Photocatalytic degradation of azo dye using nanocomposite catalyst based on zinc oxide and zeolite

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Introduction

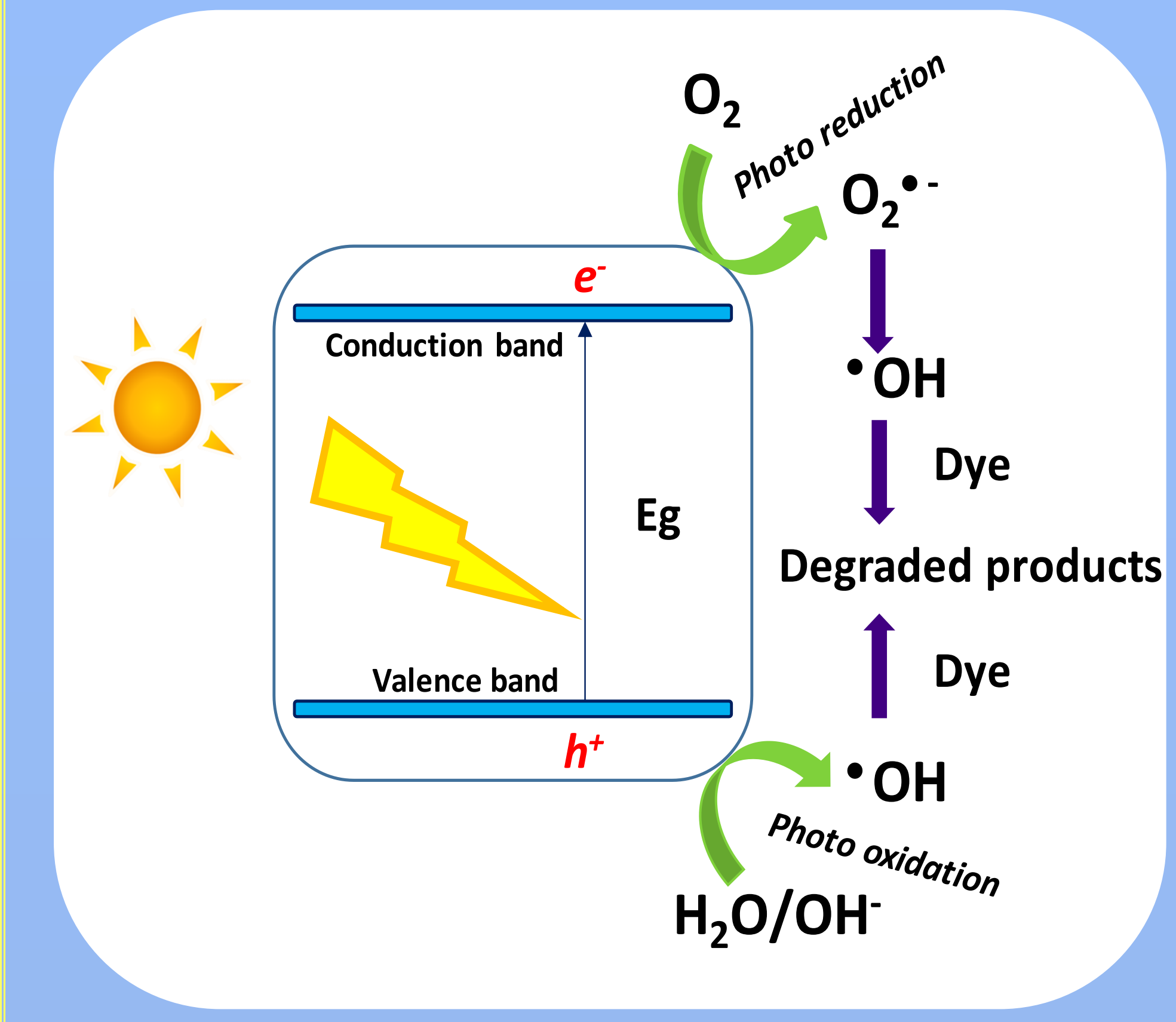

Figure 1: Photocatalytic mechanism

- Hundreds of new synthetic dyes are produced every year, which are used for various purposes.
- The textile industry is one of the biggest polluters of the environment, because it produces a large amount of dyed wastewater during its processes.
- Dyes can have acute or chronic effects on organisms, depending on the time of exposure and the concentration of the dye. They exhibit mutagenic, carcinogenic and teratogenic properties, and are therefore undesirable in the environment.
- As most of the conventional treatments, used of wastewater containing dyes, results in incomplete degradation, it is important to apply modern methods for removing dyes that could be based on natural or waste materials.
- In order to solve this problem, advanced oxidation processes (AOP) have been developed that serve to remove various types of specific pollutants.
- Heterogeneous photocatalysis is a promising process (Figure 1), as it combines the use of semiconductor materials, which are usually cheap and efficient photocatalysts and low-energy ultraviolet radiation.
- ZnO is a material that is successfully used in photocatalysis as a catalyst for extensive application is in the form of nanoparticles.
- In this paper, the possibility of Reactive Red 120 dye removal using a photocatalytic process was investigated, using ZnO/Zeolite nanocomposites as a catalyst.

Results & Discussion

- Statistical processing of the obtained results (Box-Behnken statistical analysis) of the Reactive Red 120 dye removal efficiency test using a photocatalytic process included a study of the influence of the main process factors and their interactions.

Table 1: Estimated regression coefficients (all interactions included)

Parameter	**Estimated value**	**Standard error**	***t* value**	**Probability> |t|**
Intercept	55.366667	2.343348	23.63	**<0.001***
Dye (mg/l)(20, 180)	-3.6375	1.435001	-2.53	0.0522
pH(3.10)	-18.325	1.435001	-12.77	**<0.001***
Catalyst (g/l)(0.02, .0.4)	8.5375	1.435001	5.95	**0.0019***
Dye (mg/l)*pH	-7.075	2.029399	-3.49	**0.0175***
Dye (mg/l)*Catalyst (g/l)	-4.5	2.029399	-2.22	0.0774
pH*Catalyst (g/l)	-1.275	2.029399	-0.63	0.5574
Dye (mg/l)*Dye (mg/l)	-1.258333	2.112265	-0.60	0.5773
pH*pH	9.4666667	2.112265	4.48	**0.0065***
Catalyst (g/l)*Catalyst (g/l)	-14.60833	2.112265	-6.92	**0.0010***

- The obtained results indicate that the achieved decolourization efficiency is in the range of 25 - 85.6%. Process efficiency depends on the relationship between process parameters. The highest process efficiency (85.6%) was obtained at pH 3, and the lowest process efficiency (25%) was obtained at pH 10.
- The adequacy of the adopted model was examined using diagnostic diagrams (Figures 2 and 3).
- Adequate approximation is confirmed by the diagnostic graph of the dependence of the real ones, ie. experimental values in relation to the predicted values of decolourization efficiency, which are in good correlation.

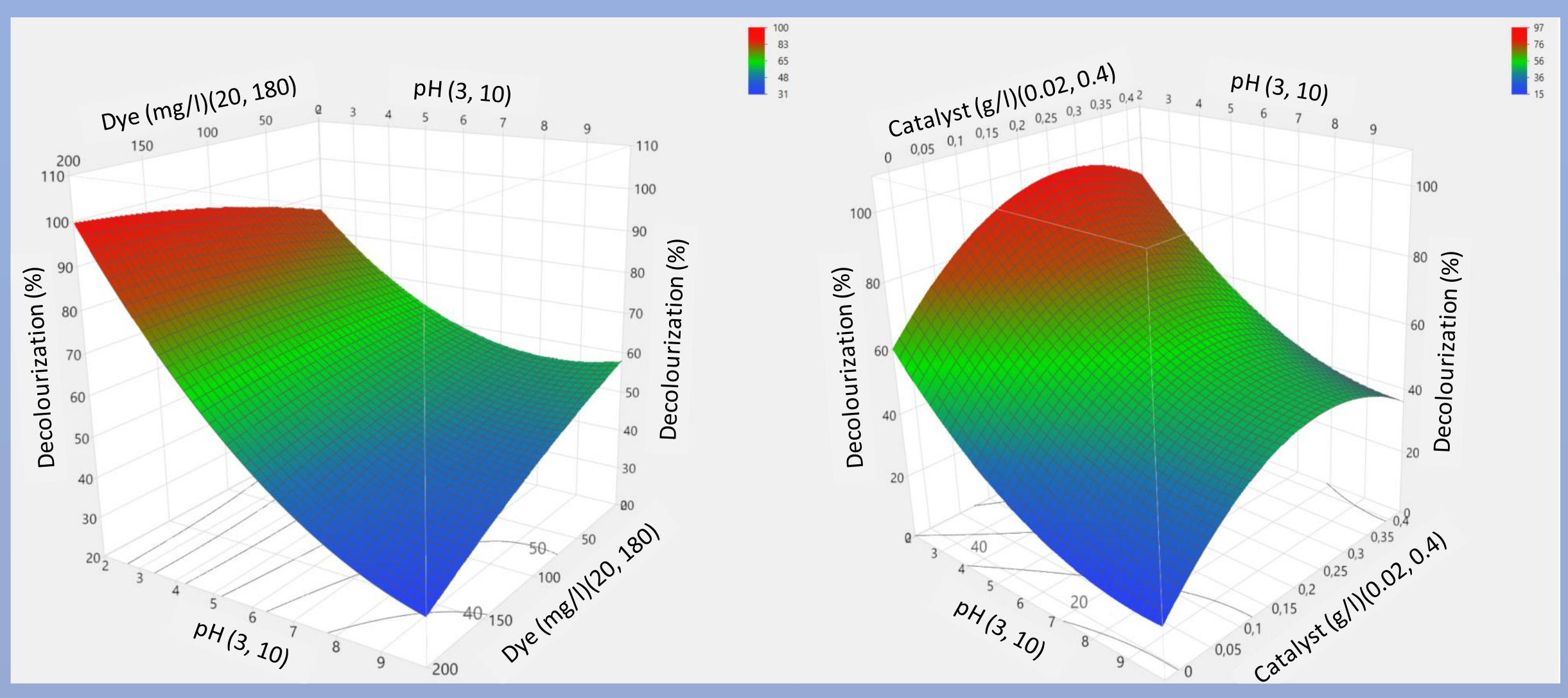

Figure 4: Diagram of the response surface of statistically significant interactions: catalyst mass and pH value

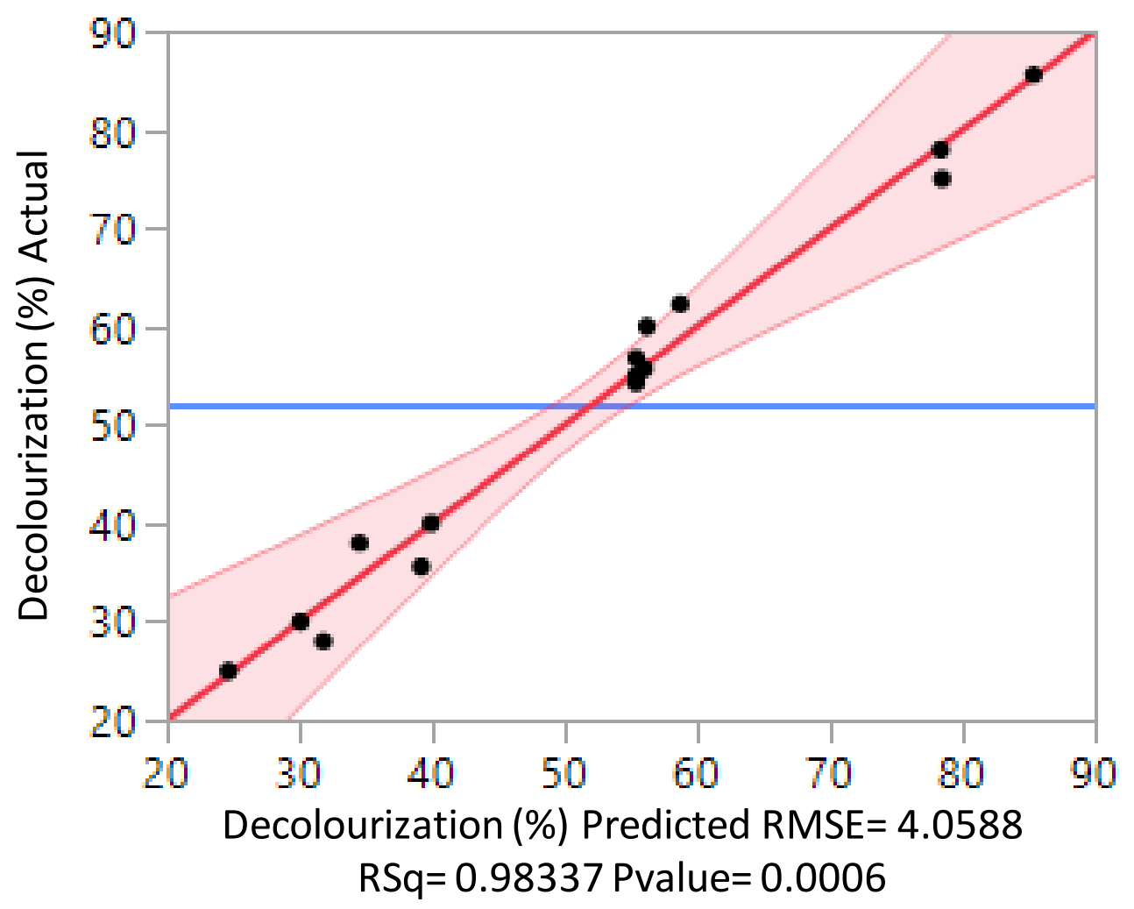

Figure 2: Diagram of the dependence of predicted and actual values

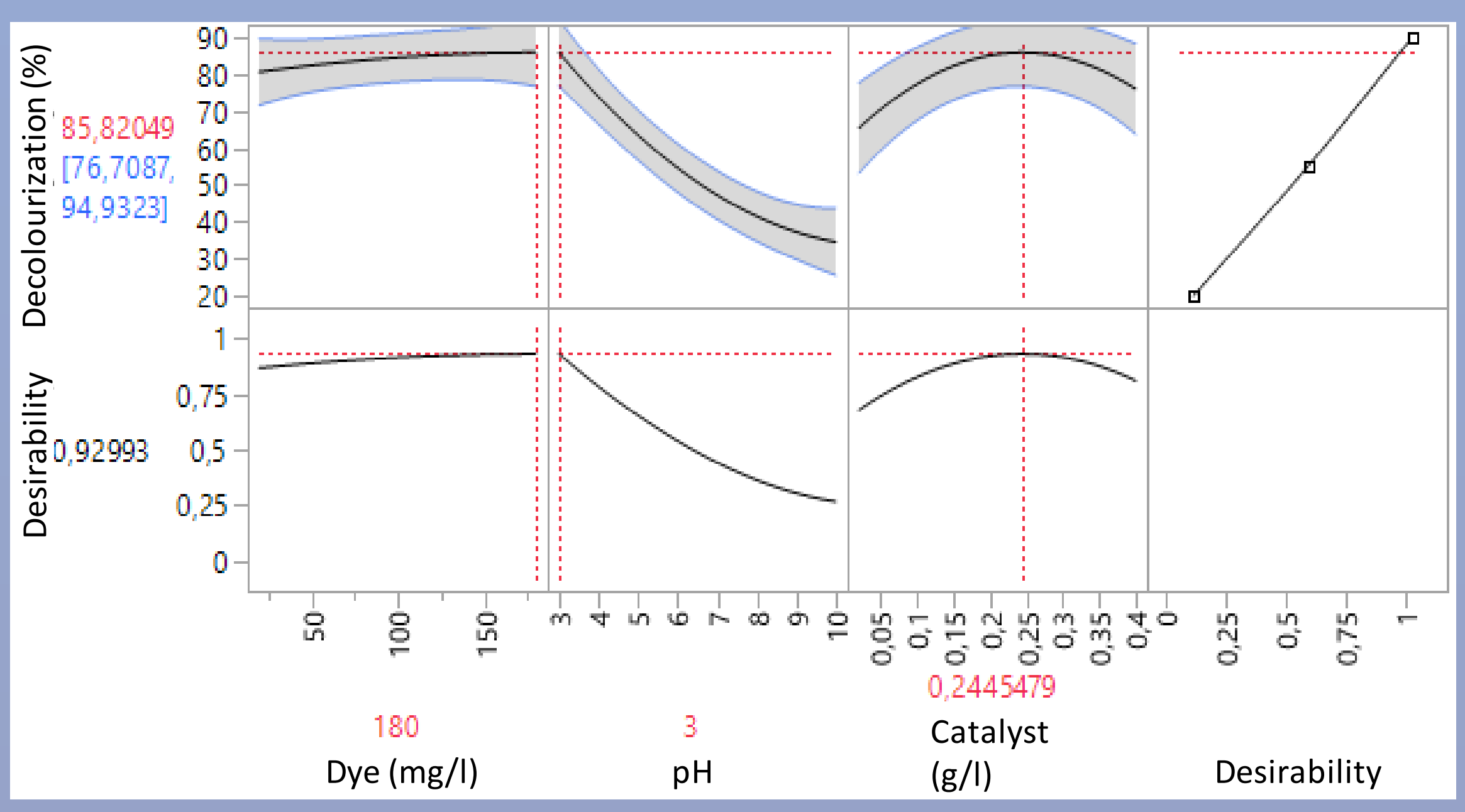

Figure 5: Photocatalytic process optimization diagram

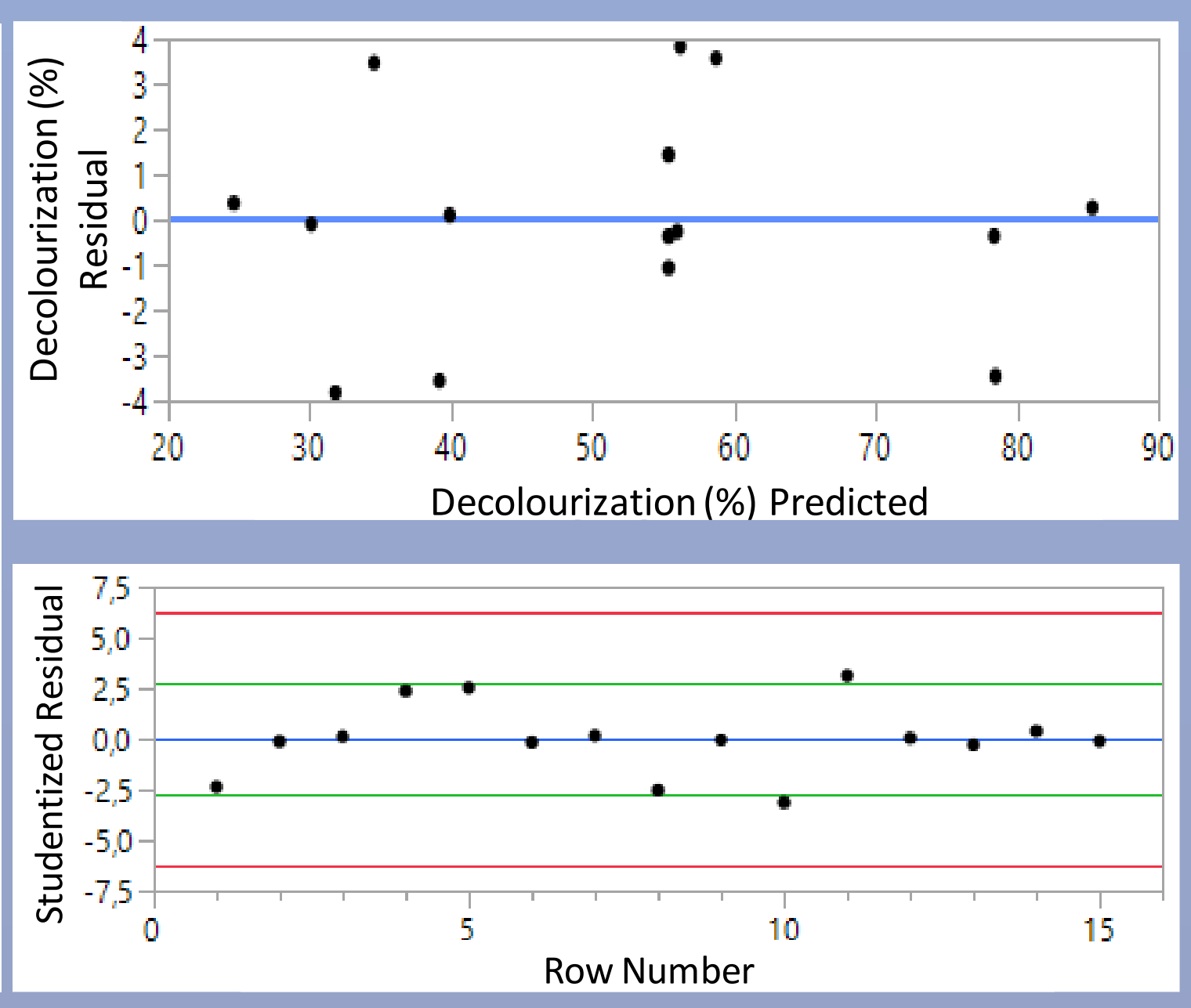

Figure 3: Deviation diagram of standardized residuals relative to the zero line + residuals

- From the diagram of deviations of standardized residuals in relation to the zero line, there is no tendency to scatter values, but the points are randomized in space, which means that the regression model describes the examined problem well.
- Based on the approximated parameter values and standard error, factors with statistical significance were singled out and shown in Table 1, which mostly contribute to the efficiency of dye removal in the photocatalytic process.
- It is noticed that the statistically significant parameters are the concentration of the dye and the mass of the catalyst, with a greater positive impact on the process of removing the dye is achieved by the concentration of the dye.
- Within the photocatalytic process, a statistically significant two-factor interaction was found, precisely between the dye concentration and the mass of the catalyst, which is shown in the response surface diagram (Figure 4).
- From the optimization diagram (Figure 5) evaluates the best dye removal capability under optimal process conditions of 89.33% at the lowest concentration of dye, but at the highest mass of catalyst at the longest reaction time.

Conclusions

- Based on research resultss, it was confirmed that individual parameters to some extent contribute to the efficiency of the photocatalytic process. At the lowest concentration of dye, and at the highest mass of catalyst (at the longest reaction time), statistical software suggests a decolourization efficiency of synthetic dye solution of ~89%.
- According to the obtained experimental data, it can be concluded that this type of catalyst has a great potential in photocatalytic reactions in order to decompose complex organic molecules.

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