original article

Annual and seasonal variation of turbidity, total dissolved solids, nitrate and nitrite in the Parsabad water treatment plant, Iran

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ABSTRACT

Aims: This study investigated the annual and seasonal variation of turbidity; total dissolved solid (TDS), nitrate and nitrite in Parsabad water treatment plant (WTP), Iran.
Materials and Methods: The water samples were obtained from the inlet and outlet of Parsabad WTP from February 2002 to June 2009. The samples' turbidity, TDS, nitrate, nitrite, pH, and temperature were measured according to standard methods once a month and the average of these parameters were calculated for each season of year.
Results: The maximum concentration of inlet turbidity, TDS, nitrate and nitrite were 691, 700.5, 25, and 0.17 mg/l, respectively. These parameters for outlet samples in the study period were 3.0, 696.7, 18, and 0.06 mg/l, respectively. While these concentrations in outlet zone were lower than World Health Organization (WHO) or United States Environmental Protection Agency (US-EPA) water quality guidelines, WTP could not reduce the TDS, nitrate, nitrite and pH value and these parameters were not different in the inlet and outlet samples. However, the WTP reduced the turbidity significantly with an efficiency of up to 85%.
Conclusion: This study showed that a common WTP with rapid sand filtration can treat a maximum river turbidity of 700 NTU in several years. As no differences were observed between inlet and outlet TDS, nitrate, nitrite and pH in the studied WTP. It can be concluded that compensatory schemes should be predicted for modification of these parameters when they exceed the standards in the emergency situations.

Key words: Annual variations, characteristics, drinking water, maximum concentration, seasonal variations, standard, water characteristics, water treatment plant, WTP standards

Access this article online
Quick Response Code:
Website: www.ijehe.org
DOI: 10.4103/2277-9183.122421

INTRODUCTION

Since the mechanism of metabolism and synthesis is in close relation with the special characteristics of water, it is one of the vital materials for life.[1] Interactions of cells with the environment and with each other is impossible in the lack of water. On the other hand, although 2.66% of the total global

This article may be cited as:
Zare MR, Poureshgh Y, Fatehizadeh A, Shahriary A, Toolabi A, Rezaei M. Annual and seasonal variation of turbidity, total dissolved solids, nitrate and nitrite in the Parsabad water treatment plant, Iran. Int J Env Health Eng 2013;2:37.

waters are fresh water resources but only 0.6% of the fresh water, is usable as drinking water.[1] Because of these reasons, water resources must be continuously and properly monitored and the variation of its parameters should be considered.[2]

Some of the critical parameters of the drinking water are turbidity, total dissolved solid (TDS), nitrate and nitrite. The potable water sources which contain more than 1000 mg/l of TDS are unusable for drinking.[3] These types of waters are also improper for agriculture because of the negative effects on the plants.[3,4]

Treatment of turbid waters is a very important stage in different industries, such as drinking water treatment plants, electronic industries, fine polishing and some other chemical manufacturing's. But low concentration of turbidity in water can decrease the rate of inter particle contacts which will limit the effectiveness of coagulation in water treatment plants (WTPs).[4] In comparison of coagulation, other treatment processes such as membrane filtration are more effective for TDS and turbidity removal, but high operating and capital costs prohibit their application in large-scale treatment plants. One of the most applicable methods for removal of turbidity in low turbidity waters is implemented by sweep coagulation, which is usually performed with aluminum sulfate.[5] However, in addition to the large amount of waste sludge produced by sweep coagulation using alum, high levels of aluminum remained in the treated water at acidic and alkaline pH is another problem, which raises the public health concerns.[6]

These facts about the turbidity and TDS indicate that these factors are among the most important parameters that influence and the applied water treatment processes. Guideline value of World Health Organization (WHO) for turbidity in drinking water is 5 Nephelometric Turbidity Units (NTU).[7,8] According to US-EPA guidelines, turbidity is used to indicate filtration effectiveness and water quality.[8] Higher levels of this parameter often causes higher rates of disease which are associated with microorganisms such as viruses, bacteria, and some other pathogens. These organisms can cause disorders such as nausea, cramps, diarrhea, and headaches.[9]

Because both high or low turbidity and TDS can cause some problems in the drinking water treatment plants, it is necessary to monitor their variation trends in the WTP.

In recent decades, nitrate concentrations in drinking water supplies have increased in the United States, Europe, and Asian countries such as Iran. This increment has caused some concerns, because nitrates cause methemoglobinemia in infants.[10] For nitrate (NO_3^-) and nitrite (NO_2^-) the US-EPA has set maximum contaminant levels (MCLs) of 10 mg/l and 1 mg/l as N, respectively. The European standard for nitrite is limited to 0.03 mg/l as N.[11,12]

The first step for controlling the future problems of such parameters is monitoring their variation trends. Significant variations in water characteristics affect the quality of a water treatment process. Hence, monitoring of seasonal variations of water characteristics is necessary for deciding on the effective type of water treatment process. In this study the variation trends of nitrate, nitrite, turbidity, TDS and pH in the water treatment plants of Pars-Abad County was investigated. The results of these studies can reveal the problems which may be faced in the other water treatment plants.

MATERIALS AND METHODS

Water samples were taken from inlet and outlet of water treatment plant (WTP) of Pars-Abad County (a county of Ardebil province in the northwest of Iran) once a month for a period of 8 years from February of 2002 to June of 2009. The mentioned WTP with a capacity of 600(l/s) consisted of 7main stages: (1) Screening, (2) Prechlorination, (3) Preparation and injection of chemicals, (4) Primary sedimentation, (5) Clarification (rapid sand filters), (6) Post chlorination, and (7) clear water well (Reservoir). The intake water of this WTP is from Aras river. The study area is located on 48° 18′ E longitude and 37°48′N latitude. The location of WTP is shown in the Figure 1.

The temperature, pH, nitrite, nitrate, turbidity, and TDS were measured once a month. The analysis of samples was

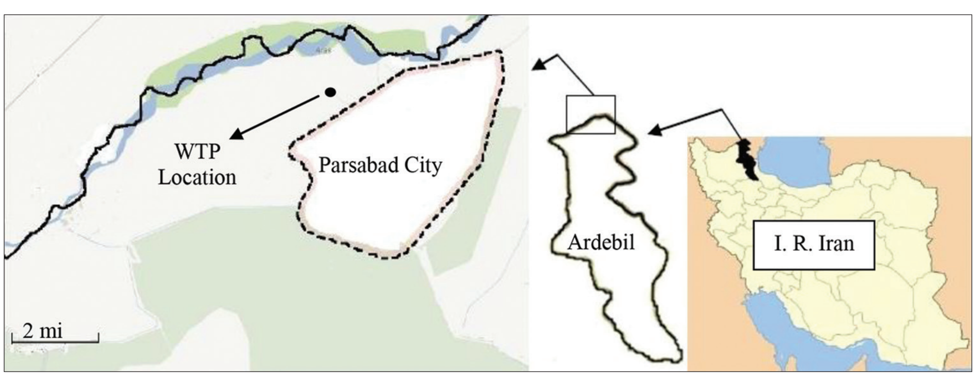

Figure 1: Location of WTP and Parsabad city

performed within maximum 8 hour. The average of these parameters was calculated for each season of years. All of these data were registered in the bureau of Parsabad WTP laboratory. The water parameters tested according to the standard methods.[13] reagents and chemicals were purchased from Aldrich chemical company, England. Samples for determination of nitrite and nitrate were collected in plastic bottles and for analysis of other parameters the samples were collected in glassware. The data were analyzed using one-way analysis of variance (ANOVA) and Pearson correlation tests by SPSS ver. 16.0 software.

RESULTS

The mean values for turbidity, TDS, temperature, pH, nitrate, and nitrite are presented in Tables 1 and 2. As the difference between inlet and outlet temperature and pH was not significant ($P > 0.05$), only outlet value of these parameters are presented in the Table 1. The maximum concentration of inlet turbidity, TDS, nitrate and nitrite were 691, 700.5, 25, and 0.17mg/l, respectively. These parameters for outlet samples in the study period were 3.0, 696.7, 18, and 0.06 mg/l, respectively.

According to Tables 1 and 2, all parameters varied over the different seasons. The measured turbidity, TDS, nitrate and nitrite concentrations were higher than the Nigeria EPA standards in some seasons of years.[14] These concentrations however, are lower than WHO or USEPA standards.[14,15] The differences between outlet and inlet samples for TDS, nitrate, and nitrite also were not statistically significant ($P > 0.05$). But turbidity had been removed significantly with a removal efficiency of up to 85% [Figure 2]. According to previous research the low turbidity can result in its low removal efficiency in WTPs.[8] The minimum inlet turbidity have been occurred in summer of 2007. In this season its value was 6.31 NTU.

The pH in almost all of the samples had not exceeded the US-EPA and WHO standards. All values of this parameter were in alkaline ranges and they were between 7.2 and 8.5 at all seasons.

DISCUSSION

This study revealed that a common WTP with rapid sand filtration can treat a maximum river turbidity of 700 NTU in a long time period of 8 years. According to the USEPA guidelines, turbidity is used to indicate filtration effectiveness and water quality,[8] hence it can be said that for a turbidity below 700 NTU, a rapid sand filtration can be an effective unit for producing a standard water.

According to Figure 2, the minimum turbidity removal efficiency was occurred in the summer and autumn 2007, although in these periods the inlet turbidity is less than the most of the other periods. The reason of this phenomenon is described by inter particle contacts theory. In fact, low

Table 1: Mean value of Parsabad WTP parameters in different seasons and years

Year	Season	Turbidity (NTU)		TDS (mg/l)		Outlet temperature (°C)	Outlet pH
		Inlet	Outlet	Inlet	Outlet		
2002	Winter	103.00	0.52	520.0	554.0	12.8	8.26
	Spring	155.00	0.73	485.0	493.0	12.8	8.54
	Summer	25.50	0.69	538.0	546.0	18.4	8.18
	Autumn	8.66	0.67	591.0	596.0	12.9	8.01
2003	Winter	92.10	1.10	362.8	367.3	15.7	7.76
	Spring	48.50	1.75	470.4	476.2	16.8	8.11
	Summer	42.80	0.97	567.6	570.7	12.5	7.92
	Autumn	45.70	1.06	647.0	655.2	7.8	8.10
2004	Winter	651.00	1.27	403.2	405.0	15.0	7.75
	Spring	97.40	0.50	340.2	338.9	22.2	7.77
	Summer	90.50	0.88	558.8	573.3	17.8	8.29
	Autumn	24.40	0.81	700.5	696.1	12.5	8.33
2005	Winter	91.30	0.39	559.4	575.8	16.8	7.99
	Spring	55.10	0.68	445.4	456.1	16.8	8.01
	Summer	48.40	0.98	594.7	597.8	18.9	8.03
	Autumn	18.10	0.86	618.6	631.2	9.2	8.14
2006	Winter	182.00	1.50	371.7	374.8	10.2	7.31
	Spring	52.60	1.86	504.6	510.9	13.1	7.21
	Summer	16.70	0.88	492.0	485.1	12.4	8.13
	Autumn	29.10	0.80	572.6	593.0	5.8	7.90
2007	Winter	25.20	0.81	456.5	447.3	12.4	8.11
	Spring	691.00	1.47	400.0	420.8	16.6	7.25
	Summer	6.31	0.91	425.8	432.8	14.4	8.10
	Autumn	21.00	3.00	695.5	696.7	3.1	8.13
2008	Winter	28.00	3.00	695.5	696.7	3.1	8.13
	Spring	38.60	0.88	672.8	668.4	3.1	8.02

WTP: Water treatment plant, TDS: Total dissolved solid, NTU: Nephelometric turbidity units

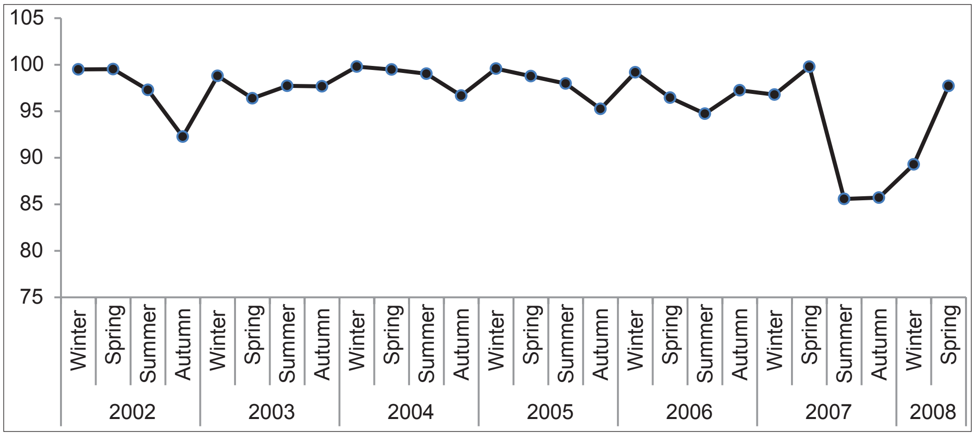

Figure 2: Turbidity removal efficiency in Parsabad WTP in the study period

Table 2: Mean value of nitrate and nitrite for Parsabad WTP in different seasons and years

Year	Season	Nitrate (mg/l)		Nitrite (mg/l)	
		Inlet	Outlet	Inlet	Outlet
2002	Winter	19	18	0.11	0.00
	Spring	10	9	0.00	0.00
	Summer	11	11	0.00	0.00
	Autumn	5	8	0.00	0.00
2003	Winter	15	11	0.06	0.01
	Spring	8	5	0.04	0.00
	Summer	22	13	0.01	0.01
	Autumn	17	15	0.11	0.02
2004	Winter	13	13	0.06	0.03
	Spring	7	12	0.02	0.01
	Summer	7	8	0.02	0.02
	Autumn	14	16	0.07	0.01
2005	Winter	12	14	0.05	0.02
	Spring	25	7	0.01	0.02
	Summer	23	6	0.02	0.02
	Autumn	16	14	0.02	0.02
2006	Winter	4	3	0.05	0.03
	Spring	3	4	0.02	0.03
	Summer	4	3	0.17	0.02
	Autumn	5	4	0.03	0.02
2007	Winter	6	5	0.05	0.03
	Spring	4	3	0.01	0.01
	Summer	5	6	0.05	0.06
	Autumn	6	5	0.00	0.00
2008	Winter	5	6	0.00	0.00
	Spring	5	6	0.00	0.00

WTP: Water treatment plant

concentration of turbidity in water can cause the lower rate of inter particle contacts, and this can limit the effectiveness of coagulation in water treatment plants.[4]

High level of nitrate from 2002 to 2005 [Table 2] in comparison to other years may originate from overland runoff from riverine agricultural fields where irrigated horticultural crops are grown and the use of inorganic fertilizers (usually as ammonium nitrate) is rather frequent.[16]

Comparison of inlet and outlet of TDS, nitrate, and nitrite showed that the WTP has no effect on them, so if these parameters in raw water are to be higher than the standard values, they can be a problem for this WTP. In this regard, emergency schemes can be considered for modification of these parameters when they exceed the standards. For example some processes including biological denitrification, ion exchange, chemical denitrification, electro-dialysis, and reverse osmosis, can remove nitrates and nitrite from water.[10]

A similar work conducted in the Taiwan which showed that high turbidity water during some seasons is a challenge for the WTP.[16] Coagulation is recognized as the best process for solving this problem; however, the dispersion of coagulants in the high turbidity waters is a very difficult process. For application of this system, the effects of rapid mixing and operational parameters on the PACl coagulation of high turbidity water is investigated by Chikuan *et al*.[16]

The efficiency of nanofiltration/reverse osmosis hybrid facilities is comparable to an ion exchange plant for TDS removal.[17] So in the investigated WTP these systems can be an appropriate alternatives for reduction of TDS. In the case of application these systems, nitrate removal can take place simultaneously with TDS removal.[17]

Unlike this study that pH was in the alkaline ranges in all seasons, the study of Efe *et al*., in 2005[18] which conducted in western Niger delta region, Nigeria, showed the pH of the water resources to be acidic with pH values below 5.50 at all of study period. They investigated seasonal variations of physico-chemical characteristics of three water resources and reported maximum and minimum concentrations of the water quality parameters. They reported that the water quality parameters are either above or below the target water quality range for human usage, making the studied water resources a source of hazard for consumers.

According to previous studies, the pH of water resources is a very important factor which may affect the toxicity and solubility of metals in the distribution network system.[18] But in Parsabad WTP, these ranges of pH would not pose these problems. However, for determination of water corrosion potential some indexes should be used.

Although this study showed almost all parameters of this WTP are not exceeding the standards, other potential problems of Parsabad WTP including trace elements, heavy metals and other chemical characteristics should be investigated in the future studies.

This study showed that a common WTP with rapid sand filtration can treat a maximum river turbidity of 700 NTU in a long time period of 8 years. But no differences between inlet and outlet of TDS, Nitrate, nitrite and pH were observed in the studied WTP. Therefore, it can be concluded that compensatory schemes should be predicted for modification of these parameters when they exceed the standards in the emergency situation.

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Source of Support: Isfahan University of Medical Sciences, **Conflict of Interest:** None declared.