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## **Necessity of meat processing industry wastewater treatment – one year trial in Serbia**

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### **ABSTRACT**

The emission of untreated or insufficiently treated wastewater is very common in developing countries and consequently has harmful effects on the environment. The aim of this study was to analyse 24 physico-chemical parameters in raw wastewater and effluent after tertiary treatment (denitrification and disinfection) derived from meat processing plants in Serbia during four sampling campaigns conducted for one year. The biochemical (BOD) and chemical oxygen demand (COD) were measured at high concentrations up to 6960 and 14160 mg/L, respectively, indicating a large amount of uncollected blood, solubilized fat, urine, and faeces in discharged wastewater. Required limits of emission in all samples according to the European and national legislation for most of the studied parameters were exceeded. According to the obtained results there is an imperative need for pre-treatment of wastewater from meat industry before discharging it into the sewer. The applied wastewater treatment improved the quality of water by reducing BOD<sub>5</sub> and COD values to 97.97 % and 98.08 %, respectively while phosphorus removal efficiency varied from 15.29 % to 68.48 %.

*Keywords:* Meat industry; Wastewater; Slaughterhouse wastewater; Water quality

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## 1. Introduction

The meat industry, an important branch of the food industry with significant water consumption, presents one of the major sources of the organic pollution and leads to the degradation of the environment to a large extent [1-2]. The most significant environmental issues associated with meat processing industry are water usage, solid waste and by-products, emission of high organic strength wastewater, emission of odours to air and the energy consumption [3]. Almost half of the water consumed in the United States is used to raising animals for food. Most of the water is used for carcass washing, hair removal from hogs, cleaning and sanitizing of both equipment and facilities, and finally, for cooling of compressors and pumps [4]. Accordingly, during the production or cleaning, fats and/or blood are becoming a part of the wastewater system. The problem might occur if fats melt in hot water and consequently become more difficult to separate them from the water. Therefore, the discharged effluents from slaughterhouses and meat processing facilities increase the deoxygenation of rivers and lead to the contamination of groundwater and ultimately drinking water [5,6]. For that reason, the characterization and the treatment of wastewater from the meat processing industry have to arouse growing concerns among the agro-industrial sector and the policy-makers especially in the developing countries.

The wastewater derived from the meat processing facilities and slaughterhouses consists of a variety of organic and inorganic pollutants. Besides the blood, which is one of the major dissolved pollutants, wastewater also contains a high concentration of etheric extract, suspended solids and biogenic matter, pathogenic and non-pathogenic viruses and bacteria, parasite eggs, detergents and disinfectants [1,7]. Moreover, high loads of nitrogen and phosphorous in wastewater effluents have become a major cause of eutrophication of surface waters [8]. Also, these wastewaters remain high strength wastes (fat, grease, hair, feathers, flesh, manure, grit, undigested feed), in comparison to domestic wastewaters, based on the concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrogen, and phosphorus [9]. Blood, solubilized fat, urine, and faeces are the primary sources of BOD and COD in meat processing wastewaters. The meat industry has the potential to generate large quantities of solid wastes and wastewater with a BOD as high as 8,000 mg/l or 10-20 kilograms per metric ton (kg/t) of slaughtered animal [10]. The highest COD strength of any liquid effluent derived from slaughterhouses has blood with a COD up to 375 000 mg/L [5,11]. Therefore, the efficacy of blood collection is a significant factor in the determination of the amount of BOD and COD in the meat processing wastewater [10].

In the developing countries such as Serbia, the emission of untreated or insufficiently treated wastewater is very common. Mostly, very scarce treatment of wastewater is applied and livestock farms and slaughterhouses usually do not have facilities for treatment and disposal of manure and wastewater. In the sampling campaigns, conducted in the spring, summer and autumn of 2013 and the winter of 2014, the wastewater was collected from four representative meat processing industry pilot plants in the Province of Vojvodina, Republic of Serbia. The aim of this study was to determine physico-chemical characteristics of raw wastewater and effluent after tertiary treatment (denitrification and disinfection) from meat

processing industry in order to get deeper insight into the current quality issues and to evaluate the efficacy of the applied treatment methods.

## 2. Material and methods

The wastewater samples discharged from four meat processing plants in the Province of Vojvodina, Republic of Serbia were collected during four sampling campaigns, in the spring, summer and autumn of 2013, and the winter of 2014. In order to obtain truly representative samples, wastewater was taken in the peak load time for each meat processing facility based on the previous research [12]. The only one, out of four meat processing plants, had wastewater treatment technology. The wastewater treatment of the selected meat processing industry was divided into three steps: 1) Primary treatment: includes equalization of waste flows, the separation of large materials, removal of suspended solids, fats and oils, standardization of composition and flow rate; 2) Secondary treatment: biodegradable organic matter is eliminated by biological processes; 3) Tertiary or advanced treatment: filtration, removal of ammonia and other specific pollutants, disinfection, sterilization and advanced oxidation processes. The raw wastewater and water after tertiary treatment (denitrification and disinfection) from meat industry pilot plant with this specified treatment technology in the Province of Vojvodina, Republic of Serbia, were analyzed in order to investigate influence of the wastewater treatment processes on physical and chemical characteristics of the wastewater discharged from the meat processing industry. The largest number of meat processing plants in Serbia is situated in the Province of Vojvodina. The number of samples was limited due to the refusal of meat processing companies to provide the wastewater.

The wastewater samples for laboratory analysis were collected in sealed 1L glass bottles and stored at 4 °C before analyses. The chemical analysis included pH, temperature, electrical conductivity, BOD<sub>5</sub>, COD, dissolved oxygen (DO), permanganate index, ammonia, nitrite and nitrate nitrogen, total phosphorus (TP), orthophosphates, chlorides, total chlorine (TC), sulphates, total suspended solids (TSS), total hardness and the concentrations of metals was performed according to the Standard Methods for the Examination of Water and Wastewater.

Conductivity and DO were determined *in situ* using portable Multi 340i WISSENSCHAFTLICH – TECHNISCHE WERKSTATTEN GMBH device. Biological oxygen demand (BOD<sub>5</sub>) was determined using the BOD Trak™ method. The Hach BOD Trak apparatus is based on the manometric principle of operation. The COD, ammonium, nitrite and nitrate nitrogen, TP, orthophosphates, TC and sulfate concentrations were measured with UV/VIS spectrophotometer (DR 5000, HACH, Germany). Precision and accuracy of the methods were verified with the certified reference materials Demand WP, Simple nutrients WP, Complex nutrients WP (RTC, UK).

For the determination of metals, the wastewater samples were spiked with 5 ml of HNO<sub>3</sub> and digested using the microwave assisted digestion system MWS-3+ (Berghof, Germany). The analysis was done on Thermo atomic absorption spectrometer and accuracy was evaluated with the certified reference materials LGC6175 (LGC, UK) and SPS-WW2 Batch 110 (SPS, Norway). The recoveries ranged from 89 % to 97 %. The procedure was described in detail by Mihajlovic et al. [13].

The total phenol content (TPC), the chromium (VI) and oil and grease concentrations in the samples were measured using standard methods EPA 420.1, EPA 7916A, EPA 1664, respectively. The determination of anionic surfactant as methylene blue active substances (MBAS) and nonionic as potassium picrate active substances (PPAS) were done applying EPA 425.1 and the method obtained by Favreuo et al. [14].

The correlations between the average capacity of facilities per day and laboratory analysis for pollutant concentrations were done using Pearson's correlation coefficients by IBM SPSS software (a significance threshold of  $p=0.05$  was retained).

### **3. Results and Discussion**

Policy-makers worldwide are setting more stringent environmental standards for discharge of wastewaters from different kinds of industry [15]. Serbia as developing country and candidate for membership in European Union is in the process of implementation of EU legislation. Although, at the meat industry level, each plant is obligated to quarterly monitor wastewater quality, the data are scarce. Therefore, one year trial of quality of meat processing wastewater was conducted.

The temperature of the samples varied from 16 to 35.2 °C while the BOD<sub>5</sub> and COD concentrations reached the highest values in the second sampling campaign. In this study, BOD<sub>5</sub> and COD values were measured at high concentrations up to 6960 and 14160 mg/L, respectively, indicating the presence of a large amount of organic matter such as uncollected blood, solubilized fat, urine and faeces in discharged wastewater. The obtained results pointed out the absence of primary treatment which would result in reduction of BOD up to 200-250 mg/L [16].

Wastewater effluents often contain high amounts of dissolved salts from domestic sewage. Electrical conductivity of water is a useful indicator of salinity or total salt content. The high salt concentrations in waste effluents can increase the salinity of the receiving water, which may result in adverse ecological effects on aquatic biota. The electrical conductivity values were high and ranged from 895 to 4690  $\mu\text{S}/\text{cm}$  in the wastewater samples during four sampling campaigns within this study. The variation of conductivity in the samples was caused by variation of the ion content and the obtained results were even higher than the reported values for slaughterhouses in Africa [17]. The biological nutrient removal could decrease conductivity in wastewater samples [18].

The concentration ranges of measured physico-chemical parameters in raw water samples at selected sampling sites are presented in Table 1. Although the content of aluminium, chromium (VI) and nonionic surfactants were under the limit of the detection in all measured samples, other monitored parameters varied at a very wide range both between the different samples within the same sampling campaign, as well as between the samples from the same facility during different sampling campaigns. Depending on the number of the non-processing days in a month, meat processing wastewater flow rates from the same facility could be highly variable. The water consumption and production of waste are relatively constant during the killing and the processing in comparison to the cleanup period that follows. Although nonionic surfactants were below the limit of the detection in all samples, anionic were measured up to 124 mg/L MBAS. Anionic surfactants are widespread in the cleaning products and the determined mean values (45-96 mg/L MBAS) cause the serious

concern due to the fact that anionic and nonionic surfactants in concentration greater than 0.1 mg/L could lead to the chronic toxicity to aquatic species [19]. Fats, as part of BOD in meat processing wastewaters, are normally determined indirectly as the concentration of oil and grease. Therefore, the high concentrations of oil and grease in all samples were expected and only in the sample 3 during the autumn campaign were under the limit of the detection, probably due to the reduced workload of that facility. However, none of the measured parameters met the criteria prescribed by the Urban Waste Water Treatment Directive (91/271/EEC) of European Commission, German Wastewater Directive (*Abwasserordnung-AbwV*) as well as the Regulations of the Republic of Serbia, No. 67/2011 and 48/2012 [20-22].

The significant source of nitrogen in wastewater from meat processing industry is blood and manure. Generally, nitrogen occurs in several forms, including ammonia. The ammonia nitrogen is the leading toxic pollutant in meat processing industry and at high effluent concentrations could have harmful effects to aquatic organisms, by reducing the level of oxygen in the waterbodies. The content of ammonia nitrogen varied greatly in all raw water samples, while it was completely removed in the treated effluents from one the meat processing plant. Although the wastewater treatment plants are indispensable to provide and secure the reduction and the elimination of the majority of organic and inorganic pollutants, only sample 1 was treated before being discharged to the recipient.

The applied denitrification and disinfection treatment improved the quality of water by reducing BOD<sub>5</sub> and COD values to 97.97 % and 98.08 % respectively, while the chloride concentrations remained constant (Fig. 1). The oil and grease were removed completely in treated water samples and the content of TSS decreased 2.5-5.6 times. However, the phosphorus removal efficiency varied from 15.29 % to 68.48 %.

Pearson's correlation coefficients by IBM SPSS software with significance threshold of  $p=0.05$  showed no connection between the average capacity of facilities per day and the laboratory analysis for pollutant concentrations.

Changeability of the analyzed samples represents a problem in the situations when drawing certain conclusions is needed. It is known that diffusely distributed polluters, no matter how small they are, have an additive effect and a significant outcome on the environment. In this respect, it is clear why this sampling campaign was needed and important in order to comprehend the potential hazards meat industry wastewater has on the environment. This is of the utmost importance, given the fact that in Serbia almost none of the meat processing facilities conduct proper wastewater treatment.

#### **4. Conclusions**

The wastewater from four meat processing facilities was analyzed during one year study in order to comprehend the potential hazards of meat industry wastewater on the environment in the Province of Vojvodina, Republic of Serbia. The obtained results suggest that heavily polluted wastewater with a high content of blood, suspended solids, inorganic salts and nutrients was discharged directly to the municipal sewerage or natural recipients. The applied denitrification and disinfection treatment improved the quality of water by reducing BOD<sub>5</sub> and COD values, while the efficiency of phosphorus removal varied.

Serbia has more than 3000 meat processing plants where only 5% has some purification wastewater system and this contamination represents great problem not only for citizens but also for nature itself. Moreover, as a developing country and a candidate to become a member of the European Union, Serbia is now in the implementation process of the European Water Framework Directive whose major goal is to secure a “good chemical and ecological status” of the rivers and lakes. Accordingly, the advanced wastewater treatment plants followed by lower water consumption and frequent effluent monitoring by national authorities are indispensable to provide and secure the recommended criteria prescribed by the European and the national legislations. Knowing and recognizing how to deal with this issue in the best way, how to measure the implications and to understand their impact is crucial for the overall improvement of the quality of the effluents derived from meat processing industry in order to keep the environment as clean as possible for better life of humans and wildlife.

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Table 1 Concentration ranges of selected physico-chemical parameters in wastewater samples (N=16)

Parameter	Sample 1		Sample 2		Sample 3		Sample 4	
	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD	Range	Mean±SD
pH	7.09-7.63	7.43±0.27	7.29-10.03	8.66±1.94	6.88-8.25	7.3±0.65	7.23-7.80	7.50±0.25
Conductivity (µS/cm)	1117-3540	2102.25±1025.86	2950-3910	3430±678.82	2450-4690	3505±939.98	895-1797	1175.25±418
DO (mg/L)	0.23-4.56	2.18±1.81	0.45-1.18	0.81±0.52	0.42-3.07	1.40±1.22	0.34-4.59	1.94±1.98
NO <sub>3</sub> -N (mg/L)	0.10-27.90	8.95±12.84	0.10-2.50	1.30±1.70	0.50-3.50	1.95±1.57	0.10-0.90	0.62±0.36
NO <sub>2</sub> -N (mg/L)	0.02-1.25	0.41±0.58	0.04-0.75	0.39±0.50	0.05-0.94	0.28±0.44	<0.01-0.35	0.10±0.16
NH <sub>3</sub> -N (mg/L)	15.50-52.40	39.27±16.95	8.92-9.40	9.16±0.34	23.60-90.50	66.30±29.95	2.90-5.70	4.18±1.16
TP (mg/L)	9.52-27.05	20.04±7.62	21.32-61.61	41.46±28.49	14.22-33.82	24.66±8.05	1.43-11.08	6.32±4.41
Permanganate index (mg/L)	69.30-260.20	117.05±96.23	137.70-367.30	252.50±162.35	98.20-371.20	233±127.10	7.70-97.40	50.82±40.31
BOD <sub>5</sub> (mg/L)	720-2490	1329±802.79	1516-6960	4238±3849.49	1264-3820	2651±1057.24	384-1084	729.50±300.85
COD (mg/L)	1255-3580	2064.25±1035.23	1880-14160	8020±8683.27	1901-5680	3867.50±1595.16	526-1580	1081.50±484.60
SO <sub>4</sub> <sup>2-</sup> (mg/l)	38-64	53.50±12.04	5-10	7.50±3.53	10-100	43.75±41.51	3-24	11.75±8.81
TSS (mg/L)	106-420	275.50±131.40	486-1955	1220.5±1038.74	158-1450	862.25±602.31	43-340	129±141.91
Cl <sup>-</sup> (mg/L)	50-290	190±100.99	20-120	70±70.71	80-1000	322.50±451.84	100-200	167.50±47.17
PO <sub>4</sub> -P (mg/L)	2.56-9.11	7.01±3.00	10.55-12.50	11.52±1.38	6.24-16.68	10.16±4.85	1.45-4.11	2.99±1.11
TC (mg/L)	<0.02-0.3	0.13±0.13	<0.02-0.7	0.35±0.49	<0.02-2.3	0.93±1.06	<0.02-0.2	0.09±0.09
Al (mg/L)	<1		<1		<1		<1	
Ca (mg/L)	13.76-127.6	77.76±51.40	36.23-74.7	55.46±27.20	29.1-261.70	111.23±103.89	13.36-91.6	41.54±34.62
Mg (mg/L)	9.71-41.13	26.59±12.97	13.28-27.49	20.38±10.05	8.92-46.71	26.27±16.14	5.43-27.39	15.42±9.36
Cr (VI)(µg/L)	<0.2		<0.2		<0.2		<0.2	
TPC (mg/L)	<1		<1		<1-2	0.5±1	<1-2	0.5±1
Oil& Grease (mg/L)	50-185	128.75±58.93	195-220	207.50±17.68	<20-265	158±113.13	120-245	192.50±52.68
PPAS (mg/L)	<1		<1		<1		<1	
MBAS (mg/L)	<2-95	45±47.08	68-124	96±39.60	8-76	49.25±29.81	<2-120	63.25±52.17

Fig. 1. Comparison of selected parameters in raw and treated water sample from the meat processing company.