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Evaluation the Correlation between Turbidity and Total Suspended Solids with other Chemical Parameters in Yazd Wastewater Treatment Effluent Plant

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ABSTRACT

Introduction: Expensive chemical tests are usually applied to control the efficiency of wastewater treatment plants. However, the cost of measuring these parameters is one of the challenges of the wastewater treatment plants. Using statistical methods has been evaluated for possibility of calculating expensive parameters by measuring the inexpensive parameters in this study.

Materials and Methods: Initial sample number in this study was 87 cases that were collected from SBR effluent treatment plants of Yazd as a routine sampling for two years in March 2013 to March 2015. Total suspended solids (TSS) and turbidity parameters were defined as independent variables and twelve parameters including BOD_5, COD, TKN, NH_3^+, NO_3^-, NO_2^-, TP, TH, Ca^{2+}, Mn^{2+}, alkalinity, and color were the dependent variables. Spearman test was used to investigate the significant relationship between independent and dependent variables. Linear regression analysis was used to determine the linear equation between TSS and turbidity as independent variables with BOD_5, COD, TKN, NH_3^-, NO_2^-, TP and color as dependent variables.

Results: The results of the regression equations in relation to turbidity and TSS with independent variables showed that the R value for color, TKN, NH_3^+, BOD_5, COD, TP, and NO_2^- were 0.942 , 0.931 , 0.91 , 0.905 , 0.874 , 0. 872 and 0.86 respectively from the highest to the lowest.

Conclusion: The measured values of BOD_5, COD, TKN, TP, NO_2^-, NH_3^+, and color in laboratory were very close to those predicted through regression equations. Therefore, regression equations created in this study can be used to calculate expensive parameters.

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Introduction

Advanced biological treatment system of sequencing batch reactor (SBR) is the intermittent cycle extended aeration (ICEAS) used for secondary purification of Yazd wastewater. Four phases are defined in ICEAS discontinuous treatment cycles, but it is actually a three-phase cycle: aeration, sedimentation and discharge. This is because of the fact that the inflow enters into the treatment phase at all phases of purification. Moreover, during the sedimentation phase, a complete standstill does not occur. In order to control the performance of the treatment plant and also determine the quality of the effluent and compare the findings with the standards on a daily, weekly and monthly basis, some parameters such as BOD_5, TSS, COD, TKN, NO_3^-, NO_2^-, NH_3^+, total phosphorus (TP), fecal coliform (FC), color, and opacity are measured. The cost of measuring these parameters is considered to be a challenge, because on the one hand besides the use of expensive chemicals, foreign-made equipment is mainly used for purification, and this increases the cost of wastewater treatment. On the other hand, the only way to control the performance of biological wastewater treatment systems, to ensure the acceptable quality of effluent, is to measure physical and chemical parameters of the wastewater [1]. Controlling the physical and chemical parameters of effluent must be in a manner to consider all financial issues and national, regional, and international standards to guarantee wastewater disposal [2, 3]. Although, to ensure implementation of the effluent quality with the standards, numerous experiments should be conducted the rationality of the expenses must always be taken into account during the controlling stage. Some countries or local governments, regardless of the cost or the need for measuring one or more parameters, by mimicking some instructions, pay some unnecessary expenses. However, in many cases, depending on the use of the effluent and by applying the appropriate technical issues, some control measures such as unnecessary experiments can be omitted to reduce the current costs [4, 5]. In a similar study, it was revealed that there was a statistically significant relationship between some parameters of the wastewater such as the microbial mass, the total amount of phosphorus produced in the stabilization pound, opacity, and TSS. In fact, the increase in opacity and TSS results in some increases in the total amount of phosphorus produced in the stabilization pound [6]. The results of an overview study exploring the wastewater treatment plants in Australia, Belgium, Denmark, France and the Netherlands showed that there are significant ratios between many wastewater parameters such as the average BOD_5 / COD = 0.4, TSS / COD = 0.5, N / COD = 0.1, SS / BOD_5 = 0.25, and P / COD = 0.016. Moreover, it is worth mentioning that, for some of these ratios, there is no known reason, currently [7]. As already mentioned, numerous chemical experiments are conducted on the effluent coming from an SBR wastewater treatment plant in Yazd and running a large number of these experiments need expensive and advanced equipment. This research, which is a correlational applied research study, explores the formulaic relationship between opacity and TSS parameters that are simple and cheap to measure, and expensive parameters, which are measured at the output of wastewater treatment plant in Yazd. These analyses are done to check the possibility of estimating expensive parameters by measuring cheap parameters using some statistical methods.

Materials and Methods

This research was a descriptive and retrospective correlational study. The initial samples included in this study consisted of all test results for 87 samples that were collected routinely for two years (ranged from March 2013 to March 2015) from the effluent of SBR treatment plants of waste water company in Yazd. Tests conducted on these samples included TSS, BOD_5, COD, TKN, NH_3^+, NO_3^-, NO_2^-, TP, Ca^{2+}, Mn^{2+}, alkalinity, color and tests conducted in the laboratory of the water treatment plant, using the Standard Testing Method. First of all, in order to remove the numbers with a large standard deviation from the mean scores in regression equations, the samples were tested using the standard deviation test in Excel software. The samples with one or more abnormal parameters were omitted. Therefore, in this stage, 17 samples were omitted and 70 samples were left to continue the process. 46 samples of the remaining samples (65%) were employed to conduct statistical regression tests, and 24 samples (35%) were used to compare the laboratory results of the samples with the results (forecasts) obtained by regression tests. For statistical analysis, SPSS software version 17 was used.

Spearman correlation coefficient test

Firstly, in this study, both Pearson and Spearman correlation coefficient tests were applied in the form of a pre-test. The results of these two tests showed no significant difference, but because the number of samples in this study was relatively small, then the

Spearman correlation coefficient was used. At this point, TSS and opacity parameters were defined as independent variables, and the parameters such as BOD_5, COD, TKN, NH_3^+, NO_3^-, NO_2^-, TP, TH, Ca^{2+}, Mn^{2+}, alkalinity, and colors were considered to be dependent variables. The correlation coefficient was equal to or more than 60% ($R \geq 60.0$) and the *p*-value was less than or equal to 0.01 and they were considered the necessary conditions for identifying any relationship between independent and dependent variables. In the current study, the relationship among each of the dependent variables was examined regarding to two independent variables. If either of the two above mentioned conditions was not established for the relation between the dependent variable and one or both independent variables, the hypothesis for the significance of the relation between the dependent variable and both independent variables would be rejected. Therefore, the dependent variables were omitted and would not be used any more in the future. In this study, the significant relationship between five dependent variables (NO_3, TH, Ca^{2+}, Mn^{2+}, and alkalinity) and two independent variables (TSS and opacity) were rejected. While, the hypothesis of the significant relationship between seven other dependent variables (BOD_5 ،COD ،TKN ، NH_3^+ ،NO_2^- ،TP, and color) and two independent variables (TSS and opacity) were approved. In a study, in order to optimize the biological reactor with MBBR Moving Bed, variance, and standard deviation statistical tests have been used to normalize the data to be used for Takeuchi method [8]. In another study, the regression analysis was used to establish a connection between the total amounts of coliform and BOD_5 [9]. Yet, in another similar study, the regression mathematical model was applied to simulate the mass of produced sludge and the effects of some parameters such as the amount of DO, BOD_5 and COD on the quantity of the sludge produced in the conventional activated sludge process [10].

Linear regression equations

The results obtained from the experiments ran for the 46 samples (65% of the total accepted samples) were used in SPSS software to conduct linear regression analysis. In order to determine the regression equation between two independent variables (TSS and opacity) and dependent variables, the Spearman correlation coefficient was used to determine the significance of the relationship. At this stage, a regression equation was used for each of the dependent variables. Through each of these equations, the levels of each of the dependent variables could be calculated by applying fixed values and the coefficients of the two independent variables (TSS and opacity).

Checking the results of the regression equations

To answer the question of to what extent the results of the regression equations were consistent with the actual measured values, regression equations were used for each of the accepted dependent variables, BOD_5, COD, TKN, NH_3^+, NO_2^-, TP, and colors. And by applying TSS and opacity values of the remaining 24 samples in these equations, the values of each of the dependent variables were calculated for the 24 mentioned samples. Then, in order to show the accuracy of regression equations' results, the values of each of the dependent variables calculated through regressions were compared with real testing values in Excel, and they were shown in a graph.

Results

Table 1 shows the *p*-values and the correlation coefficient between independent variables, TSS and opacity, and 12 dependent variables using the Spearman test to check the assumed significance of the relationship between the dependent and independent variables. The correlation coefficient between two independent variables (opacity and TSS) and NO_3^-, TH, Ca^{2+}, Mn^{2+}, and alkalinity is less than 0.06. This values higher than 0.06 for the dependent variables such as BOD_5, COD, TKN, NH_3^+, NO_2^-, TP, and color. The *p*-value for the relationship between the independent variable TSS and TH, Ca^{2+}, Mn^{2+}, and alkalinity is higher than 0.01; however, this value is equal to or less than 0.01 for other related parameters. The *p*-value for the relationship between the independent variable opacity and TH, Ca^{2+}, Mn^{2+}, NO_3^-, and alkalinity is higher than 0.01; while,, this value is equal to or less than 0.01 for dependent variables such as

BOD_5, COD, TKN, NH_3^+, NO_2^-, TP. Thus, both conditions are established for the dependent variables BOD_5, COD, TKN, NH_3^+, NO_2^-, TP and color. Whereas, at least one of these two conditions is not established for variables Ca^{2+}, Mn^{2+}, TH, NO_3^-, and alkalinity.

Table 1: *p*-values and the correlation coefficient between independent variables, TSS and opacity, and 12 dependent variables using the Spearman test to check the assumed significance of the relationship between the dependent and independent variables.

	Dependent variables / Independent variables	BOD_5	COD	TKN	NH_3	NO_3	NO_2	TP	TH	Ca^{2+}	MN^{2+}	Alkalinity	Color
TSS	p-value	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.06	0.02	0.18	0.2	≤ 0.01
	Correlation	0.92	0.92	0.89	0.82	0.56	0.83	0.71	0.91	0.48	0.38	0.38	0.93
Opacity	p-value	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.2	≤ 0.01	≤ 0.01	0.15	0.05	0.07	0.1	≤ 0.01
	Correlation	0.69	0.61	0.70	0.67	0.34	0.69	0.69	0.45	0.59	0.38	0.34	0.76
	Results	accepted	accepted	accepted	accepted	rejected	accepted	accepted	rejected	rejected	rejected	rejected	accepted

Conditions for the acceptance or rejection of the significant correlations between the dependent and independent variables were determined as *p*-value ≤ 0.01 and R ≤ 0.06.

The linear regression equation between the independent variables, TSS and opacity, and the accepted dependent variables, color, TKN, NH_3^+, BOD_5, COD TP, NO_2^-, is listed in table 2. Moreover, the R and *p*-values are given. R values from the highest to lowest amount for color, COD, BOD_5, NH_3^+, TKN, NO_2^-, and TP are respectively as 0.94, 0.93, 0.91, 0.91, 0.87, 0.87, and 0.86.

Table 2: Regression equations for the relationship between independent variables, opacity and TSS, and the dependent variables

Dependent variables	Regression equation	R	p-values
BOD_5	BOD = 5.38 + 0.74TSS + 0.26NTU	0.91	**≤ 0.01**
COD	COD = 32.43 + 1.79TSS - 0.42NTU	0.87	**≤ 0.01**
TKN	TKN = 2.69 + 0.39TSS + 0.04NTU	0.93	**≤ 0.01**
NH_3^+	NH3 = - 0.09 + 0.16TSS + 0.05NTU	0.91	**≤ 0.01**
NO_2^-	NO2 = - 1.04 + 0.08TSS + 0.06NTU	0.87	**≤ 0.01**
TP	TP = 0.96 + 4.96TSS + 0.04NTU	0.86	**≤ 0.01**
Color	Color = 8.24 + 4.96TSS + 0.04NTU	0.94	**≤ 0.01**

To demonstrate the difference between the actual amounts and the calculated values through regression equation, the remaining 24 samples were used for the comparison between the values obtained through regression equations for each accepted dependent variable such as color, TKN, NH_3, BOD_5, COD, TP, NO_2 and the actual values measured in the laboratory. The results are illustrated in figures 1 a to 5.

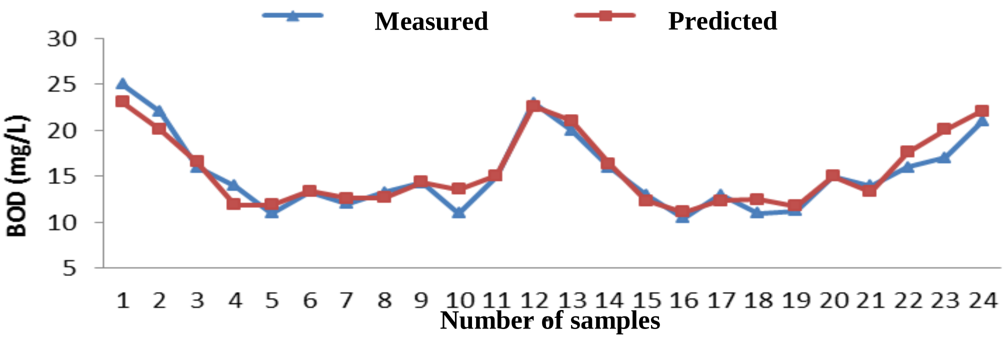

Figure 1a: The comparison between BOD_5 values calculated by the regression equation and actual values measured in samples

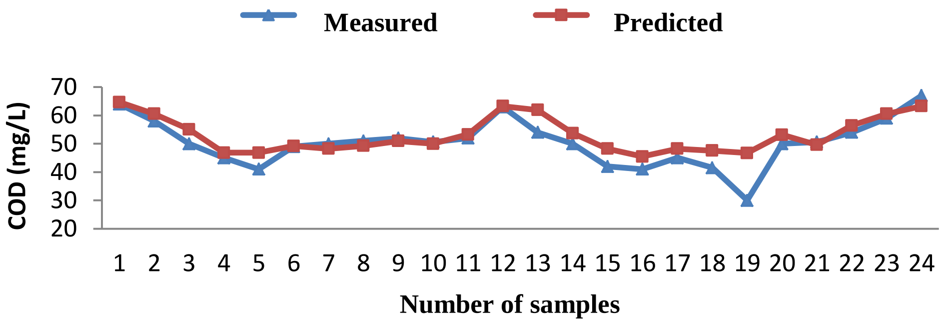

Figure 1b: The comparison between COD values calculated by the regression equation and actual values measured in samples

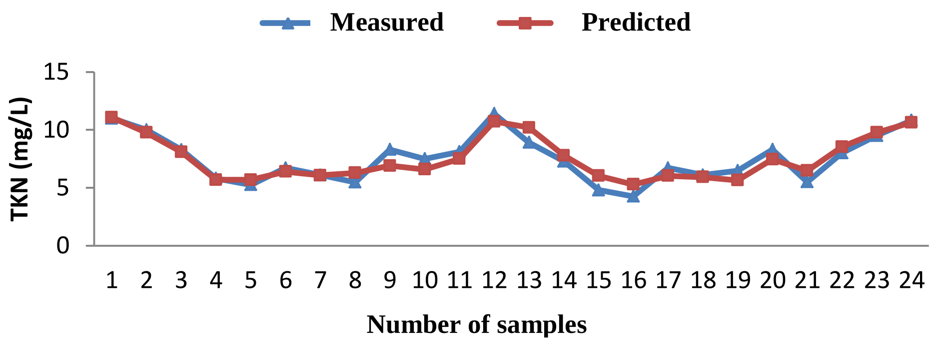

Figure 2a: The comparison between TKN values calculated by the regression equation and actual values measured in samples

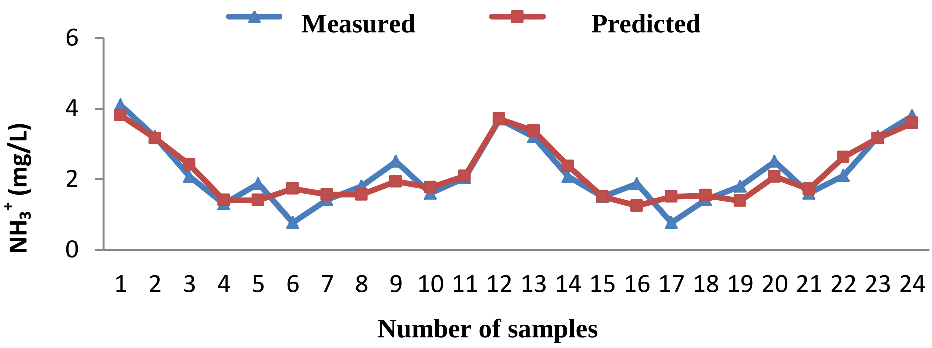

Figure 2b: The comparison between NH_3 values calculated by the regression equation and actual values measured in samples

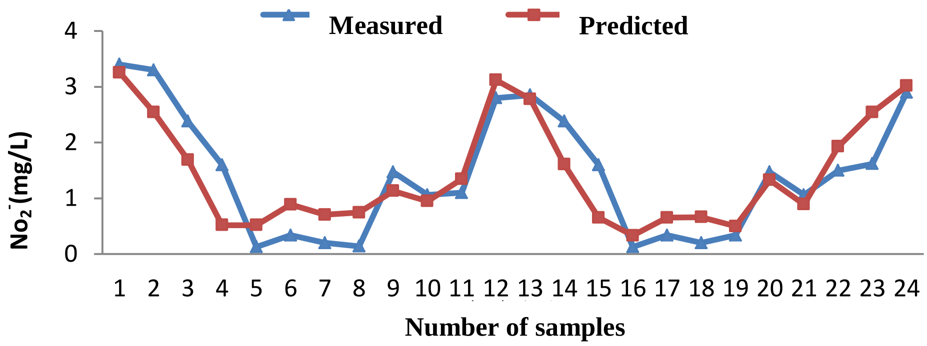

Figure 3: The comparison between NO_2 values calculated by the regression equation and actual values measured in samples

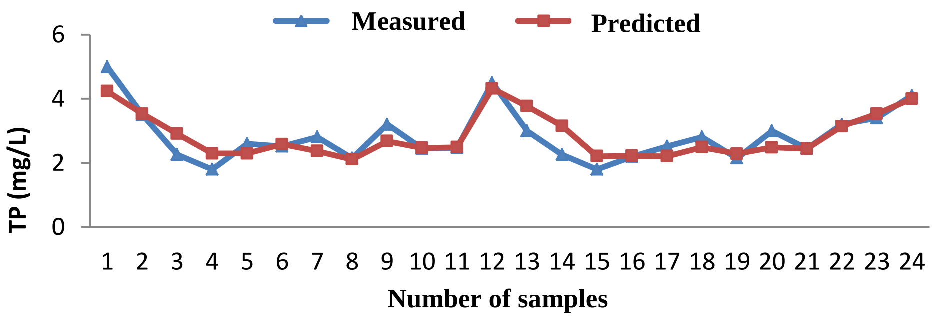

Figure 4: The comparison between TP values calculated by the regression equation and actual values measured in samples

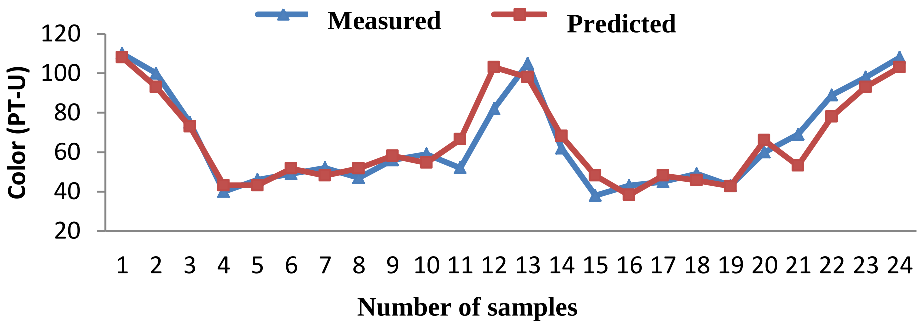

Figure 5: The comparison between color values calculated by the regression equation and actual values measured in samples

Discussion

None of the two set conditions had been violated, p-value ≤ 0.01 and $R \leq 0.06$, for the relations among the independent variables, TSS and opacity, and the variables COD, TKN, NO_2^-, NH_3^+, TP, and color. Therefore, these variables were considered as accepted dependent variables. Variables such as NO_3^-, TP, Ca^{2+}, Mn^{2+}, and alkalinity that violated at least one of the two conditions were considered as rejected variables. The results of table 1 indicate that the highest correlation coefficient between the independent variable TSS and dependent variables, color, BOD_5 and COD are 0.93, 0.92, and 0.92, respectively. The highest correlation coefficient between the independent variable opacity and dependent variables, color, TKN, BOD_5 are 0.76, 0.70, and 0.69, respectively. A similar study conducted on the effluent of the activated sludge process showed that R values were 0.71 and 0.79 and p-values, in both cases, was less than 0.001 for the relation between the independent variable TSS and variables BOD_5 and COD [8]. The results in table 2 represent that, in the regression equations, the highest correlation coefficients are related to the relation between the two independent variables and dependent variables such as color and TKN (0.94 and 0.93, respectively). The lowest correlation coefficient is related to the relation between the two independent variables and the dependent variables TP, which is just 0.860. In all cases, R values are positive; which means that increase in density of TSS and opacity can increase the density of seven accepted dependent variables seven and vice versa. In all regression equations except the regression equation of the TP, coefficient of TSS is more than an opacity factor, indicating that the role of TSS in changing the density of the examined independent variables in this study is more than opacity. Comparing the coefficients of the regression equations in this table revealed that the share of TSS density compared to that of opacity is, respectively, 8.2, 2.4, 9.8, 6.3 times more for BOD_5, COD, TKN, NH_3^+, NO_2^-, and color. The coefficient values for TSS and opacity, in the calculations of TP, are 0.076 and 0.159, respectively. This shows that the share of opacity in density of TP is twice as much as TSS. Different relations between the output parameters and their coefficients can be justified referring to the source material [11], according to which, there are various biosynthetic coefficients in different processes of biological wastewater treatment plant to remove various parameters in wastewater. Therefore, it leads to various removal efficiencies in different processes; as a result, there are a variety of different removal percentages for the parameters determining the pollution. Each parameter in the output may have different density, depending on the inlet density and biosynthetic coefficients of each parameter. Hence, inlet density, biosynthetic coefficient, type of the process, and environmental conditions create various shares between different parameters [11].

Conclusion

The effectiveness of biological systems, including the advanced SBR, for the removal of pollutants is lower in winter than summer. In samples 1, 2, 11, 12, 13, 23, and 24 the amount of output pollutants, was measured in the laboratory in winter, and it was higher than the ones in warm seasons. As it is observable in figures 1 to 5, the regression equations obtained in this study showed the changes in the examined parameters in cold and warm seasons very well. Therefore, it can be concluded that the regression equations derived from this study can predict the fluctuations of the pollutants very well. The research conducted to evaluate the performance and optimization methods of aerated lagoons in wastewater treatment plant in Bandar Gaz also showed that the efficacy of this biological method, just like the other biological methods, improved in May, June, and July. While, this efficacy decreased in cold months such as February and March [12]. Comparing the figures related to the measured amounts and predicted values, using regression values, in all 24 samples, revealed that the best harmony and correlation were related to variables, BOD_5, COD, and color. In fact, the difference between the measured values and the calculated values were very low and the fluctuations of the two figures were very harmonic and close together. The general conclusion of this research is depicted in figures 1a to 5. The graphs show that there is not much difference between the measured values of the parameter in the laboratory, and the predicted values by regression equations derived from this research. As illustrated in the figures, the diagrams have harmonic fluctuations. So, there is little difference between the actual density of the pollutants and the predicted values through regression equations. In other words, the measured values for BOD_5, COD, TKN, TP, NO_2^-, NH_3^+, and color were very close to the values predicted by the regression equation. Therefore, it is concluded that the regression equations of this research can be used instead of spending too much money for the ongoing examination of the seven parameters mentioned for the effluents of SBR process in Yazd. Hence, making it so simple and inexpensive to measure the parameters of TSS and opacity. These values can be applied in the regression equations for each of the parameters and their values can be calculated and predicted.

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Conflict of interest

We have no competing interests.

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