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ENGINEERING, ENVIRONMENT AND MATERIALS
IN PROCESS INDUSTRY
EEM2021

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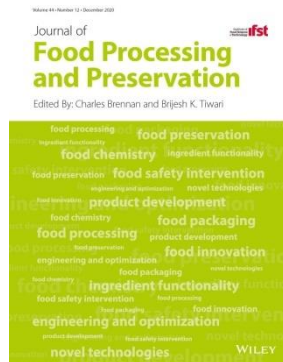


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PEACH STONE BIOCHAR AS EFFICIENT ADSORBENT FOR Cd(II) REMOVAL FROM AQUEOUS PHASE

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Abstract

Lignocellulosic waste biomass (LCW) represents valuable resource whose implementation could help growing world demands in improving environmental problems. Fruit stones, as waste from food processing industry, are contributing toward negative stresses on our natural systems through impacts associated with both waste production and its disposal. Sustainable waste management practice necessitates that industries must shift from the current linear model to a circular based economy, utilizing wastes generated as initial materials for the production of new products, such as fuels, chemicals or materials which might help in solving environmental pollution topics. Waste biomass materials can be converted into value-added products using thermochemical methods, such as pyrolysis, whereby biomass is efficiently converted into biofuels, biochars and different value added products. This paper present current development work and evaluates potential opportunities for food processing waste pyrolysis focusing on the conversion of peach stones (PS) to biochar. The wasted PS were first crushed, milled to desired dimensions and then pyrolysed, heating from 25 to 500 °C at 10 °C/min heat flow, and kept at 500 °C for 2 h. The resulting biochar (PS-B) was characterized to determine the potential of this products for Cd(II) sorption as well as to distinguish sorption kinetics of Cd removal between raw and pyrolysed material. Kinetic experiments were performed in isothermal batch system with mixing (200 rpm), at 25 °C, adding 0.1g of sorbent in 50 ml of Cd(II) solution, with initial Cd concentration of 100 mg/L. Experimental results were modelled with three kinetics (pseudo-first, pseudo-second order and Elovich equation) and one diffusion model (Weber-Morris). Results of kinetic modelling indicated chemisorption mechanism with different diffusional behaviour of the samples. The contact pH (pH_{sus}) of these materials were 4.10 (PS) and 5.76 (PS-B), indicating higher –OH content in biochars, which was also confirmed by FTIR analysis. The experimental results indicated that PS-B has almost five times higher sorption capacity than the native material (PS), under the same operational conditions, 24.50 mg/g compared to 5.25 mg/g, respectively. Conclusively, the PS derived biochar can be used as an alternative to conventional sorbents in contaminated water treatment. Moreover, more research work needs to be conducted on this waste type to biochar in order to investigate optimal operational parameters as well as flow system behaviour.

Key words: LCW biomass, peach stones, pyrolysis, biochar, cadmium, sorption.

Introduction

Numerous pollutants that are entering the water, pose a colossal threat to human health and the natural ecosystem. In order to resolve this urgent situation of water shortage and water

contamination, many efforts are being made to develop highly effective technologies and materials (Li et al., 2018). In recent decades, many investigations have been made in order to create renewable, cost effective and efficient sorbents to purify water systems, including waste biomass of different types. Although these materials might have high removal efficiency, it is often necessary to modify them in order to improve their properties and overall sorption behaviour. The modifications of the raw lignocellulosic materials are numerous, but in the recent time, slow pyrolysis seem to be one of the often used techniques, with great possibility to convert different initial stocks into biochars, which are low cost products with superior surface properties and rich functional groups with great potential to remove many kinds of heavy metal pollutants like Cd, As, Pb and organics in water (Zhang et al., 2020). Biochar is the product formed during slow pyrolysis of biomass, in a process with higher temperatures (350 – 750 °C) and oxygen-limited conditions. The thermochemical conversion changes the structure of the biomass, increasing cross-linking of carbon atoms and carbon content (Antal et al., 2003). Biochar, a closely related class of materials produced from renewable resources (agricultural and forestry waste, etc.), presents a promising alternative to activated carbon. Activated carbon is predominantly produced from fossil coal or increasingly scarce resources such as coconut shells. Therefore the production of biochar is generally considered more sustainable and less expensive (Ahmed et al., 2015; Correa and Kruse, 2018). Feedstock of biochar is abundant and low cost, offering some desirable properties such as: huge specific surface area, excellent ion exchange capacity, high porosity as well as abundant oxygen functional groups, making it suitable for wastewater treatment (Zhu et al. 2016; Li et al. 2014a).

Contamination caused by heavy metals is a worldwide problem owing to their toxicity and bioaccumulation in the food chain that leads to serious health and environmental problems (Iyer et al., 2005). Cadmium is a very toxic heavy metal that could potentially be released into the environment by various industries: electroplating, smelting, alloying, and processes such as mining, melting, welding, and refining. Cadmium must be properly removed from water sources and industrial wastewater because of its severe harm to the human body: kidney damage, respiratory insufficiency, hypertension, cancer, gastrointestinal disorder, and osteoporosis (Aeisyah et al., 2014).

Having in mind all previously described, this investigation was created to explore the possibility of cadmium sorption from aqueous solution onto two sorbents created from lignocellulosic waste biomass (LCW) originating from fruit processing industry. One of them is milled raw stones material (*Prunus persica* L.), and the other one is biochar produced from this starting waste biomass. The aim of present work was thus to investigate the some of the physicochemical properties of obtained biochar produced in limited-oxygen environment, examine sorption kinetics of Cd(II) and explore the possible adsorption mechanism of biochar. This study could provide a reference for the responsible utilization of this type of lignocellulosic waste and heavy metal removal from wastewater, avoiding waste landfilling and supporting environment sustainable demands.

Materials and Methods

Preparation of biochar: Fruit stones were taken from the local “Vino Župa” factory, where have been classified as a waste. After receiving, they have been washed and dried at room temperature, and then crushed to different sizes using vibratory disk mill “Siebtechnik – TS250” (Siebtechnik GmbH, Germany). For the purposes of these investigations, class between 0.1 to 0.5 mm was used. The ground peach stones (PS) were further pyrolysed at 500 °C under oxygen-limited conditions in a Nabertherm 1300 muffle furnace with a heating rate of 10 °C min⁻¹. Finally, the biochar (PS-B) was stored in closed vials with polypropylene caps in the dark until required for the sorption experiments.

Biochar characterisation: Contact pH, also known as the pH of the suspension (pH_{sus}) was determined according to procedure described in the ASTM D6851-02 standard. The pH of the

suspension solution was determined by suspending 0.2 g of sorbent material in 30 ml of distilled water, left in a closed container and stirred occasionally for 72 h after which the pH was measured using a pH meter SensION3 (Hach, USA).

FTIR analyses were performed in ATR mode using Thermo Scientific Nicolet IS-50 spectrometer at a spectrum resolution of 2 cm^{-1} with 256 scans over a range of $4000\text{--}400\text{ cm}^{-1}$. A background scan was acquired before the samples scanning.

Kinetic batch experiments: The Cd(II) solution was prepared using $\text{Cd}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ (Sigma-Aldrich, USA). For kinetic experiment, 100 mg/L Cd(II) solutions were shaken for different time interval (2, 5, 10, 20, 30, 60, 90, 120 and 180 min). Experiments were conducted by adding 0.1 g biochars to 50 mL Cd(II) solution in 250 mL erlenmeyer flasks, placed at orbital shaker (Heidolph Unimax 1010), 200 rpm, at $25\text{ }^\circ\text{C}$. The pH values of the solutions were monitored using pH meter. Once the sorption experiment was completed, the mixtures were collected and filtered through $0.48\text{ }\mu\text{m}$ pore size filters, and the concentration of Cd(II) in the filtrate was determined by Atomic Flame Absorption Spectrometer (Perking Elmer AAnalyst 300).

The sorption capacity q (mg g^{-1}) and the removal efficiency of Cd(II) ions, both of PS and PS-B, were calculated according to the following equation:

$$qe = \frac{(C_o - C_e)V}{m}$$

where C_e and C_o are the equilibrium and the initial Cd(II) concentrations (mg/L), respectively; V is the volume of the solution (L) and m is the weight of the sorbent (g).

Results and Discussion

Sorbent Characterisation:

The value of pH_{sus} refers to the determination of the effect that activated carbons (solids) may have on the initial pH value of the aqueous solution in which the solid is dispersed in. This value can be considered as an indicator of the overall dominance of the contained acidic or basic functional groups present on the surface of the solid phase. The values of pH_{sus} for both samples are given in Table 1.

Table 1. Sorbents characterisation

Sorbent	pH_{sus}	FTIR peaks wavelength, cm^{-1}								
PS	4.10	3340	2920	1592	1422	1230	1156	-	-	-
PS-B	5.76	-	-	1580	-	-	1166	1087	870	750

As it can be seen from Table 1, raw sorbent PS have higher content of acidic functional groups which has resulted in lower pH_{sus} value which was 4.10, compared to 5.76 related to biochar. The functional groups of the biochar are closely related to the surface properties of the parent feedstock. From the peaks obtained using FTIR techniques (graph not shown), it can be seen that the raw RS exhibited peaks at 3340, 2920, 1422 and 1230 cm^{-1} (Table 1), which later disappeared when the PS was pyrolysed. These peaks were assigned to the hydroxyl ($-\text{OH}$) stretching, alkane $-\text{CH}_2$ symmetric stretching, in-plane bending of carbonyl ($-\text{COH}$) and alkane $-\text{CH}_2$ symmetric stretching, respectively (Özçimen and Ersoy-Meriçboyu, 2010). These results indicate that the transformation of PS to biochar reduced the quantity of hydroxyl groups, and that the acidic groups such as $-\text{COOH}$ decreased quantitatively with increased pyrolysis temperature and almost disappeared at $500\text{ }^\circ\text{C}$. Similar results were obtained by Chun et al. (2004), which is consistent with the results of the present study. This is also supported by the pH_{sus} which is much higher for PS-B than for the PS. The peak at 1592 cm^{-1} observed in PS has shifted to 1580 cm^{-1} for PS-B, was assigned to $-\text{COO}^-$ anti-symmetric stretching. The band at 1152 cm^{-1} in PS which was shifted to 1166 cm^{-1} for PS-B is assigned to asymmetric C-OC bridge stretching, while the band at 1087 cm^{-1} observed in PS-B might be contributed to anhydroglucose ring asymmetric stretching, which is reasonable having in mind increase of

aromatic presence in pyrolysed samples (Poletto et al., 2013). FTIR results of PS-B compared to PS showed more aromatic structure, which is confirmed by absorption bands between 700 and 900 cm^{-1} (Cheng and Lehmann, 2009). The functional groups containing H and O disappeared during the pyrolysis and more aromatic structures are detected. A notable difference for the raw PS and PS-B might be contributed to decomposition of hemicellulose, and partially decomposition of other main components (cellulose and lignin) present in the raw material.

Sorption kinetics results:

Most sorption processes come to pass by a multistep mechanism including several stages: (i) diffusion across the liquid film surrounding the solid particles (controlled by an external mass transfer coefficient), (ii) diffusion within the sole particle assuming a pore diffusion mechanism (or intra particle diffusion), and (iii) physical or chemical adsorption at a specific site on the sorbent surface (Boudrahem et al., 2011). The passing behaviour of the Cd(II) batch sorption process onto both sorbents is analysed using three reaction models (Lagergren, pseudo second-order and Elovich model) and one diffusion model (Weber Morris intraparticle diffusion model). Applied models with their equations and parameters are listed in Table 2.

Table 2. Models/equations used for evaluation of Cd(II) sorption onto mechanically treated PS and PS-B

Model	Equation	Parameter	Reference
Pseudo first order	$q_t = q_e (1 - e^{-k_1 t})$	q_e (mg/g): sorption capacity at equilibrium q_t (mg/g): sorption capacity at any time t k_1 (g/mg/min): the pseudo first order rate constant	(Lagergren, 1898)
Pseudo second order	$q_t = \frac{t}{\left(\frac{1}{k_2 q_e^2}\right) + \left(\frac{t}{q_e}\right)}$	q_e (mg/g): sorption capacity at equilibrium q_t (mg/g): sorption capacity at any time t k_2 (g/mg/min): the pseudo second order rate constant	(Ho and McKay, 1999)
Elovich	$q_t = \frac{1}{b} \ln(ab) + \frac{1}{b} \ln t$	a (mg/g min): initial Cu(II) sorption rate b (g/mg): extent of surface coverage	(Low, 1960)
Weber-Morris	$q_t = k_i t^{\frac{1}{2}} + C$	q_t (mg/g): sorption capacity at any time t k_i (mg $\text{g}^{-1} \text{min}^{1/2}$): intraparticle diffusion rate constant C : constant related to the thickness or boundary layer	(Weber and Morris, 1963)

During the kinetics experiments, changes of pH values were also monitored, since the change in the solution pH during the sorption can be used as indicative of ion exchange processes in batch experiments (López et al., 2020). The initial pH value for the sorption experiments was 5.0. As it was expected considering pH_{sus} , there was a significant decrease of pH value for PS sorbent, which was 4.87 after only 5 min of Cd(II) sorption. This value decreased to the final measured value of 4.34 (at 120 min), indicating strong release of H^+ ions and strong competition between hydrogen and Cd(II) ions for the same active sites on the PS surface. In contrary, the pH value of PS-B-Cd(II) solution system raised from initial 5.0 up to final 5.64 (after 120 min). This PS-B behaviour can be explained by hemicellulose removal at biochar synthesis, along with conversion of surface groups responsible for the coordination and release of H^+ which are assumed to influence the adsorption of Cd(II) ions (e.g. $-\text{COOH}$ present in raw PS sample). This pH increase can also be contribution of ash contained in micropores, comprising mainly SiO_2 , Al_2O_3 , CaO , and various phosphates and carbonates, which are responsible for changes in biochar alkalinity (Yuan et al., 2011).

Table 3 summarizes data for experimental sorption capacity at equilibrium (q_e) and the values of the kinetic parameters, together with the corresponding determination coefficients (R^2) and χ^2 error values, while the graph presenting experimental kinetic values along with applied models is

given in Figure 1.

As can be seen from Table 3, Lagergren pseudo-first order equation cannot be used to predict the sorption kinetic of Cd(II) by PS and PS-B: although R^2 are not considerably low, calculated q_m values noticeably differ from experimental q_{exp} values, which is also confirmed by higher error values. It was also observed from Lagergren plots (Figure 2) that the pseudo-first order equation can be applied to kinetic data only in the initial period, where the rapid sorption of cadmium occurs.

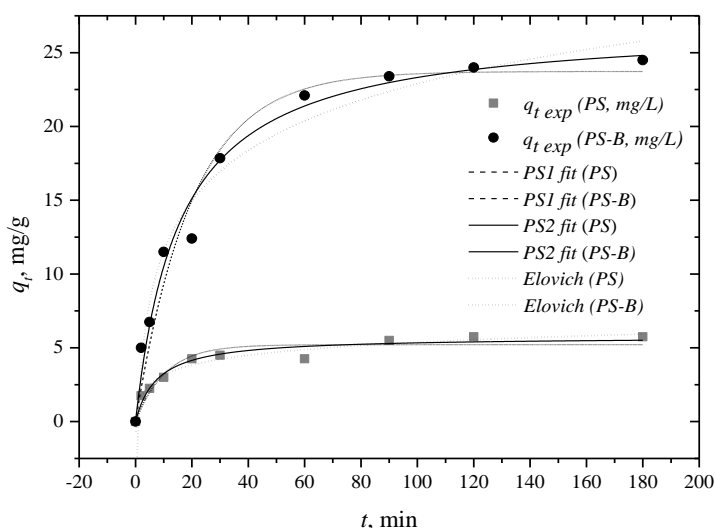


Fig 1. Experimental values for Cd(II) sorption by PS and PS-B and their fitting by appropriate models

Conversely, results presented in Table 3 show a very good compliance with the Elovich model, resulting in high correlation coefficients and low error functions for both samples. The R^2 values of Elovich model were lower than those of pseudo-second order model for PS-B sample (Table 3), very low values of χ^2 mean that the kinetic of Cd(II) sorption might also be described by chemisorption reaction given by Elovich equation. It can also be observed an increase in constant a (rate of chemisorption) and the decrease of constant b (related to the surface coverage), in sample PS-B compared to PS, meaning that PS-B sample has more sites available for fast biosorption of Cd(II) ions.

Table 3. Sorption kinetic parameters for Cd(II) removal by PS and PS-B

Model	Parameter	Sorbent	
		PS	PS-B
	q_{exp} (mg/g)	5.750	24.50
Pseudo first order	q_m (mg/g)	5.211	23.73
	k_1 (1/min)	0.096	0.050
	R^2	0.912	0.965
	χ^2	0.324	2.810
Pseudo second order	q_m (mg/g)	5.747	23.98
	k_2 (g/mg/min)	0.023	0.200
	h_2 (mg/g/min)	0.744	1.719
	R^2	0.955	0.979
Elovich	χ^2	0.166	1.634
	a (mg/g/min)	2.672	5.112
	b (g/mg)	1.050	0.203
	R^2	0.970	0.973
	χ^2	0.111	2.114

However, application of pseudo-second-order model showed better fit to the experimental data

related to the sorption of Cd(II) on PS and PS-B with the higher squared correlation coefficients, 0.955 and 0.979, respectively. In addition, as shown in Table 3, the pseudo-second-order model predicted q_{m2} values that are in better agreement with the experimental data (q_{exp}). The initial sorption rate h_2 (mg/g/min) at $t \rightarrow 0$ is calculated as $h_2 = k_2 q_e^2$. As it can be seen, rate of sorption is much higher for PS-B than for PS, for almost 2.5 times, indicating faster cadmium removal by biochar, which might be related to greater surface area of biochar (Table 1). The adsorption rate constant, k_2 , is much higher for PS-B than for PS, 0.200 g/(mg min) compared to 0.023 g/(mg min), indicating the rapid sorption of Cd(II) to biochar. Other studies published in the literature have also reported that pseudo-second order model is applicable in the case of Cd(II) sorption onto different biochar types (Li et al., 2017; Zhang et al., 2020). Although these results might indicate a chemisorption rate-controlling mechanism in Cd(II) sorption onto both samples, where the limiting step is a physical-chemical sorption or adsorption process involving valence forces, through the sharing or exchange of electrons between the sorbent and the sorbate (Vijayaraghavan and Yun, 2008), further techniques such as FTIR before and after adsorption should be applied to confirm it. In order to estimate which is the rate-limiting step involved in cadmium sorption by PS and PS-B, as well as to distinguish the sorption mechanism between them, the kinetic data were further analysed by Weber Morris intraparticle diffusion model. The obtained results are listed in Table 4, and the appropriate graphs are presented at Figure 2.

Table 4. Kinetic parameters calculated from different diffusion model for PS and PS-B

Sample	Intraparticle diffusion constant rate, k_{di}			Interception
	k_{d1} (mg/(g min ^{0.5}))	k_{d2} (mg/(g min ^{0.5}))	k_{d3} (mg/(g min ^{0.5}))	C (dimensionless)
PS	0.726	0.231	0.008	0.716
PS-B	2.757	0.411	-	1.400

In theory, Weber-Morris plot describing dependency between q and $t^{0.5}$ is given by several regions depending on the external mass transfer (boundary layer diffusion) followed by intraparticle diffusion in pores of different sizes; if the intraparticle diffusion is the only rate-controlling step, the plot passes through the origin, but if not, the boundary layer diffusion controls the Cd(II) removal to some degree (Cheung et al., 2007). As it can be observed from Figure 2, the plot of q_t versus $t^{1/2}$ does not result in a linear relationship passing through the origin, indicating that intraparticle diffusion is not the sole rate-limiting step and that Cd(II) sorption is affected by more than one process. Plots for both PS and PS-B samples gave similar initial pattern, but in the case of PS it could be seen that there are three processes that control the rate of Cd(II) sorption, while in the case of PS-B there is absence of the third region, indicating different sorption mechanism. At the beginning of the sorption process, the diffusion in bulk phase to the exterior surface of the adsorbent occurs, resulting in the fastest adsorption rate, with highest intraparticle diffusion constants, 0.726 mg/(g min^{0.5}) and 2.757 mg/(g min^{0.5}) for PS and PS-B respectively. The second portion of the plot seems to refer to the diffusion into the mesopores while the third one (with the lowest slope) to the diffusion into the micropores (Lopičić et al., 2019). From the Figure 2 it can be seen that PS reach equilibrium after certain time (close to 120 min), while the PS-B still isn't in equilibrium, indicating further explore on this sorbent type, with increased time and initial Cd(II) concentrations.

It can be concluded that sorption of Cd(II) onto PS and PS-B occurs through combination of boundary film diffusion and intraparticle diffusion mechanism, where the influence of liquid boundary layer is greater in PS-B than in PS, which can be seen from the values of initial graph interceptions (constant C, Table 4) and Figure 2. At this graph is shown that there is multiple nature of Cd(II) sorption onto both sorbent which differ in diffusion steps, which is reasonably having in mind the pore structure and the samples surfaces main components (Table 1).

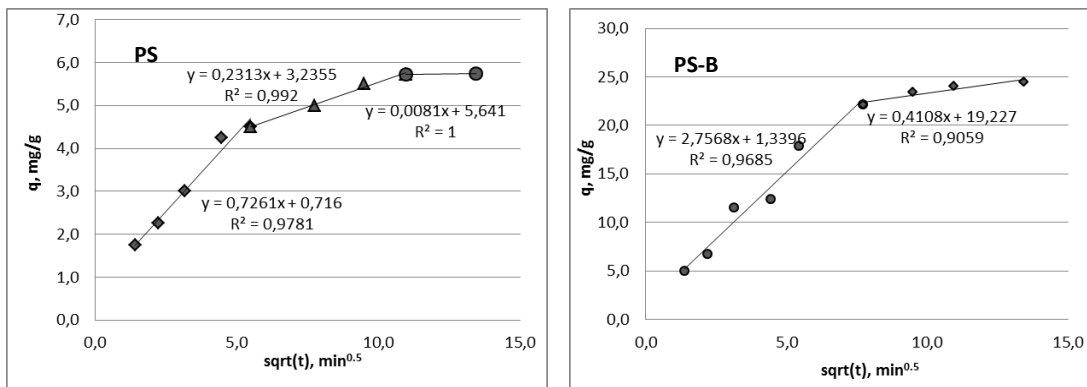


Fig 2. Weber-Morris plot for the adsorption of Cd(II) ions onto PS and PS-B ($C_i(\text{Cd})=100 \text{ mg/L}$, $m/V=2 \text{ g/L}$, stirring speed= 200 rpm , $\text{pH}=5.0$, $T=25^\circ\text{C}$)

Conclusions

The biochar application has a significant effect in the cadmium uptake from solutions. The results of this study confirmed that during the raw material pyrolysis, the significant transformation of raw feedstock into biochar product is critical for increasing the immobilization of cadmium. The cadmium uptake PS-B is almost 5 times those of PS (24.5 compared to 5.75 mg/g), due to enlarged specific surface area, total pore volume and oxygen-containing groups. Although the kinetic results revealed physical-chemical sorption or adsorption process involving valence forces, through the sharing or exchange of electrons between the sorbent and the sorbate for both samples, morphology of the samples influenced different diffusion controlling rate mechanism, which was also supported by materials characterisation. Due to cadmium's high toxicity, the development of this kind of sorbent originating from low cost, abundant and waste material is of special interest for environmental applications, and it will be further explored in our next investigations.

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CITY OF ZVORNIK

The municipality of Zvornik covers the surface area of 387 square kilometers in the north-eastern part of the Republic of Srpska in Bosnia and Herzegovina, an area with the population of 65 000. The town of Zvornik is situated on the eastern slopes of the mountain of Majeвица, at 146 m above sea level. It is surrounded by the municipalities of Bratunac, Milići, Vlasenica (to the south), Šekovići, Osmaci, Sapna, Kalesija (to the west), Lopare, Ugljevik and Bijeljina (to the north). The river Drina on the east is a borderline with Republic of Serbia, i.e. the town of Loznica and the municipality of Zvornik.

The municipality of Zvornik is a crossroads of important roads to Sarajevo, Belgrade, Novi Sad, Bijeljina and Tuzla. Two bridges on the river Drina for road and rail traffic connect this area with the wider region, with Zvornik in the center, at equal distances from the three major cities – Belgrade, Novi Sad, and Sarajevo (approximately 160 km).

Fertile plains, a river rich in fish and suitable for navigation, mountains rich with forests, game and minerals have attracted people to settle the area since prehistoric times, and the earliest known inhabitants were the Scordisci, a Celtic tribe. The name Zvornik has been used since 1519, and the settlement was first mentioned in 1410 under the name of “Zvonik“. Historic sites include the old town Đurđevgrad or the Zvornik fortress, the old town of Kušlat, The Andraš villa, the sheik's türbe, and the türbe of the poet Kaimija, necropolises and medieval tombstones called “stećci“, the church St John the Baptist, and the local museum holds a collection of specimens of the cultural and historic heritage.

Natural resources include the hydro power potential of the river Drina as it runs through its territory for 50 km. Zvornik lake covers the surface area of 19 square kilometers (25 km in length and 1.3 km in width). It offers great possibilities for tourism, sports and recreation. The resources include the springs of mineral water from Kozluk and Vitinički Kiseljak, reserves of quartz sand, brick clay, structural stone, limestone and gravel. The municipality has 13 700 ha covered by forest, 16 600 ha of arable land, and 10 500 farming households.

The municipality of Zvornik has 280 companies with 4500 employees, 800 businesses with 13000 employees, and around 40 institutions with approximately 2500 employees.

The most significant companies are AD Alumina factory Birač, Holding "Drinatrans" AD, AD "Zvornik putevi", AD "Vitinka", , DOO "Studen-prom", DOO "Obuća", AD "Vodovod i komunalije", DOO "Zo-Ži" , etc. Zvornik has founded a Business Zone covering a surface area of 10 ha with a complete infrastructure, suitable for investment.

Zvornik has 6 primary schools with 4200 pupils, two secondary schools with 18000 students, and one higher education institution - The Faculty of Technology. There is also Helath Institution and General Hospital important for the whole region.

German NGO *GTZ* has pronounced the municipality of Zvornik the best municipality in Bosnia and Herzegovina with respect to the treatment of the young, and the European Movement in Bosnia and Herzegovina has awarded Zvornik with “European open area“ award.



ALUMINA DOO

Alumina d.o.o. was released into operation on 6th October 1978 and in the period 1984-1989 has paid a special attention to a development of products in the area of aluminosilicate chemistry. During that period the company built



five plants which also rely on the company's infrastructure and its raw material resources. The company is supplied with all the necessary raw materials, i.e. bauxite, quartz sand and energy from its immediate surroundings. Alumina d.o.o. is the only company in the Western Balkans and the southeastern Europe which uses the Bayer process to produce alumina and different types of hydrates from bauxite. Bauxite, supplied from the local mines, is advantageous in terms of micro impurity and the content of organic compounds. Alumina d.o.o. is also recognized by a symbiosis of several types of productions. Apart from hydrates and different types of alumina, the company also produces different types of zeolites, sodium silicates and liquid "water glass", and all products are in accordance with ISO and REACH Standards. The company's position in the eastern part of the Republic of Srpska and Bosnia and Herzegovina allows an easy access to the ports on the Adriatic sea and the river Danube, and, consequently, to the large number of countries to which it exports, such as Spain, France, Italy, Germany, Denmark, Netherland, Switzerland, Austria, Slovenia, Slovakia, Macedonia, Hungary, Czech Republic, Romania, Bulgaria, Poland, Ukraine, Russia, Belarus, Croatia, Serbia, Montenegro, Greece, Turkey, Israel, Saudi Arabia, Jordan, Tunis, Egypt, Sudan, Morocco, Algeria, Pakistan, India, China, USA, Columbia, Costa Rica.

ZEOCHEM DOO

Zeochem d.o.o. in Zvornik is a branch of a quality-oriented Swiss company with locations throughout the world. The company is a global market leader in complex industrial separation and purification processes. It makes molecular sieves that filter the impurities out of natural gas and bioethanol, and neutralize volatile organic compounds before they give off odors. The company creates the building blocks for OLEDs that conjure razor-sharp images on smart phones and TVs. Zeochem supports the pharmaceuticals industry and the production of insulin and many other medicines, and by concentrating medical oxygen it improves many people's quality of life. The employees are committed to their customers worldwide and work with them to develop innovative solutions, products and processes. In recent years, the company has grown from a niche supplier to a global market leader in silicate chemistry. They produce in China, in the USA, in Bosnia and Herzegovina, and in Switzerland, and they are constantly expanding. Zeochem, a manufacturer of high-quality molecular sieves, chromatography gels and deuterated compounds, was established more than 200 years ago. In 1818, the Schnorf brothers lay the foundation stone for the CPH group to which Zeochem belongs when they opened a chemical factory in Switzerland. Swiss DNA is still a key factor in the company's success, shaping its identity and determining its actions. As a leading company in the silicate chemistry field, they set trends and create added value for their customers. The company's R&D teams focus on new product development, existing product improvement and understanding how their products are used in the customers' applications. Zeochem offers support for its customers as a trusted advisor and partner throughout the life of the products. Zeochem is committed to customer-focused innovation. The company continually develops new products with optimum performance for existing and new applications – offering better service lifetimes with more efficient materials.

The logo for Zeochem, featuring the word "ZEOCHEM" in a bold, sans-serif font. The letter "O" is stylized with a red dot in the center. A registered trademark symbol (®) is located at the top right of the word.

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