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SENSITIVITY ANALYSIS OF WASTEWATER FLOW QUALITY IN A CHANNEL UNDER THE INFLUENCE OF HYDRAULIC RETENTION TIME VARIATIONS

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A B S T R A C T

Urgent water supply issues coupled with environmental factors have resulted in a greater focus on treating waste water effluent. As technological treatment is costly, the use of naturally-purifying systems is significant. In this study, the sensitive analysis of flow quality under the influence of Hydraulic Retention Time (HRT) variations has been carried out using the numerical model of Q2K. The study is conducted in the proposed 10 km concrete open channel for transmission of sewage from Mashhad city to Parkand-Abad wastewater treatment plant (WWTP), Iran. Results show that after 12 hr from entering flow to the channel, Dissolved Oxygen (DO) concentrations increase with rising HRT along the transmit channel. However, BOD, Organic Nitrogen (NO), Total Coliform (Tcoli), Organic Phosphorous (PO), Particle Organic Matter (POM), Total Suspended Solids (TSS) and Total Organic Carbon (TOC) was reduced by 70%, 35%, 35%, 35%, 80%, 85%, 15%, 10% and 80% respectively. Likewise, when HRT becomes greater; NO_3, PH and NH_4increased which means greater HRTs in aerobic processes have undesirable influence on NO_3 and NH_4 indexes concentration. As well, the numerical outcomes are in conformity to experimental data.

1.0 Introduction

Treatment of sewage is very important in that it addresses both the issues of reusability of the effluent as well as the protection of the environment. To this end, numerous wastewater treatment plants (WWTPs) were constructed all over the world. However, untreated sewage may be released directly into natural water bodies due to a variety of reasons, among them electricity cuts to the WWTPs (Goel, 2006). In such cases, the self-purification capacity of the stream or river is depended on to assimilate and render the contaminants in the wastewater effluent harmless. One of the most important factor in refining and purifying contaminations in natural waters is the hydraulic retention time (HRT). Together with adequate nutrients and other determinants, sufficient HRT will enable the microorganisms in the water to reduce and eventually eliminate the contamination through natural biological processes.

One of the main components of dairy wastewaters is cheese whey (Sultana et al., 2015). Although different technologies have been used extensively in the past for cheese whey treatment, constructed wetlands (CWs) applications are limited. Furthermore, the effect of crucial operational parameters (e.g. temperature, pollutant loading rate) have not been thoroughly studied. Having this in mind, two horizontal subsurface flow pilot-scale CW units (one planted and one unplanted) were used to treat secondary cheese whey, in order to examine the effect of different chemical oxygen demand (COD) influent concentrations (1200 to 7200 mg /L), hydraulic

residence times (8, 4, 2 and 1 day) and temperature (2.4 to 32.9 °C). Constructed wetlands could successfully treat secondary cheese whey and provide COD effluent concentrations below EU legislation, when hydraulic residence time is above 2 days and COD influent concentration ranges from 1200 to 3500 mg/L.

A bench scale of activated sludge reactor was operated as extended aeration system to treat actual wastewater that was collected daily from Eastern Treatment Plant at the south east of Alexandria and to study the effect of hydraulic retention time (Abbas et al., 2001). Samples were taken daily (grab & composite) at different hydraulic retention time (modes) of 18, 12, 6.18, and 3.37 hours respectively with fixed recycle ratio (100%). COD, biochemical oxygen demand (BOD), supended solids (SS), sludge volume index (SVI) and food to microorganism (F/M) ratio were determined during the experimental work. The experimental results showed that increasing the HRT caused slight increase in the removal efficiency of COD and BOD. The quality of the effluent from bench scale activated sludge with extended aeration is within the limits reported in the Egyptian Environmental Requirements.

HRT variations influence flow quality (Villa Gomez et al., 2015). Retention tanks (RTs) are commonly used to reduce combined sewer overflows, management of which is an important way of reducing the impacts of urban development on receiving waters. A new insight in the settling processes and the pollutant behavior occurring in an off-line RT was reported by Maruéjouls et al. (2013). The authors' first focused on the total suspended solids (TSS) and the total COD dynamics at the inlet as well as the outlet of a RT. Secondly, they focus on the possible relationship between the variation of the particle settling velocity distribution of particles and the TSS concentration dynamics. Finally, analyses of the TSS and COD concentration evolution during tank emptying give information on the interaction between wastewater retention time and the settling performance. Numerical simulations on chemical processes have been monitored by different investigators (G, 2012; Misra et al., 2006). Khorasani and Fereidoun (2013) have used the Q2K mathematical model to assess the water quality of Qareso River, Iran. They have found strong correlation between the results of numerical modeling with experiment data. They also showed that Q2K is capable of predicting the effects of environmental parameters on pollution purification. According to Petrescu et al. (2011) the Olt River is exposed to the inlet of Covasna effluent in Romania. In order to reach desirable water quality, the pollution modeling in this river was carried out using Q2E software. The results showed that the best method is a three-pronged approach controlling environmental input, monitoring water quality and assessment modeling done contemporaneously. The Q2E water quality model was analyzed and calibrated using a series of field measurements of real data in extreme high temperature conditions (Drolc andKončan, 1999). The model was used to estimate the effect of discharging domestic and industrial wastewater on DO concentration in Covasna. The results showed that in order to conform to the standards of Slovenia, BOD concentration should be less than 30 milligrams per liter before releasing to the river.

Choosing an appropriate HRT has always been one of the main considerations among researchers. But rare research can be found to investigate the effect of HRT variations on flow quality in streams. The primary hypotheses in this research that the HRT is under the influence of slope variations and flow hydraulic characters. The Q2K was used to analyse the quality of wastewater under the HRT variations. Other than that, the experimental data was compared with numerical results and Q2K capability of simulating natural phenomenon will be considered.

2.0 Material and Methods

2.1 Q2K model

Q2K has been designed by Tufts University in the United States (U.S.) to simulate rivers and streams water quality (Chapra et al., 2008). One-dimensional modeling is performed in steady state hydraulics by Q2K. It uses three equations to calculate depth, flow, and velocity, all which include the Manning equation, weirs and rating curves. Q2K accommodates anoxia by reducing oxidation reactions to zero at low oxygen levels. In addition, de-nitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations. Q2K applies K_2 variations on flow quality.

2.2 Data

Software function validation is applied by experimental data. Experimental data was recorded in an almost 60 km channel near the Parkand Abad WWTP. The necessary data for municipal modeling were collected from the Parkand Abad WWTP, Mashhad, Iran. Table 1 presents inlet flow quality of the channel. The model presents a concrete open channel with rectangular shape where channel width (B) is 5 m, channel slope (S) is 2% and complete oxidation appears gradually on flow quality (Chapra et

al., 2008). In order to performsensitive analysis of flow quality under HRT variations effect, simulation was performed in a channel with length of 10 km.

Table 1: The initial flow quality indicators obtained from Parkand Abad WWTP.

Chemical	Metakaolin
BOD (mg/L)	417
COD (mg/L)	786
NO3 (mg/L)	6.1
Organic P (mg/L)	6.18
PH	7.7
Coliform (cfu/100 mL)	1500
TKN(mg/L)	97.0
TN(mg/L)	95.5

Parkand Abad WWTP is located at longitude 59.57 and latitude 36.44. There is no input or output flow along the channel. According to Kannel et al. (2007) the channel length was divided into equal segments of 500 m length (20 segments). Flow temperature is 23°C and atmospheric temperature is applied on the first summer's day during the 24 hours. Temperature used for modeling is presented in Table 2.

Table 2: Temperature data.

T (°c)	Time (hr)
25.3	0.00
29.2	3:00
35.4	6:00
38.8	9:00
43.2	12:00
39.8	15:00
33.2	18:00
28.8	21:00

The chemical reactions were simulated in the model through the course of five days. In the end, the contaminations index was calculated with interpolation from the resulting values at the end of the each day. The solution method to estimate pH and its reaction come from Brent and RungeKutta, respectively (Chapra andCanale, 1998). The amount of solar radiation in WWTP's surroundings is presented in Table 3. The Manning Equation was applied to evaluate hydraulic characteristics. The wind speed was 2 m/s and the cloud cover was set to zero. It is assumed when the flow is released for the first time into the channel that the initial flow quality conditions at standpoint were not defined and therefore not included in the studies.

Table 3: Daily Solar Radiation (NOAA, 2013).

Time (hr)	Solar radiation (w/m)
6.00	0.0
7.00	11.2
9.00	258
11.00	525
13.00	625
15.00	571
17.00	330
19.00	51
20.00	0.0

3.0Results and Discussion

Sensitive analysis of flow quality influences the HRT variations. One of the most effective parameters in biological processes is HRT, in which by increasing HRT the purification of pollutions is improved. Figure 1 shows DO variations, BOD and COD removal percentage in different HRT. The experimental data is presented by index of exp in the flow quality factor obtained by Parkand Abad WWTP laboratory.

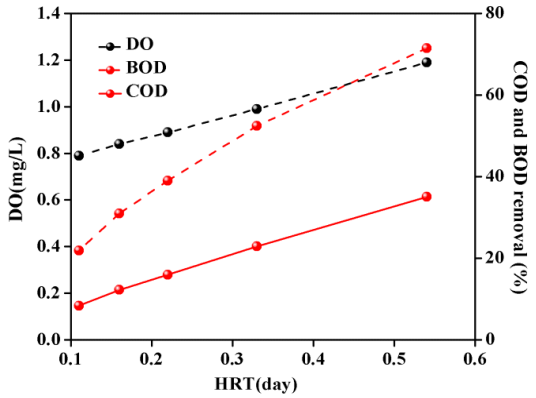

Figure 1: Variations of DO, BOD and COD removal percentage with HRT.

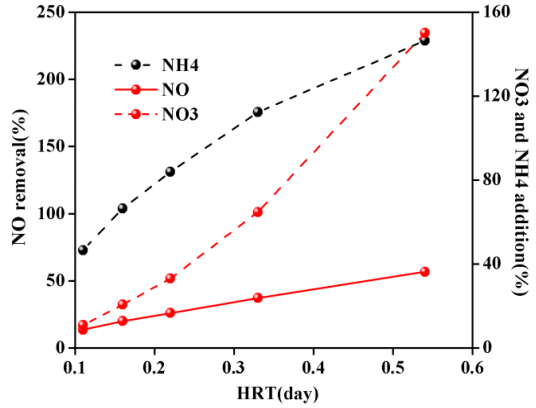

Figure 2: Variation of NO, NO_3 and NH_4 with HRT.

It is evident that there is a linear and positive relationship between DO and HRT. Hence, by

increasing HRT along the channel, the DO concentrations is increased with almost linear trend. Likewise, BOD and COD values are increased with increasing HRTs (see Figure. 1). It is observed that after 12 hours, BOD and COD have decreased 35% and 70%, respectively. Assessment of the behavior shows that increasing both Oxygen and HRT removes half of pollutions simultaneously in a short period of time. Figure 2 demonstrates Organic Nitrogen (NO) removal percentage and addition percentage of the Nitrate (NO_3) and ammonium (NH_4) at different HRTs.

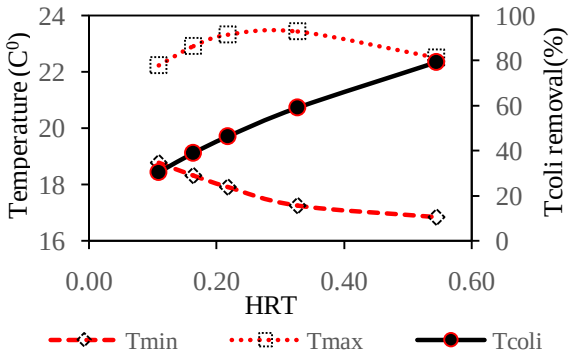

Figure 3: Temperature and Tcoli in HRTs

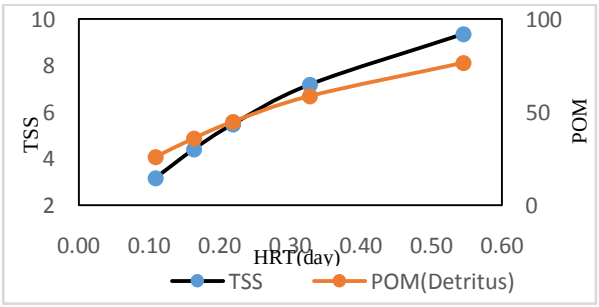

Figure 4: TSS and POM in HRTs

It shows that the more HRT increase the more phosphorus (PO) decreases; and PO variations are remarkable in 12 hours, which removes 85 percent. One of the influential flow quality parameters is PO in purifying contamination and feeding microorganism (Chapra et al., 2008). Assessment of the behavior shows that passing HRTs and nutrients presenting in flow can remove pollutions. Figure 3 removal percent of total organic carbon (TOC) and pH displays in HRTs. The three indexes TOC, pH and electrical conductivity (EC) influences each other (Chapra et al., 2008). According Figure 3, by increasing HRTs, TOC is decreased but pH is increased. Figure 4 shows TSS and particulate organic matter (POM) in different HRTs. It demonstrated the negative effects of increasing HRTs on POM and TSS. According to this study, the total organic matter was almost consumed in 12 hours.

4.0 Conclusion

In this study, sensitivity of wastewater quality under the influence of HRT variations was analyzed using Q2K numerical model. Simulation was performed using six different HRTs. Results showed that there is a positive and linear relationship between DO concentration and HRT in which by increasing the HRT the DO was also increased. Likewise, at 12 hours, BOD, COD, NO, Tcoli, PO, POM, TSS and TOC were reduced by 70%, 35%, 35%, 80%, 85%, 15%, 10% and 80%, respectively. Similarly, NO_3 and NH_4 values were increased by increasing HRTs at the rate of 150% and 200% respectively which demonstrates the undesirable effect of HRTs on the NO_3 and NH_4 in aerobic processes. In addition, it was found that HRT increased with increasing channel length. The study effectively showed the capability of numerical models such as Q2K in simulation of the interaction between the physical properties of the sewage quality and biological and chemical subsequences. It is highly suitable for design purpose to reduce the risk of unsuccessful design and implementation of the wastewater infrastructures.

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