Characteristics of Effluent Wastewater in Hospitals of Babol University of Medical Sciences, Babol, Iran

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Background: Wastewater effluent in hospitals has been increasing during the recent decades due to developments in medical services and products.

Objectives: This study aimed to investigate the qualitative parameters of effluent wastewater in hospitals affiliated to Babol University of Medical Sciences (BUMS).

Materials and Methods: Four hospitals were included and their wastewater effluent was studied. Ninety-six composited samples were collected and sent to the laboratory for determining pH, biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), total kjeldahl nitrogen (TKN), total phosphorous (TP), heavy metals, total coliforms (TC) and total heterotrophic bacteria counts (THBC) based on standard methods.

Results: Mean ± SD pH of the wastewater was 7.6 ± 0.4. Mean ± SD BOD_5, COD, TSS, TKN and TP were 372 ± 173 mg/L, 687 ± 231 mg/L, 289 ± 132 mg/L and 15 ± 5.5 mg/L, respectively. Mean concentration of Pb, Cd, Zn, Cr, Ni, Co, Hg, Fe and Cu were 26.5 (g/L), 2 (g/L), 429 (g/L), 34 (g/L), 30 (g/L), 3.7 (g/L), 7.5 (g/L), 2.1 mg/L and 49 (g/L), respectively. The total coliforms and heterotrophic bacteria were 5.4×10^8 MPN/100 mL and 2.6×10^{10} CFU/mL, respectively. Total wastewater quantity and its organic loading rate were 169 263 m^3 and 62 966 kg in a year, respectively.

Conclusions: Most of the qualitative indices evaluated in wastewater effluent of hospitals of BUMS were higher than effluent discharge standards of Iran Environment Protection Agency (IEPA). These wastewaters are usually purified improperly by wastewater treatment plants of these hospitals and polluted effluents which empty to the Babol Rood River and Caspian Sea can potentially endanger public health, natural resources and wildlife.

Keywords: Hospital; Waste Water; Effluent; Heavy Metals

1. Background

Hospital wastewater generation has been increasing during the recent decades as a result of development in medical services and products (1-3). Multiple practices that happen in hospitals (surgery, drug treatments, radiology, laundry, operation room, chemical and biological laboratories, etc.) are a principal source of pollutant discharge into the environment (4-6). Most of these pollutants such as detergents, disinfectants and drug residues can be found in hospital effluents, municipal wastewater collection systems and finally aquatic environments (7-9). Polluted wastewater discharged from hospitals causes many environmental hazards. These problems are different in terms of the activity and nature of hospitals (1, 10, 11). The World Health Organization (WHO) reported that about 85% of hospital wastes are non-hazardous, 10% infective and 5% non-infective but hazardous, in the United States of America (10). Hospital wastewater effluents contain pathogenic microorganisms, pharmaceutical par-

tially metabolized, radioactive elements and other heavy metals and toxic chemical compounds such as Cu, Fe, Cd, Pb, Hg, Ni, Pt, Cyanide, Phenol and others (2, 4, 12, 13). Hospitals discharge plenty of undesired potential pathogens like antibiotic-resistant bacteria and viruses (14-18). These hazardous agents which remain in wastewater treatment plants can provoke the pollution of the natural environment by causing biological imbalances (5).

In many cases, hospital wastewater is considered as an effluent with a similar quality to municipal wastewater, but due to activities that take place within the hospital it may also contain various potentially hazardous components including microbiological pathogens, hazardous chemical compounds, disinfectants, pharmaceuticals and radioactive isotopes (1, 4, 7).

Babol city is located in the center of Mazandaran province at a longitude of 33 degrees, 52 minutes and 43 degrees, 51 minutes and at latitude 40 degrees, 36 minutes and 36 de-

grees, 35 minutes. The city's population is 256 433 people with an area of about 10 431 square kilometers. Much of the municipal and household wastewaters of the city without treatment are discharged to cesspool and Babol Rood River. According to laws and regulations, treated hospital wastewater can be discharged into wastewater collection systems (1, 2). In general, there are six hospitals in the city of Babol of which four hospitals are affiliated to BUMS and two other hospitals are owned by the private sector. The catchment of Babol Rood river is located south of Babol city and its area is 1746.47 km^2 with a length of 110.7 km, a maximum altitude of 3180 m and a minimum height minus 10 m (-10 m) and an average slope of 0.74 m.

Referral of a large number of patients from different cities of Mazandaran province and neighboring provinces in hospitals of BUMS and various technical services in health-care centers has caused increasing changes in quantity and quality of wastewater. For the sake of the ecosystem and valuable and susceptible natural resources of this province such as river, sea, jungle, agricultural areas and pasturelands, it is necessary to continuously assess and monitor the quality of wastewater and its disposal by health-care centers.

2. Objectives

The aim of this study was to determine the chemical indices, including pH, biochemical oxygen demand (BOD$_5$), chemical oxygen demand (COD), total suspended solids (TSS), total kjeldahl nitrogen (TKN) and total phosphorous (TP), as well as chemical indices, including total coliforms (TC) and total heterotrophic bacteria counts (THBC), and heavy metals concentration of wastewater effluents from the hospitals of BUMS.

3. Materials and Methods

Babol is one of the most important cities of the Mazandaran province regarding population, economy and agriculture. This city is located in the central section of Mazandaran province and is twenty kilometers far from Caspian Sea. This city has six hospitals and in order to determine the quality of wastewater effluents, four educational hospitals were selected. Ninety-six composited wastewater samples were collected from the studied hospitals (24 samples for each hospital), during the summer

of 2013 (20th of June 20 to 20th of August), to avoid dilution effect owing to rain events. They were collected in 1 L plastic bottles then immediately sent to the water and wastewater chemistry laboratory of BUMS for analysis. Chemical and physical parameters including pH, TSS, BOD$_5$, COD, TKN, TP and total heavy metals (Hg, Cd, Pb, Cr, Co, Ni and Zn) were determined according to "Standard Methods for the Examination of Water and Wastewater" (19). The total coliforms (TC) and total heterotrophic bacteria counts (THBC) of microbial samples were measured using the multiple tubes fermentation and Gerhardt methods, respectively (19, 20). Moreover, heavy metals analysis was performed according to the Atomic Absorption Spectrometry method (19).

4. Results

The pH, TSS, BOD$_5$, COD, TKN, TP, TC and THBC values are illustrated in Table 1. According to these results, the minimum, maximum and mean pH values of wastewater were 6.9, 8.3 and 7.6, respectively. The minimum, maximum and mean concentrations of BOD$_5$ (161, 648, and 372 mg/L) and COD (379, 1187, and 687 mg/L) were determined for the investigated hospitals. The minimum, maximum and mean concentrations of TTS were 108, 538, and 289 mg/L, respectively, for the studied hospitals. Maximum, minimum and mean contents of TKN were 26.5, 8.1 and 15 mg/L, respectively. Maximum, minimum and mean total phosphorous in the studied hospitals effluents were 5, 0.8, and 2.2 mg/L, respectively.

In the current study, TC and THBC were indicators of the presence of microorganisms. Maximum, minimum and mean concentrations of TC and THBC in wastewater of the studied hospitals were 1.8×10^9, 2.4×10^3 and 5.4×10^8 MPN/100 mL, and 1.3×10^{12}, 9.5×10^5 and 2.6×10^{10} CFU/mL, respectively.

In Table 2, concentration of heavy metals such as Hg, Cd, Pb, Cr, Co, Ni and Zn are presented. Maximum, minimum and mean values of heavy metals (Hg, Cd, Pb, Cr, Co, Ni, and Zn) in the four hospitals effluents were 2.5, 0.9 and 1.2 mg/L, respectively. The maximum and minimum contents of heavy metals in the hospital wastewaters are related to Fe and Cd, respectively. Overall, heavy metal concentrations in wastewater were in the following order: Fe > Zn > Cu > Cr > Ni > Pb > Hg > Co > Cd.

Table 1. Wastewater Characteristics in the Hospitals of Babol University of Medical Sciences

Hospital	pH [a]	BOD$_5$, mg/L [a]	COD, mg/L [a]	TSS, mg/L [a]	TKN, mg/L [a]	TP, mg/L [a]	TC, MPN/100 mL	THBC, CFU/mL
1	7.8 ± 0.5	443 ± 205	876 ± 311	375 ± 163	18.5 ± 8	3.2 ± 1.8	1.8×10^9	1.3×10^{12}
2	7.5 ± 0.7	398 ± 194	729 ± 254	312 ± 148	16 ± 6.5	2.8 ± 1.6	3.5×10^8	8.5×10^{10}
3	7.6 ± 0.6	314 ± 161	608 ± 213	261 ± 117	13.5 ± 4	1.7 ± 0.6	4.2×10^6	5.7×10^8
4	7.4 ± 0.5	293 ± 132	534 ± 155	209 ± 101	11.8 ± 3.7	1.2 ± 0.4	2.4×10^3	9.5×10^5
Total	7.6 ± 0.6	372 ± 173	687 ± 231	289 ± 132	15 ± 5.5	2.2 ± 1.2	5.4×10^8	2.6×10^{10}
Effluent discharge standard [b]	5-9	30	60	40	15	4	1000	

[a] Data are presented as Mean ± SD.
[b] Iran Environmental Protection Agency (IEPA, 2008).

Table 2. Heavy Metals Content of Wastewater in the Hospitals of Babol University of Medical Sciences [a]

Hospital	Pb, μg/L	Cd, μg/L	Cr, μg/L	Zn, μg/L	Co, μg/L	Hg, μg/L	Ni, μg/L	Fe, mg/L	Cu, μg/L
1	14.6 ± 3.6	1.8 ± 0.9	33.5 ± 3	654 ± 51	2.1 ± 0.12	4.1 ± 1.7	27.4 ± 3	1.6 ± 1.2	26 ± 1.6
2	50 ± 32	1.1 ± 0.8	38.4 ± 5	468 ± 353	6.7 ± 8.3	17.2 ± 16	28.4 ± 4.5	3.25 ± 2.3	62 ± 56
3	14.8 ± 1.5	4.1 ± 3.9	35 ± 0.9	340 ± 191	2.9 ± 2.7	2.9 ± 0.6	28.6 ± 0.5	1.7 ± 1.6	56 ± 54
4	26.6 ± 8.9	0.8 ± 0.6	30 ± 14	255 ± 98	3.1 ± 1.6	5.7 ± 2	36 ± 28	1.9 ± 0.3	51.7 ± 23
Mean	26.5 ± 11.5	2 ± 1.5	34 ± 5.7	429 ± 173	3.7 ± 3.2	7.5 ± 5	30 ± 9	2.1 ± 1.4	49 ± 33.7
Effluent discharge standard, μg/L [b]	50	10	50	2000	50	5	100		

[a] Data are presented as Mean ± SD.
[b] Iran Environmental Protection Agency (IEPA, 2008).

5. Discussion

Average pH of wastewater in the investigated hospitals was determined to be 7.6. The mentioned range (6.9-8.3) is suitable from the viewpoint of wastewater treatment processes and is acceptable by the Iran Environment Protection Agency (21). The acidity or alkalinity of wastewater damages wastewater collection and treatment facilities and disrupts the biological treatment processes (1, 2).

The parameters of BOD_5 and COD are widely used to characterize the organic maters of wastewater (2, 4). The minimum concentrations of BOD_5 and COD were 161 and 379 mg/L while the maximum levels were 648 and 1187 mg/L. In most hospitals, the BOD_5 and COD concentrations of wastewater are almost equal to domestic wastewater values. Average load of organic materials of wastewater in a year was 62 966 kg. Mean of BOD_5 and COD in wastewaters of Hormozgan hospitals have been reported as 291 mg/L and 628 mg/L, respectively (22). In another study, average of BOD_5 and COD in wastewaters of Teheran hospitals was 444.3 mg/L and 792 mg/L, respectively (23). The high biodegradability of organic matters is very desirable from the viewpoint of wastewater treatment and promotes the efficiency of wastewater treatment plants (2).

One of the common parameters used in defining wastewater is TSS. Moersidik (24) studied the wastewater quality of a hospital in Indonesia and found TSS concentration to range from 36 to 269 mg/L. Average TSS in the wastewaters of Hormozgan and Tehran hospitals has been reported as 362 and 184 mg/L, respectively (22, 23).

Nitrogen compounds are important for wastewater treatment plant operators because of the role of nitrogen in the life cycle of plants and animals. Nitrogen is a nutrient and occurs in many forms including ammonia and organic nitrogen, nitrate and nitrite (2). Nitrogen in raw wastewater is normally present as organic nitrogen and ammonia forms, with small quantities of nitrite and nitrate (6). Maximum, minimum and mean contents of TKN were found 26.5, 8.1 and 15 mg/L, respectively. Mean concentration (15 mg/L) of TKN was close to standards set by IEPA for discharged effluents (21). Total contents of TKN annually produced by these hospitals were 3 115 kg. As a consequence, most of the TKN produced in the hospitals is discharged into water bodies and has dangerous effects on the environment and human health.

Phosphorus is a nutrient used by organisms for growth. It occurs in natural water and wastewater bound to oxygen to form phosphates. Phosphates are derived from a variety of sources including agricultural fertilizers, domestic wastewater, detergents, industrial process wastes and algae growth. The latter causes taste and odor problems in drinking water supplies (2, 6). Maximum, minimum and mean total phosphorous in the effluents of studied hospitals were 5, 0.8 and 2.2 mg/L, respectively. The amount of total phosphorus generated by the four hospitals was 457 kg, in one year.

Heavy metals are a major concern in the treatment of water and wastewater due to their toxic and other detrimental effects. Maximum, minimum and mean values for heavy metals (Hg, Cd, Pb, Cr, Co, Ni and Zn) in the four hospitals effluents were 2.5, 0.9 and 1.2 mg/L, respectively. The sum of the average concentrations of these metals (2.68 mg/L) was greater than the standard set by the Iranian law as reported in Table 2.

A serious concern regarding wastewater is the high content of enteric pathogens including bacteria, viruses, protozoa and helminthes, which are easily transmitted through water (16). Wastewater of hospitals where patients with enteric diseases are hospitalized is a particular problem during outbreaks of diarrheal diseases (1, 6, 15, 16). In the present study, total coliforms (TC) and total heterotrophic bacteria counts (THBC) were indicators of the presence of microorganisms. Maximum and minimum numbers of TC in wastewater of the studied hospitals were 1.8×10^9 and 2.4×10^3 MPN/100 mL, respectively. Previous studies on Iranian hospitals showed that TC numbers in wastewater of many hospitals of Tehran University of Medical Sciences were between 2.2×10^6 and 3.8×10^8 MPN/100 mL (21), and in hospitals of Iran University of Medical Sciences this was 1400 MPN/100 mL (24).

Considering the estimated quantity of wastewater

produced by these hospitals (177, 175 m^3/year) and those generated by other places such as private hospitals, clinics, industries and homes, overall the amount of wastewater which discharges to Babol Rood River and Caspian Sea will be more than 177 175 m^3/year. On the other hand, these hospitals produce 192 840 kg per year of biological organic materials discharged into environmental resources such as sea and rivers. This quantity of pollution along with other hazardous materials discharged by other pollutants will endanger public health and degrade natural resources of the city of Babol, one of the major urban centers in the province of Mazandaran. In addition, the presence of chemical materials such as antibiotics, antineoplastics, organic chlorinated compounds and other hazardous materials in the hospital wastewater and disability of wastewater treatment systems will result in many environmental disorders and consequently harmful effects on human health of this city.

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