Industrial Wastewater Monitoring in the Public Health Institutions in Serbia

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Wastewater disposal is recognized by the public health sector for its potential negative environmental health impact. This paper is a cross-sectional study, for an observational period from 2015-2017, with an aim to present the scope of involvement of public health institutions in monitoring of industrial wastewaters. Wastewaters were sampled from industrial facilities of chemical, food-processing, mining-smelting and energy, transport, service, wood-processinga and textile production origin. As a study tool we used a data-base of the Institute of Public Health of Serbia, being filled-in with data from the local IPHs, analyzing wastewater quality on contract basis. In total, summing results from three consecutive years, 13392 wastewater samples were collected and analyzed, of which 44.79% (5999) did not comply to the adopted national standards. By observing wastewater treatment dynamics, generating from the legal entities whose samples were analyzed, it appears that it is insufficiently implemented. In all three monitoring years treatment persisted in less than 50% of facilities, which can be linked to the fact that parameters burdening samples at its most are: suspended and sediment matter, chemical oxygen demand, biological oxygen demand, ammonia, fats and oils, etc. The fact that most of the effluents are disposed of directly into natural watercourses indicates the constantly present risk for both environment and health.

Key words: *industrial wastewater, samples, institutes of public health, treatment*

1. INTRODUCTION

Industrial wastewaters are among most significant sources of environmental pollution, in general, with special harm done to the natural water bodies. Negative effect of the effluents to aquatic systems and human organism, originating from present hazardous substances; have been noted at both national and international levels. Some of the effects include death of live organisms in the aquatoria, algal bloom, destruction and devastation of natural habitats through their exposure to toxic sediment matter, disposed waste, together with other effects of long-term effect on the environment of toxicants. Chemicals' accumulation and magnification, together with their entering into food chain presents a potential public health risk [1]

Irregular wastewater disposal has been a global problem for the environmental status, ever since. According to their origin and structure, the polluting substances of our concern are grouped in two fractions: biological and chemical [2]. Pollutants of key importance for the wastewater quality are nitrogen, phosphorus, heavy metals, detergents, pesticides and hydrocarbons [3].

Contents of wastewater vary significantly according to their origin, especially in the case of industrially contaminated ones. Thus, defining unique parameters for all kinds of wastewater is aggravated, due to this reason. Some key parameters are chosen as indicators of both chemical and biological pollution and processes undergoing in this environmental me-

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dium: color, turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), pH, dry matter, suspended matter, heavy metals, nutrients - nitrogen and phosphorus, toxic substances [4].

Law on Public Health regulates realization of public interests, together with generating conditions for the upgrading of the health status of general population, through comprehensive societal activities focused on preserving its physical and mental health, preservation of the living and occupational environment, prevention of the generation and harmful effects of the risk factors essential for the occurrence of disease, trauma. This Law also regulates means and procedures, together with the conditions needed for the organization and implementation of public health measures and processes [5]. Public health institutions in the Republic of Serbia are distributed according to the Decree on the Network of Healthcare Facilities [6], within the official network of 25 Institutes of Public Health (IPHs), topped by the Institute of Public Health of Serbia (IPHS) "Dr Milan Jovanović Batut", as a beacon of public health in the country. Spatial distribution of the IPHs Network is presented in Figure 1.

Figure 1 - Network of IPHs in Serbia

Activities undertaken within their territorial jurisdiction by the IPHs are in accordance with the Law on Health Protection, especially its section implying to social care for the health of the population (art.8), which ensures preservation and improvement of health through monitoring and suppression of risk factors, acquiring of knowledge and habits essential for health and wellbeing. Article 10 of the same Law, defines activities of IPHs in the field of protecting vulnerable population groups and general population from harmful effects of toxic substances originating in polluted water, air, soil and incorrectly dumped and deposited waste. Protection from both ionized and non-ionized radiation is also defined by this Law [7].

Key objective of this manuscript is to present the level of involvement of public health institutions in the process of industrial wastewater monitoring, focusing on the components of wastewaters mostly burdening their final recipient, with a potential to provoke a long-term public health threat.

2. METHODS AND DATA COLLECTION

Manuscript is based on the results of a cross-sectional study, with a 3-year time frame (2015-2017). Wastewater samples tested in the IPHs' labs in Serbia originate from industrial facilities (processes). Physico-chemical and microbiological parameters were tested by using standard methods, in accordance with currently applicable regulations [8-11]. Industrial facilities generating wastewater that was tested in this study, belong to the following industrial branches: chemical, food production and processing, metal-processing, transport, services, wood-processing and textile production.

As a research tool a data-base designed by the National IPH was used. Such was regularly updated on an annual basis, collating data from those IPHs having sufficient technical capacities for performing lab test of wastewater samples, mostly from facilities atwithin the boundaries of their territorial jurisdiction. This data-base was formed in 2005. We used the data from the regular Annual Reports on the Industrial Wastewater Quality produced by the National IPH, for the given monitoring period (2015, 2016, 2017) [12-14]. As the aim of this manuscript is to give an insight into the industrial wastewater monitoring in the network of IPHs in Serbia, the following elements shall be presented: number of industrial facilities whose wastewater samples have been analyzed, number samples, number of non-compliant samples, wastewater treatment reperesentation among the mentioned facilities, according to the industrial branch.

3. RESULTS

Table 1 presents distribution of samples by its number and IPH where laboratories are seated, together with the number of industrial facilities generating them. Samples were analyzed in 23 IPHs labs, excluding IPH Sremska Mitrovica and Novi Pazar, without technical capacities to perform such activities.

Concerning the number of industrial facilities generating the given wastewater samples, a continu-

ous decrease is noted for all 3 years in a row: 4660 in 2015, 4445 in 2016 and 4287 in 2017. Mean percentage value for non-compliant samples is beyond 40% for all reporting years, with a slight increasing tendency observed.

The IPHs having the largest number of contracts with industrial facilities for sample analyses were seated in Subotica, Užice, Šabac and Kruševac; while the most of individual samples were analyzed in labs of the following IPHs: Ćuprija, Subotica and Požarevac.

IPHs with the largest number of wastewater samples non-compliant to the Decree are in Kikinda, Valjevo and Niš, regardless the fact that their labs, actually, have not received the largest number of samples, when compared to the other IPHs

Table 1. Distribution of samples by its number and IPH where laboratories are seated in 2015-2017

IPH seat	Industrial facilities (N)			Total number of waste water samples			Number of non-compliant samples			% of non-compliant samples		
	2015	2016	2017	2015	2016	2017	2015	2016	2017	2015	2016	2017
Subotica	77	67	64	334	391	374	173	175	185	51.8	44.76	49.46
Zrenjanin	24	20	19	121	108	101	66	59	55	54.54	54.63	54.46
Kikinda	50	50	47	41	45	31	37	30	27	90.24	66.67	87.10
Pančevo	10	12	12	45	103	65	37	64	53	82.22	62.13	81.54
Sombor	19	20	14	185	207	114	75	76	70	40.54	36.71	61.40
IPH Vojvodina	49	47	39	207	208	166	120	116	75	57.97	55.77	45.18
Beograd	14	14	14	130	167	143	7	35	42	5.38	20.96	29.37
Šabac	60	59	79	145	162	233	81	71	102	55.86	43.83	43.78
Valjevo	26	18	17	41	26	26	11	21	19	26.83	30.77	73.08
Požarevac	77	76	83	307	223	356	150	120	207	48.86	53.81	58.15
IPH Kragujevac	49	44	44	210	200	223	66	139	140	31.43	69.5	62.78
Ćuprija	19	19	33	838	646	419	372	287	356	44.4	44.43	84.96
Zaječar	45	40	53	196	223	226	45	44	80	22.96	19.73	35.40
Užice	95	81	91	279	262	308	133	114	137	47.67	43.51	44.48
Čačak	105	45	46	213	205	213	66	58	64	30.99	28.29	30.05
Kraljevo	39	46	64	188	241	281	67	65	87	35.64	26.97	30.96
Kruševac	87	88	79	387	314	290	72	116	89	18.6	36.94	30.69
IPH Niš	63	54	54	253	274	350	166	176	209	65.61	64.23	59.71
Pirot	7	9	11	9	50	36	0	16	7	0	24.24	19.44
Leskovac	42	53	52	196	143	154	68	54	60	34.69	37.76	38.96
Vranje	45	37	37	263	143	112	99	42	26	37.64	24.37	23.21
KM	15	15	15	15	15	15	7	9	7	46.66	60.0	46.67
IPHS "Batut"	21	19	12	57	89	51	22	48	27	39.0	53.93	52.94
Total	1038	933	979	4660	4445	4287	1940	1935	2124	41.63	43.53	49.54

Table 2. Distribution of facilities by type of industry and number of IPHs analyzing samples

Industrial branch	2015		2016		2017	
	No of facilities	No of IPHs	No of facilities	No of IPHs	No of facilities	No of IPHs
Chemicals	93	17	74	18	71	19
Energy/ mining	116	18	89	21	96	19
Food production	405	23	391	22	407	23
Transport	49	16	38	14	46	14
Textile	21	11	20	10	24	9
Services	291	23	248	23	266	22
Wood /furniture	19	6	16	6	15	6
Other	42	10	57	12	54	9
Total	**1036**		**933**		**979**	

Table 2 shows Distribution of facilities by type of industry and number of IPHs analyzing samples. In the case of food industry, dominating with the number of wastewater samples in this study (39.09% in 2015; 41.9% in 2016; 41.57% in 2017), all listed IPHs have had such samples analyzed (23/23), excluding servicing industry wastewater samples (restaurants, hotels) being analyzed by 22/23 laboratories.

4. WASTEWATER TREATMENT PRIOR TO ITS FINAL DISPOSAL INTO THE RECIPIENT

From the insight into the available data on the issue of implementation of wastewater treatment prior to its disposal to the final recipient (centralized sewage system, natural watercourses, pit latrines), by the industrial facilities (Table 3), in all 3 consecutive years (2015-2017), more than half of them do not treat the wastewater.

Namely, inexistence of wastewater treatment was registered accordingly: in year 2015 - 57.22%; in year 2016 - 50.66% and in 2017 – 56.91%.

Further on, we emphasize the importance of results for the year 2017. Among the given industries whose facilities participated with wastewater samples, only in the case of chemical and textile industries less than 50% of them (cca 40%) performed no pre-treatment of their effluents.

The least treated wastewaters in 2017 were those from the wood/furniture and food industry.

Table 3. Wastewater treatment by type of industry - in total

Industrial branch / facilities	2015		2016		2017	
	Treatment		Treatment		Treatment	
	yes	no	yes	no	yes	no
Chemicals	43	48	43	30	42	28
Energy/ mining	49	61	43	46	44	52
Food production	149	231	148	237	154	252
Transport	28	18	19	17	19	27
Textile	7	13	9	11	14	10
Services	126	155	108	138	122	144
Wood /furniture	4	13	8	7	4	11
Other	420	566	19	33	22	32
Total	**826**	**1105**	**397**	**519**	**421**	**556**
Total (%)	**42,78**	**57.22**	**43.34**	**50.66**	**43.09**	**56.91**

We specifically focused our attention to facilities not having installed a wastewater treatment system, at all. Of the total number of facilities participating in wastewater sampling in 2017 (979), such were 200 industrial facilities (20.43%), which should not be ignored [14].

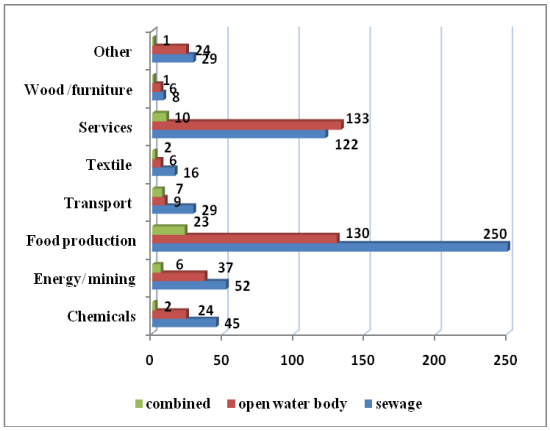

Figure 2 - Distribution of final wastewater disposal

Analysis of the distribution of wastewater final disposal into the recipient, for year 2017 is shown in Figure 2.

The chosen criterion was whether the industrial wastewater is disposed off into the centralized sewage system, natural watercourse (river flow, lake), or a combination of the both.

Actually, more than 50% of facilities involved in wastewater sampling in 2017, in chosen industrial branches, except services, use centralized sewage system as a final recipient [14].

5. THE MOST COMMON CAUSE OF THE WASTEWATER SAMPLES' NONCOMPLIANCE TO THE NATIONAL STANDARDS

In line with the adopted legal acts, parameters which have been analyzed are defined according to the industrial activity of the wastewaters' generators [9, 10].

Table 4. Dominant presence of certain parameters in wastewater samples tested in the period 2015-2017

IPH seat/year	2015	2016	2017
Subotica	SM, COD, BOD, TN, TP, pH	SM, COD, BOD, TN, TP, pH	SM, COD, BOD, TN, TP, pH, NH_3
Zrenjanin	SM, COD, BOD,TP	SM, COD, BOD,TP	SM, COD, BOD, TN, TP, MB
Kikinda	COD, BOD, TN, TP, NH_3, MB (Colif. bact., Strept. foecalis)	COD, BOD, TN, TP, NH_3, MB (Colif. bact., Streptoc. foecalis)	COD, BOD, TN, TP, MB, NH_3
Pančevo	SM, COD, TP, BOD, TN, fats/oils	SM, COD, TP, BOD, TN, fats/oils	SM, COD, TP, BOD, TN, NH_3, MB
Sombor	SM, COD, BOD	SM, COD, BOD	SM, COD, BOD
Novi Sad	SM, COD, BOD, TN, TP	SM, COD, BOD, TN, TP	SM, COD, BOD, TN, TP
Beograd	Chemical burden	Chemical burden	Chemical burden
Šabac	Organic matter	Organic matter	Organic matter, oils
Valjevo	SM, COD, BOD, NH_3, NO_3^-, NO_2^-, fats/ oils, TPO_4, MB	SM, COD, BOD, NH_3, NO_2^-, fats/ oils, Fe, MB	SM, COD, BOD, NH_3, fats/ oils, MB, TPO_4^-
Požarevac	NH_4^+, SM, COD, BOD, TPO_4	NH_4^+, SM, BOD, COD, O_2, Cr, Sn, Zn	NH_4^+, SM, COD, BOD, TPO_4
Kragujevac	MB, TPO_4^-, SM, BOD, sediment matter, NH_3, COD, fats/oils, pH	MB, TPO_4^-, sed.mat, BOD, fats/oils	MB, TPO_4^-, SM, BOD, COD, sediment matter, fats/oils, pH
Ćuprija	COD, BOD, SM, NO_2^-, NH_3	COD, BPK_5, TN, TP, NH_3, SM, MB	COD, BOD, SM, NO_2^-, NH_3
Zaječar	NH_4^+, SM, pH, BOD	NH_4^+, SM, pH, BOD, pH, As, Cu, fats/oils	NH_4^+, SM, fats/oils, sediment matter
Užice	COD, BOD, SM, MB	COD, BOD, SM, MB	COD, BOD, SM, TN, TP MB
Čačak	COD, BOD, SM	COD, BOD, SM, NH_3, fats/oils	COD, BOD, SM, NH_3, fats/oils
Kraljevo	NH_4^+, SM, BOD, o-PO_4, sed.matter, MB	NH_4^+, o-PO_4, MB, BOD, SM, sediment matter	NH_4^+, o-PO_4, MB, BOD, SM, sediment matter
Kruševac	pH, COD, BOD, SM, Cl, SO_4^{-2}, NH_3, TN, TP, fats/oils	pH, COD, BOD, SM, Cl^-, SO_4^{-2}, NH_3, TN, TP, fats/oils	pH, COD, BOD, SM, Cl^-, SO_4^{-2}, NH_3, TN, TP, fats/oils
Nis	Chemical burden	Chemical burden	Chemical burden
Pirot	/	MB, fats/oils, pH	COD, BOD, SM, SO_4^{-2}, sed.matter, fats/oils, pH
Leskovac	COD, BOD, SM, nutrients, pH	COD, BOD, SM, Cl^-, pH	COD, BOD, SM, TN, TP, sed.matter
Vranje	BOD, COD, SM, H_2S, ↓ soluble O_2, NH_3, NO_3^-, NO_2^-, phenols, detergents	BOD, COD, ↓soluble O_2, NH_3,Fe, H_2S, phenols, detergents	BPK_5, HPK, ↓soluble O_2, NH_3,Fe, H_2S, phenols, detergents
K.Mitrovica	MB (Strept. foecalis)	MB (Strept.foecalis)	MB (Strept.foecalis)
IPHS Batut	pH, NH_4^+, fats/oils, BOD, COD	NH_4^+, fats/oils, o-PO_4, BOD,	pH, NH_4^+, fats/oils, BOD, COD, SM, TPO_4^-

Among parameters of key importance for the assessment of the complexity of potential harmful effect that an effluent can influence the characteristics of the final wastewater recipient, being analyzed in laboratories of the IPHs Network, we chose for this purpose the following: biological oxygen demand (BOD), chemical oxygen demand (COD), suspended matter (SM), sediment matter, ammonia (NH_3), total nitrogen (TN), total phosphorus (TP), nitrates (NO_2), nitrites (NO_3), metals and metalloids in their elementary form, ortho-phosphates (o-PO_4). Samples belonging to food production industry and service activity

are in majority of cases additionally burdened with fats and oils. Table 4 shows range of the burden of present parameters on the quality of wastewater samples analyzed in IPHs labs, giving an insight into components of industrial wastewater with a potential environmental impact after its final disposal into sewage or surface water bodies, if released without pre-treatment [12-14].

6. DISCUSSION

From the preliminary analysis of the results, it is clear that periodical reports on the quality of industrial wastewater, generated by the Network of IPHs, point to numerous problems and bottle-necks in the process of data managing and analysis in the field of industrial wastewater quality monitoring. Primarily, number of wastewater samples analyzed in the IPHs labs is insuficient for any kind of an in-depth analysis, especially in the light of its constant decrease. This situation is sustaining as such, despite the fact that Law on Health Documentation and Records in the Field of Health (Article 26), clearly defines that: „Based on records from Pragraph 2. of this Article, licenced laboratories, competent institutions and other legal entities being involved in monitoring of environmental risk factors are obliged to submit reports to the competent IPH, depending on the territorial jurisdiction.“ Reporting on the quality of wastewater and surface water is defined in Point 8, of the same Paragraph 2, Article 26 [15].

It is, also, clear that industrial wastewater treatment is poorly implemented, as number of industrial facilities which do not treat their wastewater in all 3 years of continuous monitoring (2015-2017) was beyond 50%, which can be linked to the fact that parameters that burden samples at its most are: suspended and sediment matter, chemical oxygen demand, biological oxygen demand, ammonia, fats and oils, etc. The fact that most of the effluents are disposed of directly into natural watercourses indicates at the constantly present risk for both environment and health. Preventing the pollution of water supply sources and public health protection through preventing spread of waterborne diseases, are two key reasons for more significant implementation of comprehensive treatment of wastewater generating from various industrial sources [16,17].

Considering the fact that Serbian state is in the process of pre-accession to the EU, with inevitable opening of the Chapter 27, for the broad field of overall environment protection, it is of utmost importance to approach the problem of wastewater management through a series of concrete activities, among which regulating disposal of wastewater from healthcare facilities should also be included. Mentioning this „industrial“ branch is not unimportant for the issue of this manuscript, as newly adopted regulation take this wastewater type into account as „municipal wastewater“, which it surely is not, due to heavy presence of very diverse toxic substances and microbial agents in them [18].

Public health sector in Serbia, whith its institutional network, should be responsible for the environmental health impact assessment of the exposed population, not only from this kind of environmental pollution. As mentioned above, while interpreting IPHs role in preventing increase of environmental burden of disease, defined by the Law on Health Protection, namely this segment of environmental protection is an excellent example of a multisectoral approach to a public-health issue.

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REZIME

PRAĆENJE KVALITETA INDUSTRIJSKIH OTPADNIH VODA U INSTITUCIJAMA JAVNOG ZDRAVLJA U SRBIJI

Dispozicija otpadnih voda prepoznata je od strane sektora javnog zdravlja, zbog svog negativnog učinka na životnu sredinu i zdravlje. Rad je studija preseka, za period monitoringa 2015-2017. Ključni cilj je prezentovanje obima učešća institucija javnog zdravlja u monitoringu kvaliteta industrijskih otpadnih voda. Uzorci otpadnih voda uzeti su u pogonima iz oblasti: hemijske, prehrambene, rudarsko-metalurške i energetske, kao i saobraćajne, uslužne, drvno-prerađivačke i tekstilne delatnosti. Kao instrument istraživanja korišćena je baza podataka Instituta za javno zdravlje Srbije, ažurirana na godišnjem nivou sa podacima iz lokalnih zavoda za javno zdravlje, čije laboratorije analiziraju uzorke otpadnih voda, na tržišnom principu. Sumirajući rezultate dobijene u sve tri uzastopne godine, ukupno je analizirano 13392 uzorka otpadnih voda, od kojih 44.79% (5999) nije bilo usklađeno sa važećom nacionalnom legislativom. Opserviranjem dinamike prečišćavanja otpadnih voda poreklom iz pogona čiji su uzorci analizirani, vidna je nedovoljna primena ovog procesa. U sve tri godine praćenja, nedostatak prečišćavanja otpadnih voda pre uliva u konačni recipijent nadmašuje 50% pogona, a što se može povezati sa činjenicom da najdominantnije opterećenje uzoraka predstavljaju: suspendovane i sedimentne materije, hemijska potrošnja kiseonika, biološka potrošnja kiseonika, amonijak, masti i ulja, itd. Činjenica da se u većini slučajeva dispozicija otpadnih voda vrši direktno u u prirodne vodotokove dodatno ukazuje na postojanje kontinuirano prisutnog rizika po životnu sredinu i zdravlje.

Ključne reči: *industrijske otpadne vode, uzorci, zavodi za javno zdravlje, prečišćavanje*