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Colloidal properties of industrial titanium dioxide nanoparticles in aqueous solutions

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INTRODUCTION & AIM

Titanium dioxide (TiO_2) nanoparticles (NPs) are widely used in various industries due to their low absorption coefficient, high dielectric permeability, good biocompatibility, high hardness, and photocatalytic activity. However, the colloidal properties (size, charge, sedimentation properties) of NPs TiO_2 in aqueous solutions have not been sufficiently studied, and the results of studies are not comparable due to different experimental conditions and the diversity of nanoparticles produced, which limits the application of NPs TiO_2 suspensions.

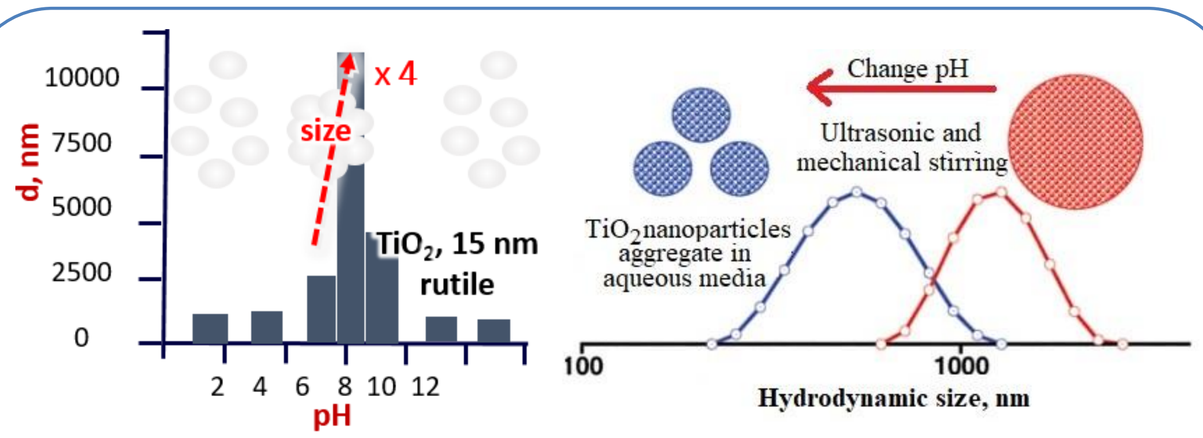

Figure 1. The effect of pH changes and suspension stirring methods on the size of NPs TiO_2 [1, 2]

METHOD

We examined two types of NPs TiO_2: anatase and rutile particle with average particle sizes of 18 and 83 nm and phase composition of anatase:rutile 87:13 and 73:27 wt.%, respectively.

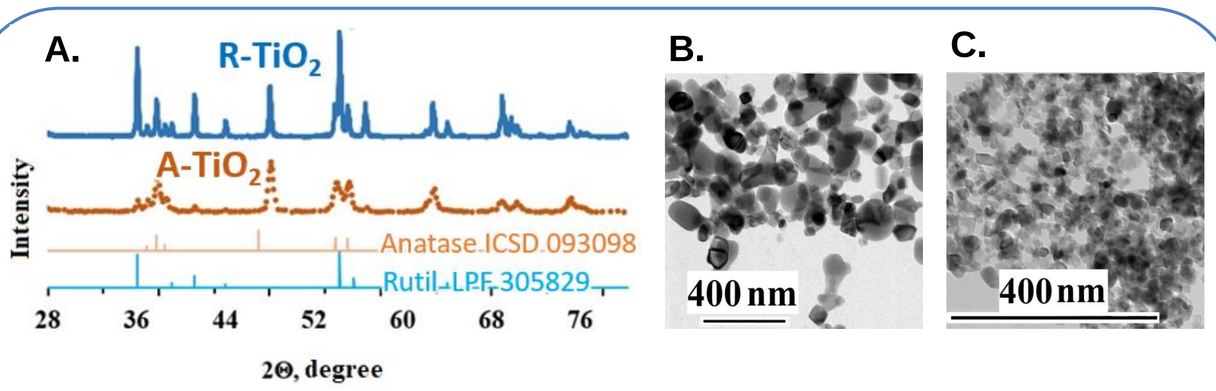

Figure 2. Research objects: A) results of X-ray phase analysis, R-TiO_2 – rutile, A-TiO_2 – anatase; B) TEM for NPs rutile; C) TEM for NPs anatase

In this work, we determined the effects of the method (ultrasonic and mechanical) and duration (up to 60 min) of mixing and the pH of the solution (from 3 to 11) on the colloidal properties of NPs TiO_2 in 10 mM NaCl solution. The concentration of particles was 100 mg/L. Particle size distribution was determined using dynamic light scattering, zeta–potential was measured by using laser doppler electrophoresis, and light transmittance coefficient was estimated by spectrophotometry method.

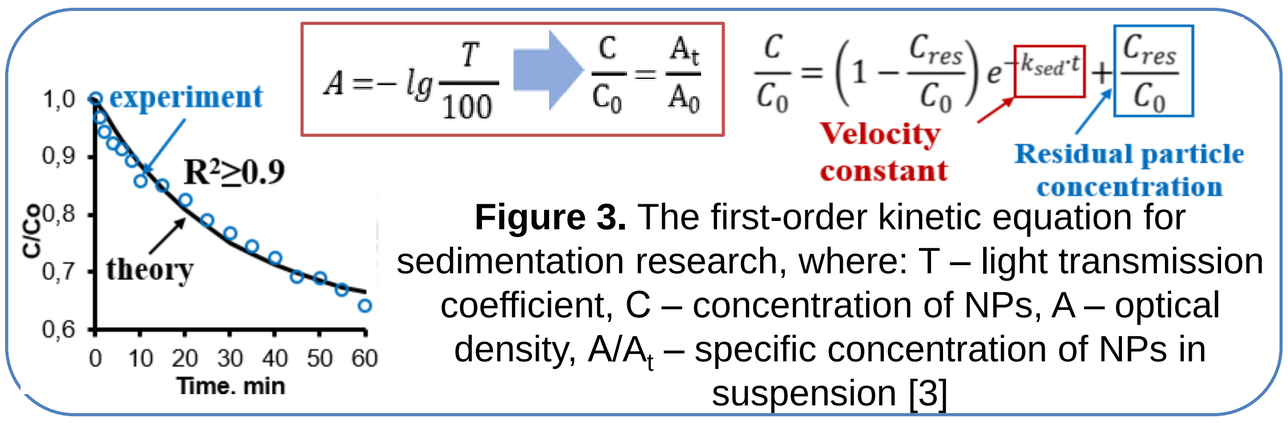

Figure 3. The first-order kinetic equation for sedimentation research, where: T – light transmission coefficient, C – concentration of NPs, A – optical density, A/A_t – specific concentration of NPs in suspension [3]

RESULTS & DISCUSSION

It was found that prolonged treatment of suspensions of NPs TiO_2 (>30 min) led to surface overcharging and enhanced aggregation and sedimentation of nanoparticles. For both nanoparticles in an acidic environment, suspensions with maximum resistance to aggregation and sedimentation were formed. The sedimentation curves for suspensions were well described by a first-order kinetic equation (R^2>0.9). All other things being equal, the behaviour of anatase nanoparticles is more sensitive to the pH value, meanwhile rutile nanoparticles were more affected with the method of mixing.

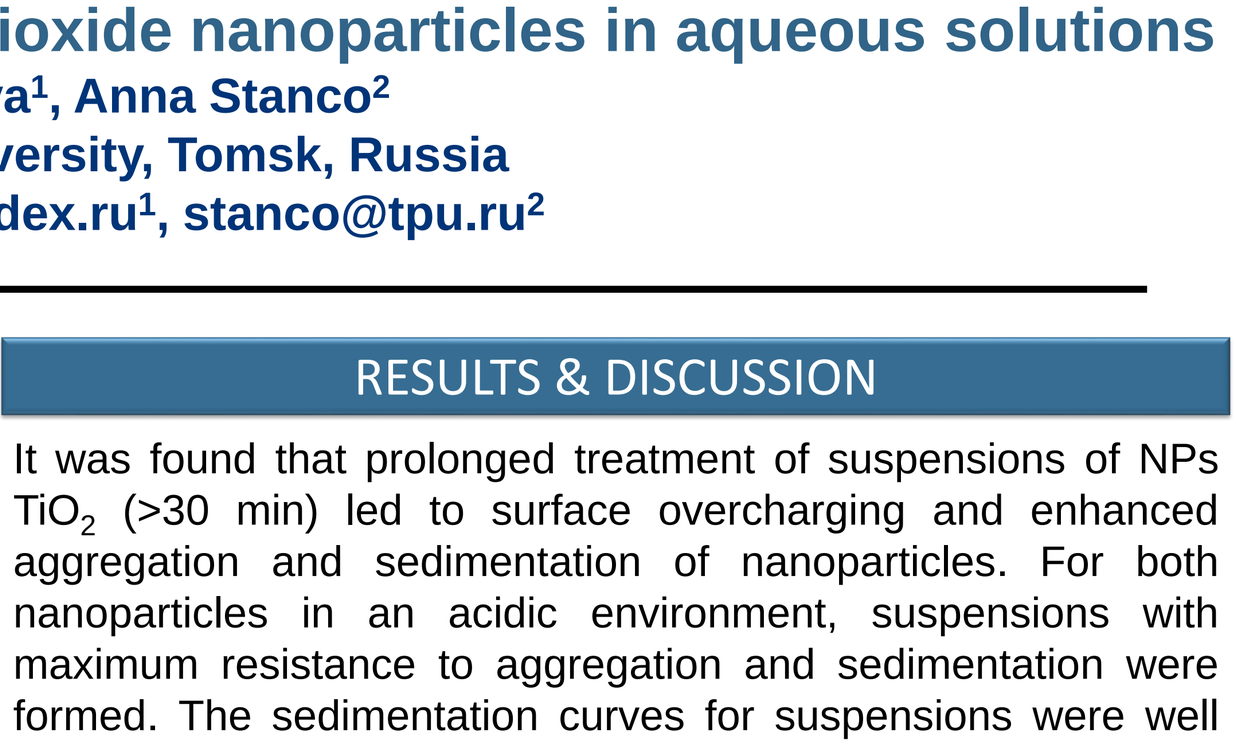

Figure 4. The effect of stirring method on aggregation: A) ultrasonic stirring; B) mechanical stirring; C) the effect of pH on aggregation of NPs

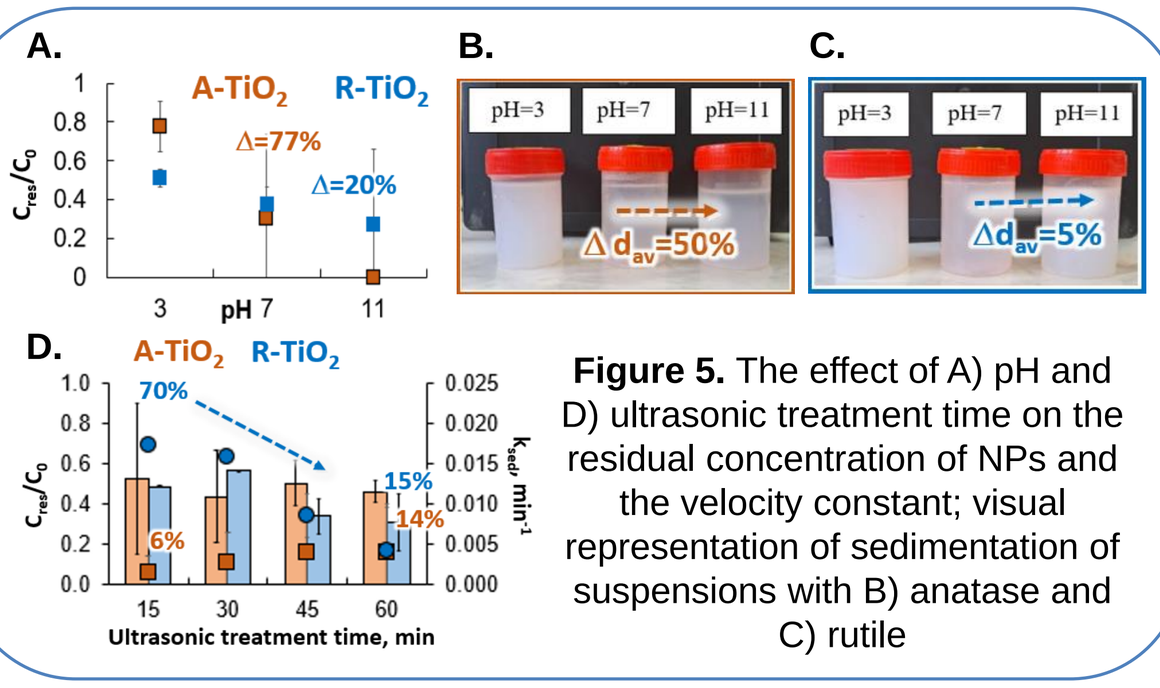

Figure 5. The effect of A) pH and D) ultrasonic treatment time on the residual concentration of NPs and the velocity constant; visual representation of sedimentation of suspensions with B) anatase and C) rutile

CONCLUSION

The effect of pH and mixing method on the electrokinetic, dispersion, and sedimentation properties of suspensions provides valuable information that can be used to distinguish the colloidal stability of particles in aqueous solutions and broaden the application of TiO_2 nanoparticle suspensions.

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3. Quik J.T.K., Stuart M.C., Wouterse M., Peijnenburg W., Hendriks A.J., Meent D. *Env. Toxic. and Chem.*. 2012; 31; 1019-1022.