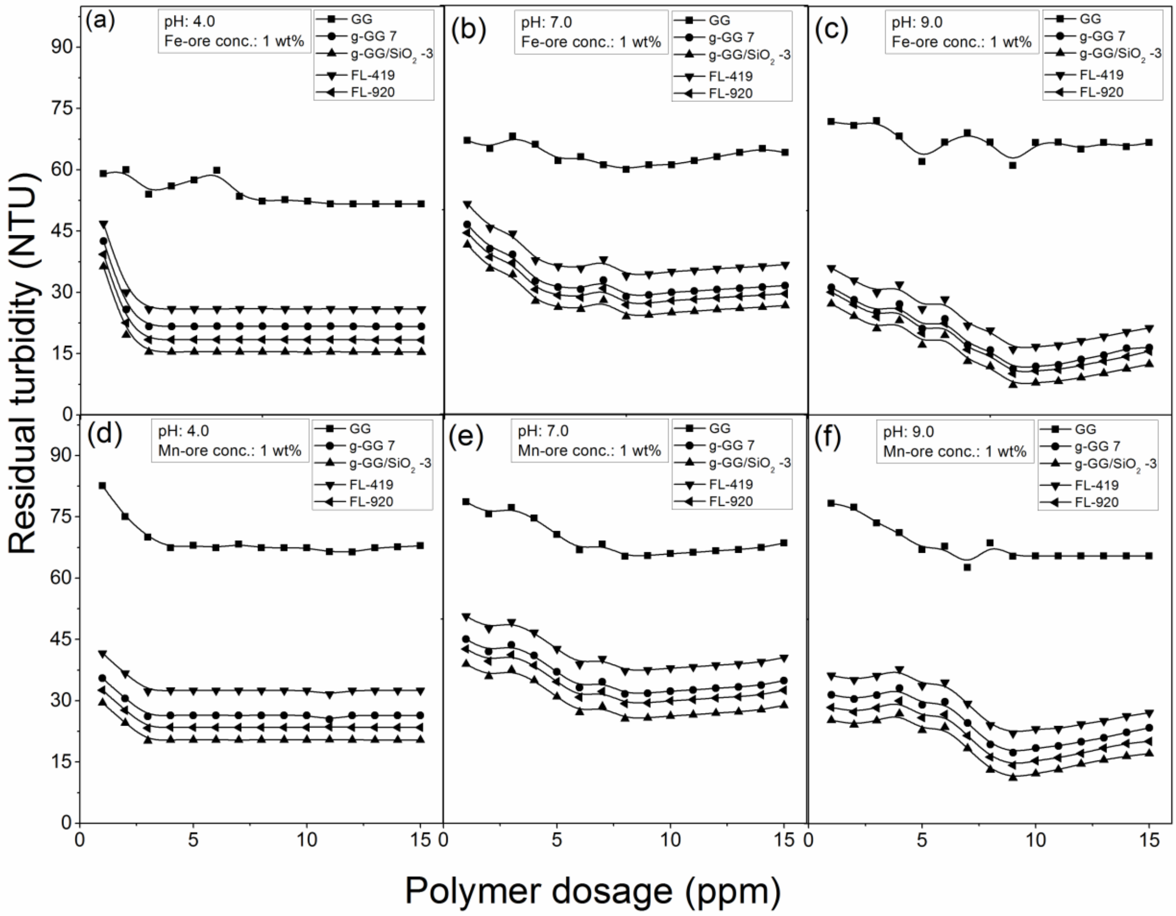


**Fig. S6:** Jar test results using various flocculants at (a) *pH* 4, Fe-ore suspension, (b) *pH* 7, Fe-ore suspension, (c) *pH* 9, Fe-ore suspension, (d) *pH* 4, Mn-ore suspension, (e) *pH* 7, Mn-ore suspension, and (f) *pH* 9, Mn-ore suspension.

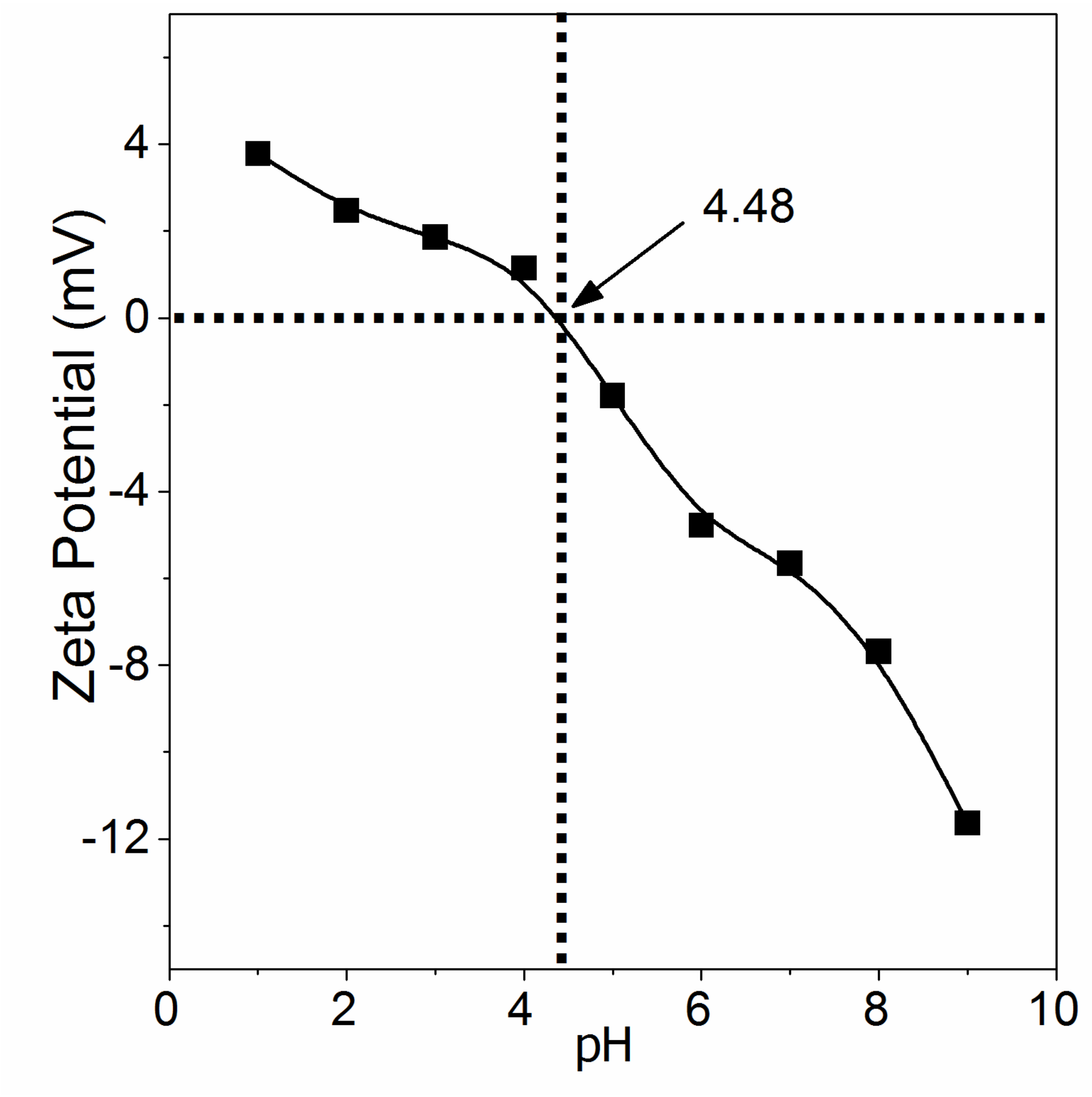


**Fig. S7:** Point to zero charge of g-GG/$SiO_2$-3 nanocomposite.

**Table S3:** Parameters of flocculation kinetics.

| Flocculant dose (ppm) | Kinetics of aggregation of particles | | | | Frequency of collisions of particles | | | |
|---|---|---|---|---|---|---|---|---|
| | $k_1$ (count$^{-1}$ s$^{-1}$) | | $k_2$ ( s$^{-1}$ ) | | K (s$^{-1}$) | | $R^2$ | |
| | Fe-ore ( ×10$^{-15}$ ) | Mn-ore ( ×10$^{-15}$) | Fe-ore ( ×10$^{-3}$) | Mn-ore ( ×10$^{-2}$) | Fe-ore (×10$^{-15}$) | Mn-ore (×10$^{-14}$) | Fe-ore | Mn-ore |
| 3 | 3.46 | 4.09 | 3.56 | 1.90 | 2.22 | 0.07 | 0.9974 | 0.9859 |
| 6 | 4.86 | 4.99 | 2.19 | 1.16 | 11.78 | 0.64 | 0.9915 | 0.9947 |
| 9 | 5.24 | 5.95 | 1.52 | 1.01 | 15.10 | 8.70 | 0.9997 | 0.9999 |
| 12 | 4.69 | 2.64 | 1.80 | 1.46 | 4.56 | 0.34 | 0.9984 | 0.9985 |