

Cerium Oxide nanoparticles application for rapid adsorptive removal of tetracycline in water

by Vincensius Gunawan

Submission date: 03-Jul-2020 11:37AM (UTC+0700)

Submission ID: 1352891929

File name: cation_for_rapid_adsorptive_removal_of_tetracycline_in_water.pdf (1,009.17K)

Word count: 5884

Character count: 30886



Cerium oxide nanoparticles application for rapid adsorptive removal of tetracycline in water

Iis Nurhasanah*, Kadarisman, Vincensius Gunawan, Heri Sutanto

Department of Physics, Faculty of Science and Mathematics, Universitas Diponegoro Jalan Prof. Soedarto, S.H., Tembalang, Semarang, Central Java, 50275, Indonesia



ARTICLE INFO

Keywords:

CeO₂
Adsorption
Tetracycline
Water treatment

ABSTRACT

This study investigates the potential of CeO₂ nanoparticle as an adsorbent to remove tetracycline (TC) in water. CeO₂ nanoparticle was synthesized using precipitation method in water/alcohol mixed solvents. As-synthesized sample was characterized using x-ray diffractometer, scanning electron microscope, and Fourier transform infrared spectroscopy. The adsorption isotherm experiment was conducted in liquid phase by varying the contact time and the temperature at initial TC concentration of 25–125 mg/L. The result showed that CeO₂ has a cubic structure with crystallite size of 10.86 nm and is composed by aggregate particles. The equilibrium adsorption is reached after a contact time of 60 min that yield the removal efficiency of 80–97% and adsorption capacity of 58.03 mg/g. The adsorption kinetic analysis indicated that the adsorption process could be described by a pseudo second order model. The thermodynamic parameters confirmed that TC adsorption onto CeO₂ nanoparticle was exothermic and spontaneous. The high removal efficiency and short time adsorption equilibrium suggest that CeO₂ nanoparticle can be used as an antibiotic adsorbent for water treatment.

25

1. Introduction

Tetracycline (TC) is the second broad spectrum antibiotics largely used in human and veterinary medicine. Most TC used in medical treatment is poorly absorbed by humans or animals. Around 30 %–90 % of TC is excreted through urine and faeces as an active compound into the environment and becomes one of the emerging pollutants in water. Even though relatively low in concentration, the residue of TC in the aqueous environment leads to serious pollutant which contributes to increasing resistance of human pathogens, affecting human health and damaging ecosystem [1–3]. Therefore, the treatment method for TC removal in water is interesting to develop.

The waste water treatment method based on photodegradation [4–6], biocatalytic [7,8], Fenton-like process [9,10] and ultrasound irradiation [11,12] have been developed for TC removal in water. Among these methods, adsorption has been considered as an effective, economic and simple-operating method for removal of various water pollutants. Activated carbon is most intensively studied as effective adsorbent to remove antibiotic in water due to large surface area with microporous structure and high porosity [1–3]. Consequently, activated carbon showed superior adsorption capacity. However, the adsorption equilibrium of antibiotic onto activated carbon takes long time i.e in order of several to hundred hours [3]. In other report it is suggested to

develop high performance of activated carbon preparation using feasible method from cheap raw materials to reduce cost production of activated carbon [1,2].

In recent years, a number of materials have been investigated as alternative adsorbents for TC removal [13–19]. CeO₂ is the most important rare earth metal oxide due to its wide range application including environmental [20,21], biomedical [22,23] and energy fields [24]. In term of water treatment application, CeO₂ is commonly used as a photocatalyst [25,26] and an adsorbent for removal of dye and heavy metal [27–31]. Furthermore, CeO₂ shows ability to degrade dyes by adsorbing/photodegrading simultaneously [32]. Even though CeO₂ nanoparticle has been considered as an excellent adsorbent for heavy metal and dyes removal, only few reports about CeO₂ application as an adsorbent for pharmaceutical removal are found. Brigante and Schultz showed the adsorption of minocycline on the CeO₂ is very fast in the initial several minutes [33,34]. Zhang et al. reported that the adsorption-desorption equilibrium of salicylic acid on the CeO₂-H₂O₂ system is reached after 40 min [35]. In addition, Guan et al. reported that catalytic activity of Co₃O₄/CeO₂ nanocomposite mediated with persulfate showed maximum TC degradation efficiency of 79% within 60 min [19]. Hence CeO₂ has the potential as an adsorbent to eliminate antibiotics in water quickly.

The adsorption properties of CeO₂ nanoparticle is influenced by

* Corresponding author.

E-mail address: nurhasanah@fisika.fsm.undip.ac.id (I. Nurhasanah).

<https://doi.org/10.1016/j.jece.2019.103613>

Received 13 September 2019; Received in revised form 28 November 2019; Accepted 15 December 2019

Available online 16 December 2019

2213-3437/© 2019 Elsevier Ltd. All rights reserved.

particle size as well as preparation method [31,32]. The high adsorption capacity of CeO₂ nanoparticle obtained using cerium (IV) sulphate precursor and cetyltrimethylammonium as a template in alkaline media due to smaller crystallite size than that CeO₂ nanoparticle prepared in acidic media [32]. In the previous report, we studied synthesis of CeO₂ nanoparticle using precipitation method in alkaline condition and calcined at various temperatures. The small crystallite size and good crystallinity of CeO₂ nanoparticle obtained at calcination temperature of 500 °C [23]. In this paper, we demonstrate the effectiveness of that CeO₂ nanoparticle as an adsorbent for TC removal in water. Precipitation is a simple method that can be utilized for large scale production of nanoparticle with low cost. CeO₂ nanoparticles were characterized by XRD, SEM, and FTIR techniques. The adsorption of TC onto CeO₂ nanoparticles was analysed using various adsorption models to determine kinetic parameters and adsorption mechanism. In addition, the effect of temperature on the adsorption of TC onto CeO₂ nanoparticle was studied to estimate the thermodynamic parameters.

2. Materials and methods

2.1. Materials

Cerium nitrate (Ce(NO₃)₃·6H₂O) as cerium precursor was purchased from Sigma-Aldrich Ltd. Ammonium hydroxide (Merck) was used as precipitant. Demineralized water (DW) and iso-propanol (Merck) were utilized as solvent. Tetracycline (TC) was obtained from pharmaceutical company in Indonesia.

2.2. Synthesis and characterization of CeO₂ nanoparticles

CeO₂ nanoparticle was synthesized by precipitation by following the procedures described previously [23]. Cerium nitrate solution (0.08 M) was made by dissolving cerium nitrate with mixed solvent of DW and iso-propanol. The solution was stirred by magnetic stirrer to obtain homogeneous solution. After that, ammonium hydroxide was added into the solution until pH 10 was reached. The precipitate was filtered and washed with ethanol several times, then dried at 100 °C for 3 h. The dried precipitate was finally calcined at 500 °C for 2 h to form crystalline of CeO₂ nanoparticles. X-ray diffractometer (PANalytical), scanning electron microscope (JEOL JSM 6360) and Fourier transform infrared spectroscopy were used to characterize structure, morphology and functional group of CeO₂ nanoparticles respectively. The average crystal size of CeO₂ nanoparticle was calculated using Scherer formula:

$$D = \frac{0.9\lambda}{\beta \cos \theta} \quad (1)$$

where D represents crystallite size, λ is wavelength of x-ray, β denotes FWHM and θ is diffraction angle.

2.3. Adsorption experiment

The adsorption isotherm experiment of TC was carried out at initial concentration in the range 25–125 mg/L. Sample with 15 mg nanoparticles CeO₂ was added to 10 mL TC solution. The mixture was stirred with the speed rotation of 300 rpm in the dark condition at different temperature (303 K, 313 K and 323 K). Experiment was performed at natural condition of TC solution. The sample was taken in interval time of 15–120 min and centrifuged at 6000 rpm for 10 min to separate adsorbent from solution. The residual of TC concentration was analysed by UV-vis spectrophotometer (UV Vis 1240 Shimadzu) at 356 nm. The removal efficiency and the adsorption capacity of CeO₂ nanoparticles were calculated using the following equations:

$$RE (\%) = \frac{(C_0 - C_e)}{C_0} \times 100 \quad (2)$$

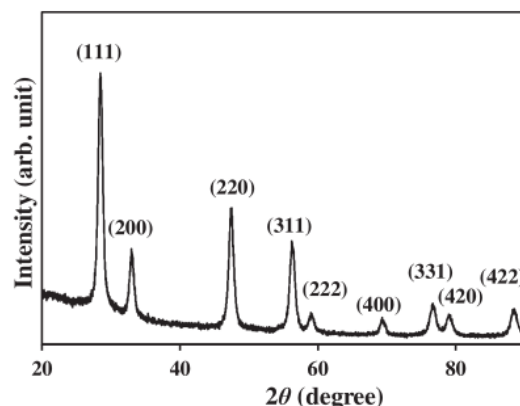


Fig. 1. The XRD pattern of CeO₂ nanoparticles.

$$q_t = \frac{(C_0 - C_t)V}{m} \quad (3)$$

where RE (%) and q_t (mg/g) are adsorptive removal efficiency and adsorption capacity, C_0 (mg/L) and C_t (mg/L) represent the initial concentration and concentration of TC at contact time (t), V is volume of TC solution (L), and m (g) denotes the weight of CeO₂ nanoparticle.

3. Results and discussion

3.1. Properties of CeO₂ nanoparticles

The structure of CeO₂ was analysed using XRD with the results illustrated in Fig. 1. In that figure, the diffraction peaks were shown at $2\theta = 28.43^\circ; 32.97^\circ; 47.52^\circ; 56.37^\circ; 59.10^\circ; 69.29^\circ; 76.51^\circ; 78.98^\circ$ and 88.20° . These peaks were corresponded to the plane: (111), (200), (220), (311), (222), (400), (331), (420) and (422) for face centre cubic (fcc) structure in XRD standard pattern for CeO₂ (JCPDS No. 43-0394).

The XRD pattern did not show diffraction peaks which was associated to the other phase. This indicated a single phase of CeO₂ [21,25,32]. The high and sharp diffraction peaks designated CeO₂ had a good crystallinity. The average crystal size was 10.68 nm which is obtained based on full width at half-maximum (FWHM) of (111) plane and using Scherer formula (Eq. (1)).

The SEM image in Fig. 2a shows that CeO₂ consists of particles in the sphere-like form. It seems that particles interconnected each other to form aggregates. This is possible since coagulation occurs when the precipitation process is taking place in the medium base. The appearance of the aggregates is similar to CeO₂ nanoparticles which is synthesised using sol gel [25], precipitation [26], and hydrothermal method [30].

FTIR spectroscopy is employed to identify functional group and also atomic and molecule vibration. Functional group is one of the many factors which affects adsorption efficiency. In Fig. 2b, FTIR spectrum shows several absorption peaks in the interval of wavelength of 400 cm^{-1} to 4000 cm^{-1} . The spectrum band is wide, around 3413 cm^{-1} which is associated with the stretching vibration of O–H. The absorption band at 1542 cm^{-1} and 1342 cm^{-1} is related to OH-adopted water molecule. An absorption peak at 492 cm^{-1} which is associated to the vibration of Ce–O indicates formation of pure CeO₂ phase as it is observed by XRD analysis [21,26,32].

3.2. Adsorption TC on CeO₂ nanoparticles

Fig. 3 shows TC removal efficiency and adsorption capacity of CeO₂ nanoparticles versus contact time for various initial TC concentrations at temperature of 303 K. It seems that the removal efficiency more than

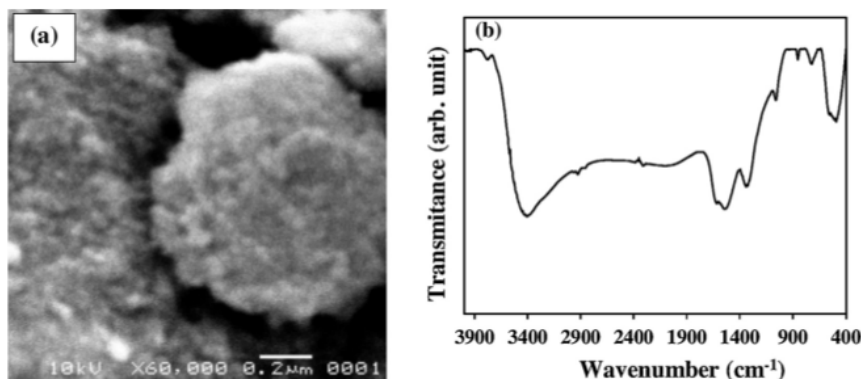


Fig. 2. (a) SEM image of nanoparticle CeO_2 and (b) FTIR spectrum of nanoparticle CeO_2 .

60% was obtained within the first 15 min contact time for initial TC concentration 25 mg/L to 100 mg/L and around 80–96% of TC was removed within 60 min. As a comparison, the removal efficiency of 50% TC (40 mg/L) occurred within 60 min using MgO nanoparticle [36] and 96% using MOF-5 [16]. On other report, removal efficiency of 86 % TC (10 mg/L) was observed within 60 min using MgO -loaded SiO_2 nanocomposite [15], while removal efficiency of 20 mg/L TC was 70–88 % using activated carbon with agitation time of 24 h [37]. Likewise, the adsorption capacity increased as the contact time and the initial TC concentration increased up to 100 mg/L and decreased at the initial TC concentration of 125 mg/L. Rapid adsorption occurred in the first 15 min of contact time. In this interval time, the rate of TC adsorption was high indicating that the high amounts of active sites existed at the surfaces of nanoparticle CeO_2 . After 15 min contact time, the adsorbed TC on CeO_2 nanoparticle increased slightly until 60 min. The adsorption process was extended to 120 min to ensure the equilibrium condition is achieved. Then after 60 min, the rate of adsorption

decreased. It is showed that in the interval of contact time from 60 min to 120 min, TC is difficult to be adsorbed onto CeO_2 nanoparticle due to repulsive force between TC molecules. Hence, we concluded that 60 min was a required time to achieve equilibrium condition. This was faster compare to the time to achieve equilibrium state for activated carbon (8 h) [37], CU-immobilized alginate (24 h) [17], porous carbon (8 h for TC concentration of 25–45 mg/L and 24 h for high TC concentration) [38], and graphene oxide (90 min) [18] in TC adsorption process.

The removal efficiency and adsorption capacity versus initial TC concentration were summarized in Fig. 4(c). The removal of TC decreased slightly when the concentration increased from 25 mg/L to 100 mg/L, then decreased sharply at concentration of 125 mg/L. The high removal efficiency of 80–97% showed that CeO_2 nanoparticle can be used as an effective adsorbent for TC removal with concentration up to 100 mg/L. On the other hand, adsorption capacity increased with enhanced TC concentration. The maximum adsorption capacity of CeO_2

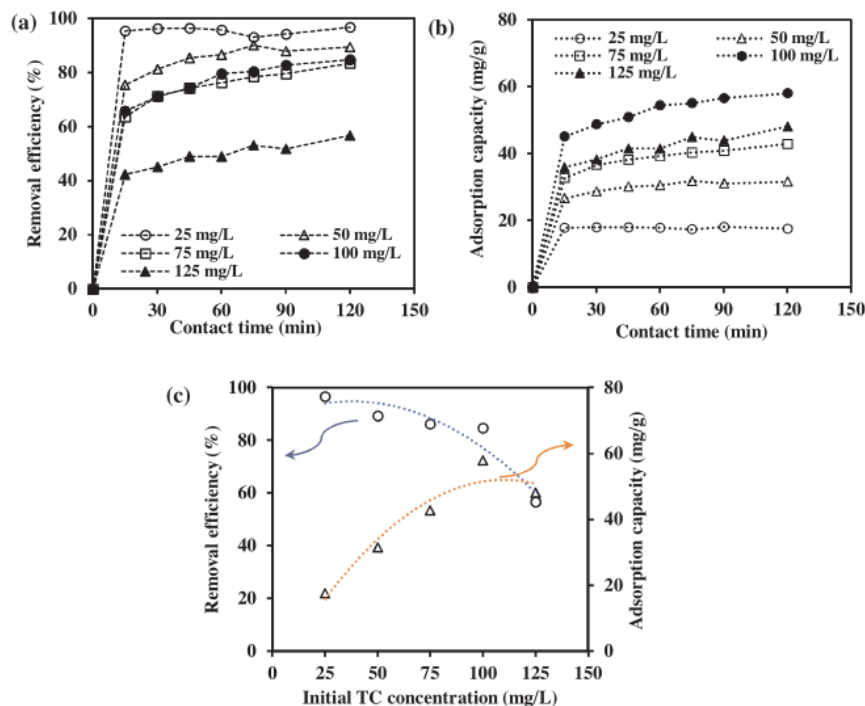


Fig. 3. (a) Removal efficiency, (b) Adsorption capacity versus contact time and (c) Removal efficiency and adsorption capacity versus initial TC concentration.

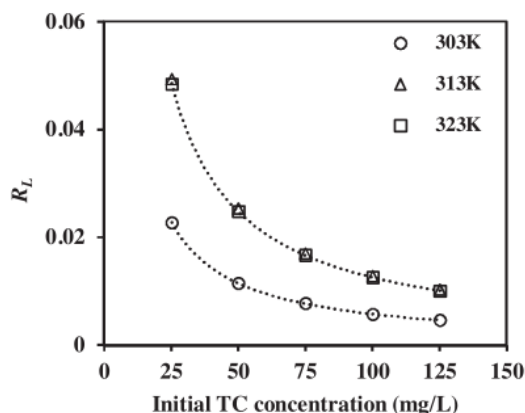


Fig. 4. Langmuir separation factor versus initial TC concentration.

nanoparticles for TC adsorption was 58.03 mg/g for initial TC concentration of 100 mg/L. Although, those value was smaller than TC adsorption capacity of activated carbon but this result was comparable with TC adsorption capacity of CU-immobilized alginate i.e 5326 mg/g at initial TC concentration of 90 mg/L [17]. This finding implies that the adsorptive removal performance of our CeO₂ nanoparticle is higher than other adsorbent as reported in literature [15,36,37].

To analyse the adsorption mechanism, the experimental data of TC onto CeO₂ nanoparticle at 303 K, 313 K and 323 K were fitted using three isotherm models i.e Langmuir, Freundlich and Temkin [18]. The highest correlation coefficient (R^2) was obtained for data fitting by the Langmuir model. The linear equation of Langmuir model is given by Eq. (4).

$$\frac{1}{q_e} = \frac{1}{q_m} + \frac{1}{K_L q_m C_e} \quad (4)$$

where q_m (mg/g) is the maximum adsorption capacity, K_L (L/mg) is the Langmuir isotherm constant. Therefore, TC adsorption onto CeO₂ nanoparticle was more appropriate described by the Langmuir model than Freundlich and Temkin model. This result is in accordance with tetracycline adsorption on other adsorbent i.e porous carbon [38], graphene oxide [18] and dyes adsorption onto CeO₂ nanoparticle [31]. The Langmuir isotherm model assumes the equivalent and uniform adsorption site exist on the adsorbent surface where the adsorbate molecule did not interact to each other. The maximum adsorption is achieved when the adsorbate covers the entire adsorbent surface completely formed monolayer [14,16,39,40]. The adsorption isotherm parameters of TC onto CeO₂ nanoparticles based on Langmuir model were listed in Table 1. The high R^2 obtained at adsorption temperature of 303 and 313 K showed that TC adsorption onto CeO₂ nanoparticle was monolayer adsorption on homogeneous adsorbent surface [16,38]. The maximum monolayer adsorption capacity increased from 46.51 mg/g to 57.14 mg/g when the temperature raised from 303 to 313 K. Then, the maximum monolayer adsorption capacity decreased to 52.36 mg/g when the temperature as high as 323 K which could be associated to the water evaporation of TC solution [15]. Therefore, the TC adsorption onto CeO₂ is more favourable at moderate temperature.

The nature of Langmuir model of TC adsorption onto CeO₂

Table 1
Adsorption Isotherm Parameters of Langmuir Model.

T (K)	q_m (mg/g)	K_L (L/mg)	R^2
303	46.51	1.72	0.9352
313	57.14	0.81	0.9780
323	52.36	0.79	0.7900

nanoparticle can be determined using the value of Langmuir separation factor (R_L) as described by equation (5). Langmuir separation factor is essential isotherm characteristic. The value of this separation factor determines the nature of adsorption process. The process is linear ($R_L = 1$) or irreversible ($R_L = 0$) or unfavourable ($R_L > 1$) or favourable ($R_L < 1$) which is calculated by

$$R_L = \frac{1}{1 + K_L C_e} \quad (5)$$

Fig. 4 shows the Langmuir separation factor versus initial TC concentration at adsorption temperature of 303, 313 and 323 K. It can be seen that R_L values for different TC concentration and different temperature were smaller than 1. This result confirms that adsorption TC onto CeO₂ nanoparticle was favourable.

The effect of contact time on the TC adsorption onto CeO₂ nanoparticle was used to analyse adsorption kinetics. The adsorption kinetic determines the mechanism and parameters of adsorption which is important to realize the practical application of CeO₂ nanoparticle adsorbent. Several adsorption kinetic models have been used for representing TC adsorption onto various adsorbents. These models are: pseudo-first-order, pseudo-second-order and intra-particle diffusion [16,17,38]. The kinetic of adsorption for pseudo-first-order model is given by

$$\log(q_e - q_t) = \log q_e - \frac{k_1}{2.303} t, \quad (6)$$

where q_e and q_t represent the amount of adsorbate (mg g⁻¹) in equilibrium condition and in certain time t , respectively while k_1 is the rate of adsorption (min⁻¹).

In pseudo second order model, the rate of adsorption is determined as

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{1}{q_e} t \quad (7)$$

where k_2 is the adsorption rate constant of pseudo second order (g mg⁻¹ min⁻¹). The slope and intercept of the curve t/q_t against t is used to calculate a constant k_2 .

The third model, based on intra-particle diffusion (Weber-Morris), is formulated as:

$$q_t = k_p t^{1/2} + C, \quad (8)$$

where k_p represents the constant of diffusion intra-particles rate (mg g⁻¹ min^{1/2}) and C is the thickness of boundary layer. The k_p and C can be obtained from the slope and intercept of linear curve q_t against $t^{1/2}$.

The fitting of the experiment data using pseudo first-order kinetic model yields poor linearity with the small correlation coefficient value ($R^2 < 0.9$). It indicated that the TC adsorption onto CeO₂ nanoparticle did not dominated by physical adsorption [17]. The experimental data fitted well to both other models (pseudo-second order and intra-particle diffusion) with the high $R^2 > 0.9$. The fitting of experiment data using the adsorption kinetic models of pseudo-second order and intra-particle diffusion was depicted in Fig. 5. Parameters for each kinetic model are summarized in Table 2. The highest R^2 obtained for pseudo-second order model and the theoretical values of q_e for all concentration TC are close to the experimental values. The rate adsorption (k_2) constants were found to be 0.187 to 0.472 g/mg min which much higher than TC adsorption on graphene oxide i.e 0.104×10^{-3} g/mg min [14], 0.065 g/mg h [18], and activated carbon (2.7×10^{-4} g/mg h) [38].

In order to analyse effect of the rate controlling step in the TC adsorption, the intraparticle diffusion plot was used for fitting experiment data. Fig. 5(b) shows two stages of linear relationship. Rapid adsorption at the initial contact time resulted in line passed through the origin which confirmed that intraparticle diffusion in TC adsorption was the rate-controlling step. In this stage, the main factor affecting the adsorption process is outer surface adsorption. The second line did not pass through the origin, the intercept (C) increased as the TC

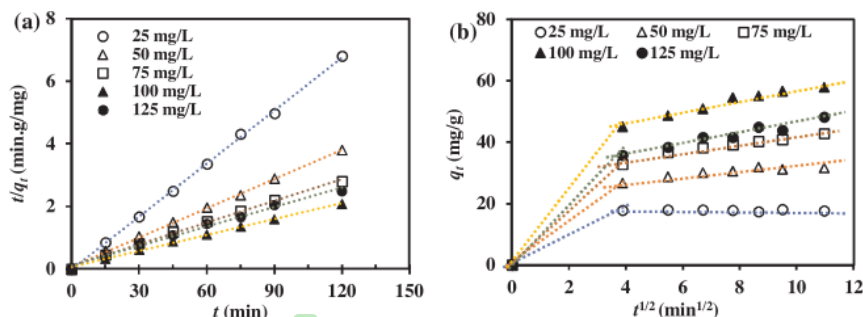


Fig. 5. Adsorption kinetic model (a) pseudo-second order, and (b) intra-particle diffusion.

Table 2
Parameters of adsorption kinetic of Tetracycline onto nanoparticles CeO₂.

Model	Parameter	TC concentration (mg/L)			
		50	75	100	125
Pseudo second order	$q_{e,exp}$ (mg/g)	31.63	42.88	58.02	48.16
	$q_{e,cal}$ (mg/g)	32.05	43.10	58.82	48.08
	k_2 (g/mg min)	0.472	0.242	0.235	0.187
	R^2	0.9990	0.9966	0.9966	0.9917
		31.63	42.88	58.02	48.16
Intraparticle diffusion	$q_{e,exp}$ (mg/g)	31.63	42.88	58.02	48.16
	$q_{e,cal}$ (mg/g)	32.49	43.26	59.13	47.72
	k_p (mg/g min ^{1/2})	0.7009	1.3405	1.8878	1.6635
	C (mg/g)	24.811	28.574	38.449	29.492
	R^2	0.8453	0.964	0.9701	0.9528

concentration increased up to 100 mg/L. The C value suggested that the intra-particle diffusion was not only controlled by the rate-controlling step but also controlled by boundary layer. Therefore, the TC adsorption onto CeO₂ nanoparticle was suitable described by pseudo-second order kinetic model, and confirmed that adsorption process was homogeneous and controlled by chemisorption [33,39]. This finding is similar to the previous study that used other adsorbent [16–19].

The effect of temperature on the equilibrium adsorption capacity of TC adsorption onto CeO₂ nanoparticle was investigated at temperature of 303, 313 and 323 K. As shown in Fig. 6, the temperature dependence of the amount of TC adsorbed on the CeO₂ nanoparticle for different initial TC concentration was irregular in nature. There was slightly increased in the amount of TC adsorbed on the CeO₂ nanoparticle with increasing temperature for low TC concentration of 25 mg/L and 50 mg/L. However, the amount of TC adsorbed on CeO₂ nanoparticle for initial TC concentration of 75, 100 and 125 mg/L increased firstly from 303 K to 313 K and then decreased with increasing temperature at 323 K.

Based on the experiment data of TC adsorption at different temperature, the thermodynamic parameters were studied to determine the

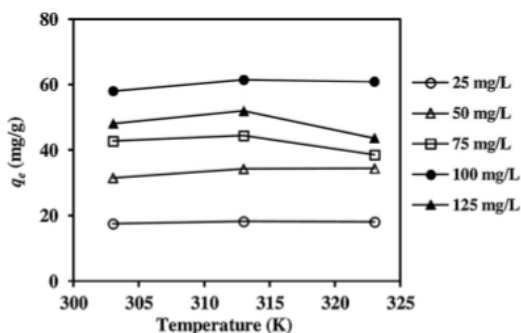


Fig. 6. Adsorption capacity of TC for different concentration and temperature.

Table 3
Change of thermodynamic parameters with temperature.

Thermodynamic parameter				
ΔH (kJ/mol)	ΔS (J/mol)	ΔG (kJ/mol)		
		303 K	313 K	323 K
-27.23	-54.01	-11.038	-9.956	-9.982

nature of adsorption process whether physical or chemical, endothermic or exothermic, spontaneous or nonspontaneous. Table 3 displays the thermodynamic parameters including Gibbs' free energy change (ΔG), enthalpy change (ΔH) and entropy change (ΔS) which were obtained using equations as [17]:

$$\Delta G = -RT \ln K_d \quad (9)$$

$$\ln K_d = \frac{\Delta S}{R} - \frac{\Delta H}{RT} \quad (10)$$

Here, parameters R and T refer to the gas constant (8.314 J/mol K) and absolute temperature (K), respectively. K_d is equilibrium constant equals to $q_m k_L$ (L/mg). The value of ΔH and ΔS were obtained from the slope and intercept of the graph of $\ln K_d$ versus $1/T$, while the value of ΔG was calculated at 303, 313 and 323 K using equation (9).

The negative of ΔG in the range temperature of 303–323 K represented that TC adsorption was feasible and spontaneous process. The increasing of ΔG value as the temperature increases indicated that adsorption is more feasible and spontaneous at lower temperature. The negative value of ΔH revealed that TC adsorption was exothermic process. These results are different from adsorption of minocycline onto CeO₂ nanoparticle [33]. Therefore, the nature of adsorption property of CeO₂ nanoparticle depend on the type of antibiotic. Moreover, the negative of ΔS confirmed that randomness at the liquid-solid interface was reduced as well as the affinity of adsorbent for adsorption. The negative or positive values of ΔH and ΔS were depended on initial TC concentration. Both negative values of ΔH and ΔS were found for TC adsorption onto activated carbon at initial concentration below 200 mg/L [13,41], otherwise the positive value of ΔH and ΔS observed for initial concentration higher than 200 mg/L [41]. The initial TC concentration in this study is lower than 200 mg/L, therefore our result consistent with the result that reported previously [13,41].

Our study showed that, CeO₂ nanoparticle has excellent adsorption performance for TC removal in water. CeO₂ nanoparticle possesses high removal efficiency and high rate adsorption constant. The rapid antibiotics removal, as well as inexpensive preparation methods of CeO₂ nanoparticle are very beneficial for practical application.

4. Conclusion

The CeO₂ nanoparticle had the potential as an adsorbent for rapid removal of TC in water. The high removal efficiency of 96% was achieved within 15 min of contact time. The TC adsorption onto CeO₂

nanoparticles followed the Langmuir isotherm and the pseudo-second order kinetic model. The thermodynamic study indicated that TC adsorption was exothermic and spontaneous. The fast and high removal efficiency of TC suggested that CeO₂ nanoparticle have the opportunity to be used for pharmaceutical wastewater treatment.

Author contributions

Author 1: Iis Nurhasanah

Conceived and designed the analysis

Collected the data

Contributed data or analysis tools

Performed the analysis

Wrote the paper

Author 2: Kadarisman

Collected the data

Contributed data or analysis tools

Author 3: Vincensius Gunawan

Performed the analysis

Wrote the paper

Author 4: Heri Sutanto

Performed the analysis

Declaration of Competing Interest

Authors have declared that no conflict of interest exists in this publication.

Acknowledgments

We acknowledge The Ministry of Research, Technology and Higher Education of Indonesia for full funding of this research with contract number: No. 125/SP2H/ PTNBH/DRPM/2019.

References

- [1] F. Yu, Y. Li, S. Han, J. Ma, Adsorptive removal of antibiotics from aqueous solution using carbon materials, *Chemosphere* 153 (2016) 365–385, <https://doi.org/10.1016/j.chemosphere.2016.03.083>.
- [2] X. Zhang, W. Guo, H.H. Ngo, H. Wen, N. Li, W. Wu, Performance evaluation of powdered activated carbon for removing 28 types of antibiotics from water, *J. Environ. Manage.* 172 (2016) 193–200, <https://doi.org/10.1016/j.jenvman.2016.02.038>.
- [3] M.J. Ahmed, Adsorption of quinolone, tetracycline, and penicillin antibiotics from aqueous solution using activated carbons: review, *Environ. Toxicol. Pharmacol.* 50 (2017) 1–10, <https://doi.org/10.1016/j.etap.2017.01.004>.
- [4] J. Lyu, Z. Hu, Z. Li, M. Ge, Removal of tetracycline by BiOBr microspheres with oxygen vacancies: combination of adsorption and photocatalysis, *J. Phys. Chem. Solids* 129 (2019) 61–70, <https://doi.org/10.1016/j.jpcs.2018.12.041>.
- [5] P. Demirci, E.B. Simsek, Visible-light-enhanced photoactivity of perovskite-type W-doped BaTiO₃ photocatalyst for photodegradation of tetracycline, *J. Alloys. Compd.* 774 (2019) 795–802, <https://doi.org/10.1016/j.jallcom.2018.09.354>.
- [6] N. Belhouichet, B. Hamdi, H. Chenchouni, Y. Bessekhouad, Photocatalytic degradation of tetracycline antibiotic using new calcite/titania nanocomposites, *J. Photochem. Photobiol. A: Chem.* 372 (2019) 196–205, <https://doi.org/10.1016/j.jphotochem.2018.12.016>.
- [7] S. Shao, Y. Hu, J. Cheng, Y. Chen, Biodegradation mechanism of tetracycline (TEC) by strain Klebsiella sp. SQY5 as revealed through products analysis and genomics, *Ecotoxicol. Environ. Safety* 185 (2019) 109676, <https://doi.org/10.1016/j.ecoenv.2019.109676>.
- [8] X. Liao, R. Zou, B. Li, T. Tong, S. Xie, B. Yuan, Biodegradation of chlortetracycline by acclimated microbiota, *ProSafe Environ. Protect.* 109 (2017) 11–17, <https://doi.org/10.1016/j.psep.2017.03.015>.
- [9] M. Khodadadi, A.H. Panahi, T.J. Al-Musawi, M.H. Ehrampoush, A.H. Mahvi, The catalytic activity of FeNi₃@SiO₂ magnetic nanoparticles for the degradation of tetracycline in the heterogeneous Fenton-like treatment method, *J. Water Process Eng.* 32 (2019) 100943, <https://doi.org/10.1016/j.jwpe.2019.100943>.
- [10] N. Zhang, J. Chen, Z. Fang, E.P. Tsang, Ceria accelerated nanoscale zerovalent iron assisted heterogeneous Fenton oxidation of tetracycline, *Chem. Eng. J.* 369 (2019) 588–599, <https://doi.org/10.1016/j.cej.2019.03.112>.
- [11] R.D.C. Soltani, M. Mashayekhi, M. Naderi, G. Boezkaj, S. Jorfi, M. Safari, Sonocatalytic degradation of tetracycline antibiotic using zinc oxide nanostructures loaded on nano-cellulose from waste straw as nanosonocatalyst, *Ultrason. Sonochem.* 55 (2019) 117–124, <https://doi.org/10.1016/j.ultsonch.2019.03.009>.
- [12] S. Nasser, A.H. Mahvi, M. Seyedsalehi, K. Yaghmaei, R. Nabizadeh, M. Alimohammadi, G.H. Safari, Degradation kinetics of tetracycline in aqueous solutions using peroxydisulfate activated by ultrasound irradiation: effect of radical scavenger and water matrix, *J. Mol. Liq.* 241 (2017) 704–714, <https://doi.org/10.1016/j.molliq.2017.05.137>.
- [13] J. Ma, Y. Lei, M.A. Khan, F. Wang, Y. Chu, W. Lei, M. Xia, S. Zhu, Adsorption properties, kinetics and thermodynamics of tetracycline on carboxymethyl-chitosan reformed montmorillonite, *Inter. J. Bio. Mac.* 124 (2019) 557–567, <https://doi.org/10.1016/j.ijbiomac.2018.11.235>.
- [14] J. Miao, F. Wang, Y. Chen, Y. Zhu, Zhou Y, S. Zhang, The adsorption performance of tetracyclines on magnetic graphene oxide: a novel antibiotics absorbent, *Appl. Surf. Sci.* 475 (2019) 549–558, <https://doi.org/10.1016/j.apsusc.2019.01.036>.
- [15] Y. Yue, Z. Peng, W. Wang, Y. Cai, F. Tan, X. Wang, X. Qiao, Facile preparation of MgO-Loaded SiO₂ nanocomposites for tetracycline removal from aqueous solution, *Powder Technol.* 347 (2019) 1–9, <https://doi.org/10.1016/j.powtec.2019.02.034>.
- [16] S.M. Mirsoleimani-azizi, P. Setoodeh, S. Zeinali, M.R. Rahimpour, Tetracycline antibiotic removal from aqueous solutions by MOF-5: adsorption isotherm, kinetic and thermodynamic studies, *J. Environ. Chem. Eng.* 6 (2018) 6118–6130, <https://doi.org/10.1016/j.jece.2018.09.017>.
- [17] X. Zhang, X. Lin, Y. He, Y. Chen, X. Luo, R. Shang, Study on adsorption of tetracycline by Cu-immobilized alginate adsorbent from water environment, *Inter. J. Biol. Macromol.* 124 (2019) 418–428, <https://doi.org/10.1016/j.ijbiomac.2018.11.218>.
- [18] Y. Gao, L. Zhang, H. Huang, J. Hu, S.M. Shah, X. Su, Adsorption and removal of tetracycline antibiotics from aqueous solution by graphene oxide, *J. Colloid Interface Sci.* 368 (2012) 540–546, <https://doi.org/10.1016/j.jcis.2011.11.015>.
- [19] R. Guan, X. Yuan, Z. Wu, L. Jiang, J. Zhang, Y. Li, G. Zeng, D. Mo, Efficient degradation of tetracycline by heterogeneous cobalt oxide/cerium oxide composites mediated with persulfate, *Sep. Purif. Technol.* 212 (2019) 223–232, <https://doi.org/10.1016/j.seppur.2018.11.019>.
- [20] M.S. Hasan, R. Khan, T. Amna, J. Yang, I.H. Lee, M.Y. Sun, M.H. El-Newehy, S.S. Al-Deyab, M.S. Khil, The influence of synthesis method on size and toxicity of CeO₂ quantum dots: Potential in environmental remediation, *Ceram. Int.* 42 (2016) 576–582, <https://doi.org/10.1016/j.ceramint.2015.08.149>.
- [21] A. Umar, R. Kumar, M.S. Akhtar, G. Kumar, S.H. Kim, Growth and properties of well-crystalline cerium oxide (CeO₂) nanoflakes for environmental and sensor applications, *J. Colloid Interface Sci.* 454 (2015) 61–68, <https://doi.org/10.1016/j.jcis.2015.04.055>.
- [22] H.E. Liying, S.U. Yumin, J. Lanhong, S.H.I. Shikao, Recent advances of cerium oxide nanoparticles in synthesis, luminescence and biomedical studies: a review, *J. Rare Earths* 33 (8) (2015) 791–799, [https://doi.org/10.1016/S1002-0721\(14\)60486-5](https://doi.org/10.1016/S1002-0721(14)60486-5).
- [23] I. Nurhasanah, W. Safitri, T. Windarti, A. Subagio, The calcination temperature effect on the antioxidant and radioprotection properties of CeO₂ nanoparticles, *Reaktor* 18 (1) (2018) 22–26, <https://doi.org/10.14710/reaktor.18.1.22-26>.
- [24] M. Melchionna, P. Fomasiero, The role of ceria-based nanostructured materials in energy applications, *Mater. Today* 17 (7) (2014) 349–357, <https://doi.org/10.1016/j.matod.2014.05.005>.
- [25] L. Nadjia, E. Abdelkader, B. Naceur, B. Ahmed, CeO₂ nanoscale particles: synthesis, characterization and photocatalytic activity under UVA light irradiation, *J. Rare Earths* 36 (2018) 575–587, <https://doi.org/10.1016/j.jre.2018.01.004>.
- [26] P.K. Sane, S. Tambat, S. Sontakke, P. Nemade, Visible light removal of reactive dyes using CeO₂ synthesized by precipitation, *J. Environ. Chem. Eng.* 644 (2018) 4476–4489, <https://doi.org/10.1016/j.jece.2018.06.046>.
- [27] H. Wang, Y. Zhong, H. Yu, P. Aprea, S. Hao, High-efficiency adsorption for acid dyes over CeO₂xH₂O synthesized by a facile method, *J. Alloys. Compd.* 776 (2019) 96–104, <https://doi.org/10.1016/j.jallcom.2018.10.228>.
- [28] Q. Feng, Z. Zhang, Y. Ma, X. He, Y. Zhao, Z. Chai, Adsorption and desorption characteristics of arsenic onto ceria nanoparticles, *Nanoscale Res. Lett.* 7 (84) (2012) 1–8, <http://www.nanoscale-reslett.com/content/7/1/84>.
- [29] S. Yari, S. Abbaszadeh, S.E. Mousavi, M.S. Moghaddam, A.Z. Moghaddam, Adsorption of Pb(II) and Cu(II) ions from aqueous solution by an electropun CeO₂ nanofiber adsorbent functionalized with mercapto groups, *Process Saf. Environ. Prot.* 94 (2015) 159–171, <https://doi.org/10.1016/j.psep.2015.01.011>.
- [30] J. Sun, C. Wang, L. Zeng, P. Xu, X. Yang, J. Chen, X. Xing, Q. Jin, R. Yu, Controllable assembly of CeO₂ micro/nanospheres with adjustable size and their application in Cr(IV) adsorption, *Mater. Res. Bull.* 75 (2016) 110–114, <https://doi.org/10.1016/j.materresbull.2015.11.035>.
- [31] C. Ji, J. Gan, Y. Xue, J. Zhang, R. Zhang, J. Liu, J. Hao, Adsorption selectivity of cubic nano-CeO₂ and effect of particle size on adsorption thermodynamics, *Fluid Ph. Equilibria* 502 (2019) 112277, <https://doi.org/10.1016/j.fluid.2019.11.2277>.
- [32] S. Mishra, S. Soren, A.K. Debnath, D.K. Aswal, N. Das, P. Parhi, Rapid microwave-hydrothermal synthesis of CeO₂ nanoparticles for simultaneous adsorption/photodegradation of organic dyes under visible light, *Optik* 169 (2018) 125–136, <https://doi.org/10.1016/j.jllo.2018.05.045>.
- [33] M. Brigante, M.P.C. Schulz, Adsorption of the antibiotic minocycline on cerium (IV) oxide: effect of pH, ionic strength and temperature, *Microporous Mesoporous Mater.* 156 (2012) 138–144, <https://doi.org/10.1016/j.micromeso.2012.02.033>.
- [34] M. Brigante, M.P.C. Schulz, Cerium (IV) oxide: synthesis in alkaline and acidic media, characterization and adsorption properties, *Chem. Eng. J.* 191 (2012) 563–570, <https://doi.org/10.1016/j.cej.2012.02.064>.
- [35] N. Zhang, J. Chen, Z. Fang, E.P. Tsang, Ceria accelerated nanoscale zerovalent iron assisted heterogeneous Fenton oxidation of tetracycline, *Chem. Eng. J.* 369 (2019) 588–599, <https://doi.org/10.1016/j.cej.2019.03.112>.
- [36] T.J. Al-Musawi, F. Brouers, M. Zarrabi, Kinetic modelling of antibiotic adsorption onto different nanomaterials using the Brouers-Sotolongo fractal equation, *Environ. Sci. Pollut. Res.* 24 (2017) 4048–4057, <https://doi.org/10.1007/s11356-016-8182-z>.

- [37] H.R. Pourtedal, N. Sadegh, Effective removal of Amoxicillin, Cephalixin, Tetracycline and Penicilin G from aqueous solution using activated carbon nanoparticles prepared from vine wood, *J. Water Process Eng.* 1 (2014) 64–73, <https://doi.org/10.1016/j.jwpe.2014.03.006>.
- [38] M.J. Ahmed, Md. Azharul Islam, M. Asif, B.H. Hameed, Human hair-derived high surface area porous carbon material for the adsorption isotherm and kinetics of tetracycline antibiotics, *Bioresour. Technol.* 243 (2017) 778–784, <https://doi.org/10.1016/j.biortech.2017.06.174>.
- [39] A. Sheikhmohammadi, M. Safari, A. Alinejad, A. Esrafil, H. Nourmoradi, E. Asgari, The synthesis and application of the $\text{Fe}_3\text{O}_4/\text{SiO}_2$ nanoparticles functionalized with 3-aminopropyltriethoxysilane as an efficient sorbent for adsorption of ethylparaben from wastewater: Synthesis, kinetic, thermodynamic and equilibrium studies, *J. Environ. Chem. Eng.* 7 (2019) 103315, , <https://doi.org/10.1016/j.jece.2019.103315>.
- [40] H. Godini, F. Hashemi, L. Mansuri, M. Sardar, G. Hassani, S.M. Mohseni, A.A. Alinejad, S. Golmohammadi, A. Sheikh Mohammadi, Water polishing of phenol by walnut green hull as adsorbent: an insight of adsorption isotherm and kinetic, *J. Water Reuse Des.* 06 (4) (2016) 544–552, <https://doi.org/10.2166/wrd.2016.068>.
- [41] R. Acosta, V. Fierro, A. Martinez de Yuso, D. Nabarlantz, A. Celzard, Tetracycline adsorption onto activated carbons produced by KOH activation of tyre pyrolysis char, *Chemosphere* 149 (2016) 168–176, <https://doi.org/10.1016/j.chemosphere.2016.01.093>.

Cerium Oxide nanoparticles application for rapid adsorptive removal of tetracycline in water

ORIGINALITY REPORT

19%

SIMILARITY INDEX

10%

INTERNET SOURCES

17%

PUBLICATIONS

12%

STUDENT PAPERS

PRIMARY SOURCES

1

www.tandfonline.com

Internet Source

2%

2

Peifen Wang, Junlan Zheng, Xuli Ma, Xiao Du, Fengfeng Gao, Xiaogang Hao, Bing Tang, Abuliti Abudula, Guoqing Guan. "Electroactive magnetic microparticles for the selective elimination of cesium ions in the wastewater", Environmental Research, 2020

Publication

1%

3

link.springer.com

Internet Source

1%

4

worldwidescience.org

Internet Source

1%

5

Wu, Yixiao, Beidou Xi, Guangji Hu, Dihua Wang, Aimin Li, Weihao Zhang, Lei Lu, and Huijun Ding. "Adsorption of tetracycline and sulfonamide antibiotics on amorphous nano-carbon", Desalination and Water Treatment, 2016.

1%

-
- | | | |
|----------|---|----------------|
| 6 | iwaponline.com
Internet Source | <1 % |
|----------|---|----------------|
-
- | | | |
|----------|--|----------------|
| 7 | Anitha T., Senthil Kumar P., Sathish Kumar K..
"Synthesis of nano-sized chitosan blended
polyvinyl alcohol for the removal of Eosin Yellow
dye from aqueous solution", Journal of Water
Process Engineering, 2016
Publication | <1 % |
|----------|--|----------------|
-
- | | | |
|----------|---|----------------|
| 8 | C. Namasivayam, D. Sangeetha. " Removal of
chromium(VI) by ZnCl activated coir pith carbon
", Toxicological & Environmental Chemistry,
2006
Publication | <1 % |
|----------|---|----------------|
-
- | | | |
|----------|---|----------------|
| 9 | www.journalrepository.org
Internet Source | <1 % |
|----------|---|----------------|
-
- | | | |
|-----------|---|----------------|
| 10 | Huacai Ge, Hui Chen, Shiyong Huang.
"Microwave preparation and properties of O-
crosslinked maleic acyl chitosan adsorbent for
Pb ²⁺ and Cu ²⁺ ", Journal of Applied Polymer
Science, 2012
Publication | <1 % |
|-----------|---|----------------|
-
- | | | |
|-----------|--|----------------|
| 11 | Submitted to University of Nottingham
Student Paper | <1 % |
|-----------|--|----------------|
-
- | | | |
|-----------|---|----------------|
| 12 | Ali Fakhri, Sajjad Behrouz. "Improved uptake of
steroid hormone from aqueous solution using γ- | <1 % |
|-----------|---|----------------|

13

Hamid Rashidi Nodeh, Hassan Sereshti. "Synthesis of magnetic graphene oxide doped with strontium titanium trioxide nanoparticles as a nanocomposite for the removal of antibiotics from aqueous media", RSC Advances, 2016

Publication

<1 %

14

Zhan, Y.. "Removal of nitrate from aqueous solution using cetylpyridinium bromide (CPB) modified zeolite as adsorbent", Journal of Hazardous Materials, 20110228

Publication

<1 %

15

Pushpal Ghosh. "Synthesis and characterization of different shaped Sm₂O₃ nanocrystals", Journal of Physics D Applied Physics, 10/13/2010

Publication

<1 %

16

Jian Cheng, Jiang-Jiang Gu, Wei Tao, Ping Wang, Lian Liu, Cao-Yu Wang, Yong-Ke Li, Xiong-Han Feng, Guo-Hong Qiu, Fei-Fei Cao. "Edible fungus slag derived nitrogen-doped hierarchical porous carbon as a high-performance adsorbent for rapid removal of organic pollutants from water", Bioresource Technology, 2019

Publication

<1 %

17

www.iiste.org

Internet Source

<1 %

18

Hameed, B.H.. "Equilibrium and kinetics studies of 2,4,6-trichlorophenol adsorption onto activated clay", Colloids and Surfaces A: Physicochemical and Engineering Aspects, 20071015

Publication

<1 %

19

Submitted to University of Newcastle upon Tyne

Student Paper

<1 %

20

A. Safa Özcan, Adnan Özcan, Sibel Tunali, Tamer Akar, Ismail Kiran, Tefvik Gedikbey. "Adsorption Potential of Lead(II) Ions from Aqueous Solutions onto Seeds ", Separation Science and Technology, 2007

Publication

<1 %

21

jocpr.com

Internet Source

<1 %

22

Venegas, M.. "Heat and mass transfer during absorption of ammonia vapour by LiNO₃-NH₃ solution droplets", International Journal of Heat and Mass Transfer, 200406

Publication

<1 %

23

sciencepublishinggroup.com

Internet Source

<1 %

24

eprints.ucm.es

Internet Source

<1 %

25

Jeong-Ann Park, Aram Nam, Jae-Hyun Kim, Seong-Taek Yun, Jae-Woo Choi, Sang-Hyup Lee. "Blend-electrospun graphene oxide/Poly(vinylidene fluoride) nanofibrous membranes with high flux, tetracycline removal and anti-fouling properties", Chemosphere, 2018

Publication

<1 %

26

Elham Nariyan, Aylin Aghababaei, Mika Sillanpää. "Removal of pharmaceutical from water with an electrocoagulation process; effect of various parameters and studies of isotherm and kinetic", Separation and Purification Technology, 2017

Publication

<1 %

27

www.degruyter.com

Internet Source

<1 %

28

Murat Topal, E. Işıl Arslan Topal. "Optimization of tetracycline removal with chitosan obtained from mussel shells using RSM", Journal of Industrial and Engineering Chemistry, 2020

Publication

<1 %

29

Rui Zhao, Tingting Ma, Shuai Zhao, Huazhen Rong, Yuyang Tian, Guangshan Zhu. "Uniform

<1 %

and stable immobilization of metal-organic frameworks into chitosan matrix for enhanced tetracycline removal from water", Chemical Engineering Journal, 2020

Publication

30

M.J. Ahmed, Md. Azharul Islam, M. Asif, B.H. Hameed. "Human hair-derived high surface area porous carbon material for the adsorption isotherm and kinetics of tetracycline antibiotics", Bioresource Technology, 2017

Publication

31

Submitted to Botswana International University of Science and Technology

Student Paper

32

Yari, Saeed, Saeed Abbasizadeh, Seyyed Ebrahim Mousavi, Mojtaba Saei Moghaddam, and Abdolsamad Zarringhalam Moghaddam. "Adsorption of Pb(II) and Cu(II) ions from aqueous solution by an electrospun CeO₂ nanofiber adsorbent functionalized with mercapto groups", Process Safety and Environmental Protection, 2015.

Publication

33

Submitted to Malaviya National Institute of Technology

Student Paper

34

W.A. Khanday, M.J. Ahmed, P.U. Okoye, E.H.

Hummadi, B.H. Hameed. "Single-step pyrolysis of phosphoric acid-activated chitin for efficient adsorption of cephalexin antibiotic", Bioresource Technology, 2019

Publication

<1 %

35

Sawanya Laohaprapanon, Marcia Marques, William Hogland. "Removal of Organic Pollutants from Wastewater Using Wood Fly Ash as a Low-Cost Sorbent", CLEAN - Soil, Air, Water, 2010

Publication

<1 %

36

Manickavasagan Abinaya, Kadarkarai Govindan, Murugesan Kalpana, Karunamoorthy Saravanakumar et al. "Reduction of hexavalent chromium and degradation of tetracycline using a novel indium-doped Mn₂O₃ nanorod photocatalyst", Journal of Hazardous Materials, 2020

Publication

<1 %

37

Gh. Chizari Fard, M. Mirjalili, F. Najafi. "Hydroxylated α -Fe₂O₃ nanofiber: Optimization of synthesis conditions, anionic dyes adsorption kinetic, isotherm and error analysis", Journal of the Taiwan Institute of Chemical Engineers, 2017

Publication

<1 %

38

Submitted to University of Hull

Student Paper

<1 %

39 Muhammad Zulfiqar, Suriati Sufian, Nurul Ekmi Rabat, Nurlidia Mansor. "Photocatalytic degradation and adsorption of phenol by solvent-controlled TiO₂ nanosheets assisted with H₂O₂ and FeCl₃: Kinetic, isotherm and thermodynamic analysis", Journal of Molecular Liquids, 2020

Publication

40 Submitted to Universiti Teknologi MARA

Student Paper

41 Zhan, Yanhui, Jianwei Lin, Yu Liu, and Zhiliang Zhu. "Adsorption of Cr (VI) from Aqueous Solution by Cetylpyridinium Bromide (CPB) Modified ZeoLite: Kinetic, Equilibrium and Thermodynamics Study", 2011 Second International Conference on Digital Manufacturing & Automation, 2011.

Publication

42 Shubo Deng, Gang Yu, Yen Peng Ting. "Removal of Humic Acid Using PEI-Modified Fungal Biomass", Separation Science and Technology, 2006

Publication

43 Quanfa Zhong, Qintie Lin, Runlin Huang, Hengyi Fu, Xiaofeng Zhang, Haoyu Luo, Rongbo Xiao. "Oxidative degradation of tetracycline using persulfate activated by N and Cu codoped

44

Prakash Kumar Palai, Aparna Mondal, Chandra Kanti Chakraborti, Indranil Banerjee, Kunal Pal, V. Shanmuga Sharan Rathnam. "Doxorubicin Loaded Green Synthesized Nanoceria Decorated Functionalized Graphene Nanocomposite for Cancer-Specific Drug Release", Journal of Cluster Science, 2019

Publication

<1 %

45

Hui Wang, Dingyu Yong, Shichuan Chen, Shenlong Jiang, Xiaodong Zhang, Wei Shao, Qun Zhang, Wensheng Yan, Bica Pan, Yi Xie. "Oxygen-Vacancy-Mediated Exciton Dissociation in BiOBr for Boosting Charge-Carrier-Involved Molecular Oxygen Activation", Journal of the American Chemical Society, 2018

Publication

<1 %

46

Alisson S. Thill, Francielli O. Lobato, Mauricio O. Vaz, Williams P. Fernandes et al. "Shifting the band gap from UV to visible region in cerium oxide nanoparticles", Applied Surface Science, 2020

Publication

<1 %

47

onlinelibrary.wiley.com

Internet Source

<1 %

48

pubs.rsc.org

<1 %

49

M.J. Ahmed, B.H. Hameed. "Removal of emerging pharmaceutical contaminants by adsorption in a fixed-bed column: A review", *Ecotoxicology and Environmental Safety*, 2018

Publication

<1 %

50

Mei-fang Li, Yun-guo Liu, Guang-ming Zeng, Shao-bo Liu et al. "Tetracycline absorbed onto nitrilotriacetic acid-functionalized magnetic graphene oxide: Influencing factors and uptake mechanism", *Journal of Colloid and Interface Science*, 2017

Publication

<1 %

51

R. Anjali, S. Shanthakumar. "Insights on the current status of occurrence and removal of antibiotics in wastewater by advanced oxidation processes", *Journal of Environmental Management*, 2019

Publication

<1 %

52

Y. G. Wang, L. G. Wang, D. Q. Li. "Synergistic Extraction of Zinc(II) with Mixtures of CA-100 and Cyanex 272", *Separation Science and Technology*, 2003

Publication

<1 %

53

Duygu Ozdes, Ali Gundogdu, Celal Duran, Hasan Basri Senturk. " Evaluation of Adsorption

<1 %

Characteristics of Malachite Green onto Almond Shell () ", Separation Science and Technology, 2010

Publication

54

Submitted to Nanyang Technological University, Singapore

Student Paper

<1 %

55

Jiahe Miao, Fenghe Wang, Yajun Chen, Yezhi Zhu, Yan Zhou, Shengtian Zhang. "The adsorption performance of tetracyclines on magnetic graphene oxide: A novel antibiotics absorbent", Applied Surface Science, 2019

Publication

<1 %

56

Zhu Mengting, Tonni Agustiono Kurniawan, You Yanping, Mohd Hafiz Dzarfan Othman, Ram Avtar, Dun Fu, Goh Hui Hwang. "Fabrication, characterization, and application of ternary magnetic recyclable Bi₂WO₆/BiOI@Fe₃O₄ composite for photodegradation of tetracycline in aqueous solutions", Journal of Environmental Management, 2020

Publication

<1 %

57

A. P. Gupta, Vijai Kumar, Manjari Sharma, S. K. Shukla. "Physicochemical Studies on Interaction Behavior of Potato Starch Filled Low Density Polyethylene Grafted Maleic Anhydride and Low Density Polyethylene Biodegradable Composite

<1 %

58

Dinesh Kumar Subbiah, Arockia Jayalatha
Kulandaisamy, Rijo Baby George, Prabakaran
Shankar et al. "Nano ceria as xylene sensor –
Role of cerium precursor", Journal of Alloys and
Compounds, 2018

Publication

<1%

Exclude quotes Off

Exclude matches Off

Exclude bibliography On