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Study and modeling of dairy effluents treatment using design of experiments methodology

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ABSTRACT

This study focuses on the physico-chemical properties of the Moroccan dairy industrial unit in various locations of the facility between 2014 and 2015. Also to confirm the significant level of pollution caused by the different activities of this industrial unit. Using adsorption on commercial activated carbon, the treatment of the dairy effluent of the facility in terms of chemical oxygen demand (COD) removal, suspended solids, and conductivity decrease. The results show that the dairy effluent is loaded with the organic matter with an average COD of 3,500 mg/L, total Kjeldahl nitrogen (TKN) with an average TKN-N: 45.35 mg/L, the total suspended solids (TSS) value for the main discharge is 460.214 mg/L. Daily monitoring of this physico-chemical characterization in the plant reveals significant values that greatly exceed the permissible limits of the Moroccan standard. Using the experimental design software for the commercial activated carbon treatment model showing p-values for TSS (p-values = 0.0397) and for COD and conductivity, the p-values are greater than 0.05 p-values (COD = 0.1167; p-values) (conductivity = 0.152). Analysis of variance showed that the R-squared coefficients for COD, TSS, and conductivity, R^2 (COD) = 1, R^2 (TSS) = 1, and R^2 (conductivity) = 0.99, respectively. Because the coefficient values are close to 1. In addition, the best conditions for adsorption of dairy wastewater by commercial activated carbon are adsorbent dose = 10 g/L, pH = 10, and T = 40°C.

Keywords: Modeling; Dairy effluent; Physico-chemical; Treatment; Adsorption

1. Introduction

In recent years, Morocco has become a major producer and consumer of milk and its derivatives. According to the Moroccan Ministry of Agriculture and Rural Development, annual production is still increasing [1]. In addition, the waste from the dairy industry is not only an important loss of valuable organic sources but also a pollution problem for the environment [2,3]. However, the treatment of these residues is a major concern for the industry, which is subject to increasingly stringent regulations [4]. As a result, the elimination or treatment of effluents represents a significant part of the budget devoted to the environment. Indeed, the effluent discharged is rich in organic matter and bacteria in addition to the variability of its acidity [5,6]. During the processing of milk, various types of

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liquid wastes are produced, including wastewater from equipment and pipe cleaning, acid and sugar whey, cooling water, and domestic wastewater [7,8]. Dairy industries are the most consumers in terms of the amount and quality of water utilized among the food industries [9,10], they are also the most harmful to the environment and impact negatively the aquatic and human life because they use not only vast volumes of water, but they also reject great quantities of effluent that are rich in micro-organisms and organic matter [11–15]. In developing countries, such as Morocco, industrial effluents are poured into sanitation networks without any prior treatment due to the absence of an environmental policy and the lack of planning and disclosure of irresponsible practices [16,17]. Moroccan environmental regulations restrict the discharge of untreated urban and industrial liquid effluents into the natural environment [18,19]. As a result, treatment of this effluent is critical to protect the environment. Several approaches for treating effluents are often utilized, although the methodology used is mostly determined by the physico-chemical and biological characteristics of the discharges as well as the nature of the receiving environments [20,21]. The present study aims to determine the physico-chemical composition of raw and purified wastewater from a Moroccan dairy industrial facility between 2014 and 2015. Emphasize the level of pollution produced by this industrial unit's varied activities. This study's findings are based on physico-chemical tests including pH, temperature, biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS), turbidity, and conductivity. The objective of our study is also to treat the wastewater treatment plant of the dairy industry in order to have a minimal COD, SS, and conductivity, using a physico-chemical treatment such as adsorption by commercial activated carbon.

2. Materials and methods

2.1. Description of the study site

This study was carried out in the dairy factory of Sale (Morocco) the capital of the prefecture in the region of Rabat-Salé-Kénitra. It is located on Morocco's Atlantic coast and on the right bank of the Bouregreg River, which separates it from Rabat. The communes of Tiflet and Khémisset border it on the east, the city of Rabat on the south, the Atlantic Ocean on the west, and the communes of Sidi Bouknadel and Kenitra on the north.

2.2. Sample collection

Due to the complexity, multiplicity, and diversity of the wastewaters, selecting a suitable sampling site is difficult. On the other hand, the identification of the sewage discharge network allowed for the selection of three essential sample points: the main rejection, the cleaning outputs, and the parboiling conditioning outlet. These three sampling locations are designated by P_1, P_2, and P_3 respectively.

- P_1: This position corresponds to the wastewater treatment plant (WWTP) of the dairy industry, taken from the main collector's termination point, roughly ten meters from the sea dumping point. Sampling was possible during the 24-h manufacturing period. Where the water's flow was important.
- P_2: This sampling point is associated with WWTP and was taken from the plant's last cleaning point.
- P_3: This sampling site corresponds to the WWTP conditioning station, and it was possible to collect samples for 24 h. Over a year, samples were taken everyday.

Samples were taken all day at specific times for each sampling point to measure pH and dissolved oxygen levels. Samples were taken regularly throughout this time for BOD_5, COD, SS, total Kjeldahl nitrogen (TKN), and total phosphorus (TP).

Additional samples were taken whenever necessary to monitor and confirm the reproducibility of measurements for these parameters. All these samples were taken with a hand sampler with a pole length of 2 m and a sampling depth of roughly 50 cm.

Given the organic content of the wastewater and its fairly rapid biodegradation, all samples that might be altered were analyzed on-site, while the rest were done in the lab, taking into account the samples' preservation conditions during transport [22]. The effluent samples were mixed and kept at 4°C until they were used. Sampling and storage were carried out in accordance with the samples' conservation and handling general guide [23]. Temperature, pH, electrical conductivity, COD, BOD_5, suspended solids, and other physico-chemical parameters were investigated.

2.3. Analytical procedure

The physico-chemical analyses of the wastewater were carried out according to the standard techniques for the evaluation of water and wastewater [24] and included the following parameters: temperature, pH, SS, COD, BOD, N-TKN and TP.

2.3.1. Turbidity and pH

The turbidity of the sample was determined by using a CL 52D ELICO Nephelometer while the pH of the samples was recorded by using the HI98121 pH meter.

2.3.2. Electrical conductivity (EC) and total suspended solids

ELICO EC-TDS meter (CM 183) was used to evaluate electrical conductivity and total dissolved solids of diluted effluent concentrations of 1%, 2%, 3%, and 4%. Total solids were determined using the gravimetric technique, and suspended solids were computed using the TS = TDS + TSS equation.

2.3.3. Chemical oxygen demand

The COD was determined using the dichromate reflux method, which involved adding 10 mL of 0.25 N potassium dichromate ($K_2Cr_2O_7$) and 30 mL $Ag_2SO^{4+}H_2SO_4$ reagent to a 20 mL diluted sample. After 2 h of refluxing, the mixture was cooled to room temperature. Excess $K_2Cr_2O_7$ was titrated with ferrous ammonium sulfate (FAS) using a ferroin indicator after the solution was diluted to 150 mL with distilled water.

$$\text{COD} = \frac{(A - B) \times N \times 1,000 \times 8}{\text{Volume of sample}} \quad (1)$$

where A represents the mL of FAS used for the blank; B represents the mL of FAS used for the sample; N represents FAS normalcy, and 8 represents the mill equivalent weight of oxygen.

2.3.4. Biological oxygen demand

BOD was estimated by adding nutrients such as phosphate buffer, magnesium sulfate, calcium chloride, and ferric chloride to the appropriate volume of dilution water. BOD bottles were filled with the diluted sample. After calculating the initial DO, the final DO of the bottles stored for a five-day incubation period was calculated. 2 mL manganese sulfate ($MnSO_4$), and 2 mL alkali iodide azide ($NaOH^{+}KI^{+}NaN_3$) were added to the bottles kept for DO determination and blank.

2.4. Processing technique

Activated carbon s (ACs) are carbonaceous materials with remarkable surface characteristics, namely a highly developed internal surface and associated pore volume, and a reactive surface chemistry. The pores distributed on the surface or in the internal part of the AC are at the origin of their textural properties. This research uses the commercial activated carbon adsorption method of dairy effluents.

2.5. Experimental design

The response surface methodology was a modeling technique used to assess the relationship between variables and determine the best experimental conditions [25,26]. In this present study, we used the full factorial design to identify the factors that influence the responses studied. Adsorbent dose of commercial activated carbon per 1 L of effluent in (g/L) (X_1), solution pH (X_2), and temperature in (°C) (X_3) are the three factors chosen. COD (mg/L), TSS, and conductivity (μS/cm) are represented by Y_1, Y_2, and Y_3 respectively. Table 1 shows the experimental domain for each parameter, which is divided into two levels (upper +1 and lower (1).

Table 1
Assess experimental levels and range of the independent process variables

Variable	Code	Level	
		−1	+1
Adsorbent dose, g/L	X_1	10	30
pH	X_2	3	10
Temperature, °C	X_3	25	40

3. Results and discussion

3.1. Characterization of dairy industrial effluents

3.1.1. Physico-chemical parameters

3.1.1.1. Temperature

P_1 has a temperature range of 26°C–31°C, P_2 has a temperature range of 21°C–50°C, and P_3 has a temperature range of 16°C–33°C. These temperatures respect the Moroccan industrial water discharge guideline of 30°C [17]. However, the temperature of the cleaning outputs water (P_2) and the main discharge might approach 50°C. This is due to the use of hot rinse water on the manufacturing equipment. This temperature accelerates the acidification process by fermenting lactose to lactic acid and promotes the formation of large bacterial biomass. The important processes of organisms will be slowed if temperature regulating systems are not present [27]. Fig. 1 shows the average temperature of all samples at different times.

3.1.1.2. pH

The pH of the dairy industrial effluent from the different samples is on average between 2 and 12.5 (Fig. 2). These variations could be related to the overdose of cleaning products, insufficient rinsing of the production equipment, and the natural bacterial acidification of milk and whey. The aquatic fauna and plants are negatively affected by this pH range.

3.1.1.3. Conductivity

One of the methods for confirming water physico-chemical analyses is conductivity. Contrasting structures on a medium may be used to show the presence of pollution, melange zones, and infiltration. Also, to appreciate the amount of dissolved salts in the water. The electrical conductivity of the measured on average samples ranges from 2,551.33 μS/cm (P_3) to 4,272.66 μS/cm (P_2). Maximum values range from 8,700 μS/cm (P_1) to 5,000 μS/cm (P_3), while lowest values range from 1,000 μS/cm (P_3) to 2,060 μS/cm (P_2) (Fig. 3). These values are still higher than the limit value of 2,700 μS/cm.

3.1.1.4. Turbidity

Turbidity is the pollution measure that indicates the presence of organic matter or mineral colloidal form suspended in the wastewater. It is inversely proportional to water clarity. It fluctuates depending on the amount of SS in the water. Fig. 4 presents the average values of turbidity of water at the sampling points at different times.

3.1.1.5. Organic and suspended solids

The main quality parameters usually studied to indirectly assess the overall organic load contained in wastewater are the BOD_5, representing the amount of biodegradable organic matter as well as the COD, which accounts for the quantity of the main biodegradable or non-biodegradable carbon elements that can be chemically oxidized in the

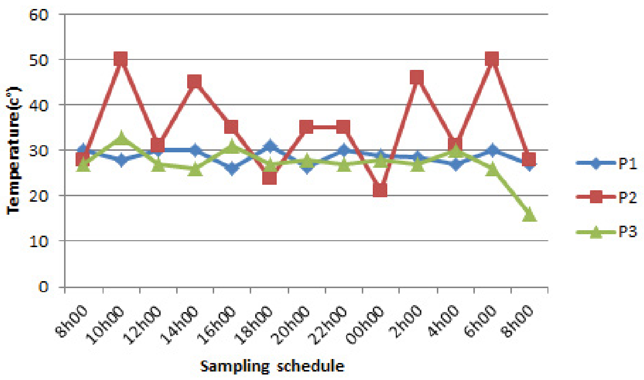

Fig. 1. Average temperature of all samples at different times.

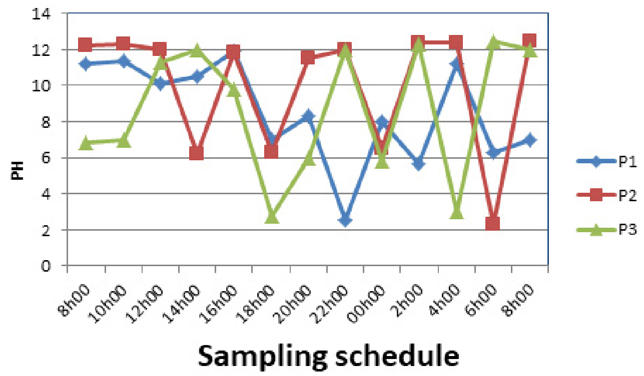

Fig. 2. Average evolution of water pH of all samples at different times.

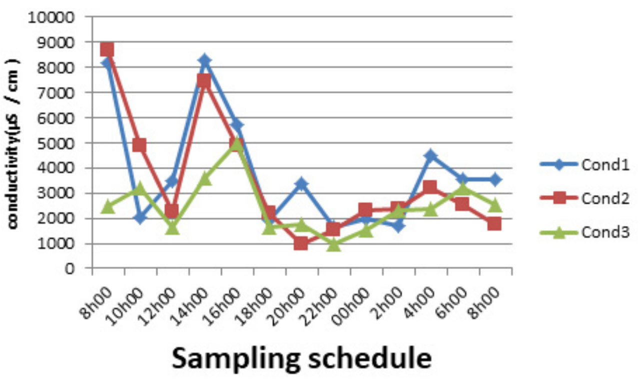

Fig. 3. Average values of electrical conductivity at the sampling points at different times.

receiving medium, and finally, the SS, which represents the mineral and organic particles contained in the effluent.

During the study period, BOD_5 values for the main rejection (P_1) ranged from 1,218 to 2,591 mg/L, with an average of 1,994 mg/L. These values range from 934 to 2,318 mg/L at the cleaning outputs water (P_2), with an average of 1,526 mg/L, and from 1,116 to 2,318 mg/L at the parboiling conditioning outlet (P_3), with an average of 1,877.85 mg/L. (Table 2 and Fig. 5). COD values range from 2,317 to 5,492 mg/L for the

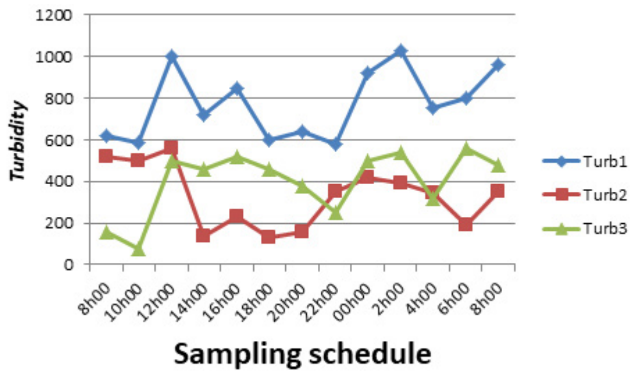

Fig. 4. Average turbidity of water values at several sample points at various times.

main rejection, with an average of 3,753.78 mg/L, and 1,650 to 3,500 mg/L for the cleaning outputs, with an average of 2,455 mg/L, and 2,164 to 4,623 mg/L for the parboiling conditioning outlet with an average of 3,419.14 mg/L. (Table 2 and Fig. 5). In addition, the average total suspended solids values for the main rejection (P_1), cleaning outputs (P_2), and parboiling conditioning outlet (P_3) are 510.571, 374, and 460.214 mg/L, respectively (Table 2 and Fig. 6). The daily monitoring of organic matter and suspended solids in the factory reveals significant values that considerably exceed the Moroccan norm's permissible limits [13]. These SS are high in fat and curd, as well as particulate debris from soil washing water, and tanks, as a result of the manufacturing process. To avoid major repercussions like blockage of fish gills and a decrease in oxygen content in the water, which hinders photosynthesis, the amount of SS included in this effluent directly rejected in the sea must be reduced.

3.1.1.6. Total Kjeldahl nitrogen

In practice, total Kjeldahl nitrogen is an environmental pollution indicator, and its control makes it possible to follow the evolution of contamination [28]. In our study, the TKN vitiated a lot throughout the investigation. The variables (Table 2) range from 30 to 72 mg N/L, which is greater than the permissible standard (30 mg/L) [29].

Detailed results of the physico-chemical assays of wastewaters of a dairy industrial plant in Sale, Morocco, are gathered in Table 1.

3.1.2. Bacteriological analysis

The results of the three wastewater sampling analyses reveal the presence of fecal contamination-related microorganisms as well as dangerous germs. The average values for fecal coliforms in the main rejection (P_1), cleaning outputs (P_2), and parboiling conditioning outlet (P_3) are 1.430, 1.084, and 1.037 CFU/mL, respectively. According to fecal staphylococci (FS), the average values are 2.414 CFU/mL in the main rejection (P_1), 1.892 CFU/mL in the cleaning outputs (P_2), and 1.761 CFU/mL for the parboiling conditioning outlet (P_3).

Table 2
Physico-chemical parameters of wastewaters of a dairy industrial plant in Sale, Morocco at different sampling points P_1, P_2 and P_3

Parameter		P_1				P_2				P_3			
	NS	Min	Moy	Max	ST	Min	Moy	Max	ST	Min	Moy	Max	ST
pH	16	2.5	8.54	11.9	2.807	2.3	10.3	12.5	3.42	2.8	8.71	12.5	3.481
T (°C)	16	26	28.2	31	1.939	21	35.3	50	10.12	16	26.8	33	4.778
Cond. (µs/cm)	16	4,110	1,630	8,300	2,432.37	2,060	4,272.66	8,700	2,256.134	1,000	2,551.33	5,000	1,217.061
Tur. (NTU)	16	626	761.066	1,030	166.01	133	331.733	560	154.355	79	386.6	560	164.145
SS (mg O_2/L)	16	288	510.571	718	146.22	110	374	610	160.849	275	460.214	619	122.094
COD (mg O_2/L)	16	2,317	3,753.785	5,492	1,048.512	1,650	2,455	3,500	592.351	2,164	3,419.142	4,623	918.565
BOD_5 (mg O_2/L)	16	1,218	1,994.064	2,591	499.346	934	1,526	2,091	432.056	1,116	1,877.857	2,318	479.31
TKN (mg O_2/L)	16	30	52.25	72	14.691	31	45.35	70	13.57	26	41.35	65	13
BOD_5/COD	16	0.525	0.531	0.472	0.566	0.621	0.626	0.627	0.271	0.515	0.549	0.501	0.521
SS/BOD_5	16	0.236	0.256	0.277	0.139	0.066	0.152	0.278	0.372	0.246	0.245	0.267	0.254
COD/BOD_5	16	1.902	1.878	2.119	2.099	1.766	1.608	1.597	1.371	1.939	1.820	1.994	1.916

Cond.: conductivity; Tur.: turbidity; *T*: temperature; SS: suspended solids; COD: chemical oxygen demand; BOD_5: biological oxygen demand over 5 d.

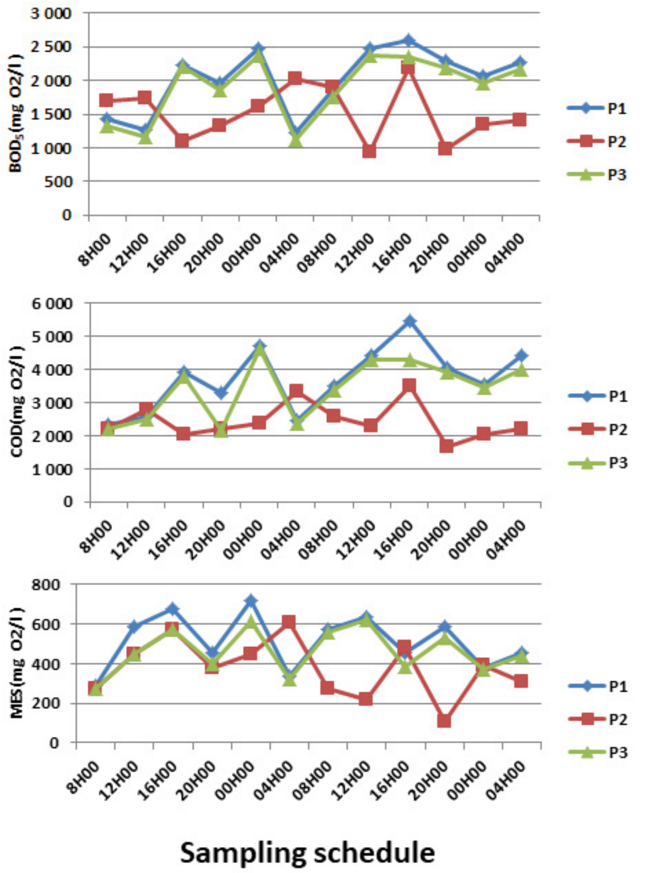

Fig. 5. Average COD, BOD_5, and TSS evolution of effluents at several sample points at different times.

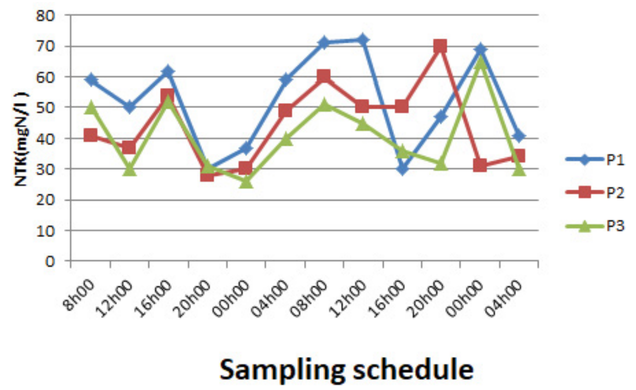

Fig. 6. Average TKN evolution of effluents at several sample points at various times.

3.1.3. Ratio COD/BOD_5

The COD/BOD_5 ratio (less than 3) is important for defining the effluent treatment chain. In our study, a low COD/BOD_5 ratio indicates the existence of a high proportion of biodegradable compounds, allowing biological treatment to be considered. An important value of this ratio shows that a significant portion of the organic solid is not biodegradable, and it is better to seek physico-chemical treatment in this instance. The findings of this paper demonstrate the significance of contaminants with low to non-biodegradable. Table 2 shows that the COD/BOD_5 ratios are between 1.5 and 2, indicating that these effluents have good biodegradability [3,16,17].

3.1.4. Ratio BOD_5/COD

The BOD_5/COD ratio provides important information about the source of wastewater pollution and treatment possibilities. This ratio is relatively high in this study, on the order of 0.53. This is usually the case with discharges containing a lot of organic materials. This organic content makes these wastewaters particularly unstable, meaning that they will swiftly change into "digested" forms, potentially releasing odors. The wastewater from this collector is predominantly organic [30–33].

3.2. Design of the experiment for absorption treatment

JMP software was used to design the experiment and randomize the runs. Randomization ensures that the conditions in one race do not depend on the conditions in previous races and do not predict the conditions in subsequent races. It is essential for concluding the experiment under correct, unambiguous, and defensible conditions. Table 3 lists the results of the experiments performed with all of the input parameters.

3.2.1. Analysis of the variance

The analysis of variance (ANOVA) was used to determine the significance of the curvature in the responses at a confidence level of 95% [33–35]. After discarding the insignificant terms, the ANOVA data for the coded quadratic model for the response are reported in Fig. 4. The effect of a factor is defined as the change in response produced by a change in the level of the factor. This is frequently called the main effect because it refers to the primary factors of interest in the experiment. The ANOVA results showed that the equations adequately represented the actual relationship between each response and the significant variables. The *F*-value implies that the models are significant and values of "Prob. > *F*" less than 0.05 indicate that models terms are significant [36].

Fig. 7 shows the results of the ANOVA for the coded model for the response. As evidenced by *p*-values less than 0.05 for TSS (*p*-values = 0.0397) and for COD and conductivity the *p*-values are higher than 0.05 (*p*-values (COD) = 0.1167; *p*-values (conductivity) = 0.152). Furthermore, the *p*-value of the TSS as a response in the ANOVA is less than 0.05, indicating that the complete

Table 3
Limit values for different physico-chemical parameters for rain waters and wastewaters [29]

Parameter	VLR direct rejection	VLR indirect rejection
Temperature, °C	30	35
pH	6.5–8.51	6.5–8.51
BOD, mg/L	100	500
COD, mg/L	500	1,000
TSS, mg/L	50	600
Conductivity	2,700	–
Sulfates	–	400
Total Kjeldahl nitrogen, mg N/L	30	
Total phosphorus, mg P/L	10	10
Chloride (Cl)	Chlore actif Cl_2 (0.2)	–
N–NO_3	–	–

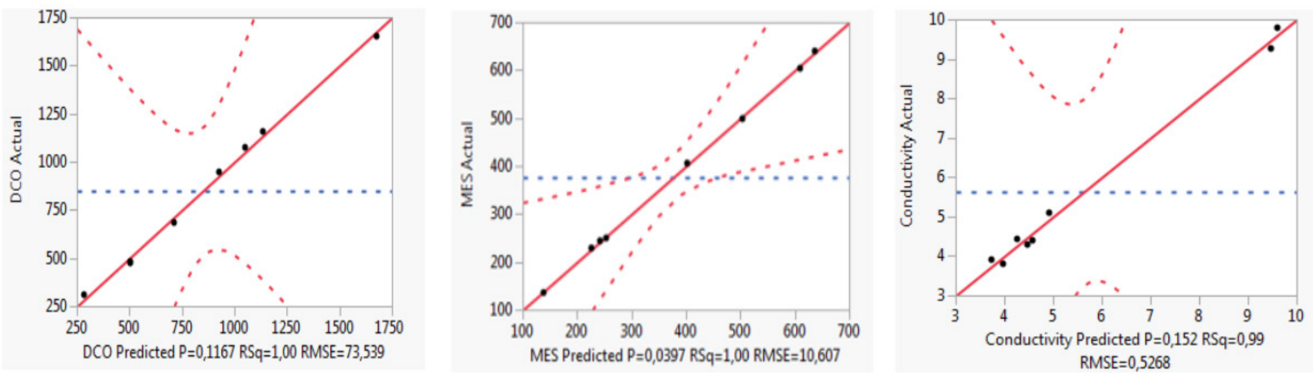

Fig. 7. Experimental and predicted results of the three responses to treating dairy wastewater using commercial activated carbon.

factorial design describes well the reduction of suspended solid using commercial activated carbon as an adsorbent. Fig. 7 shows also a perfect alignment of the points, demonstrating an excellent correlation between the experimental and theoretical values of the three responses: COD, TSS, and conductivity, with *R*-square coefficients R^2 (COD) = 1, R^2 (TSS) = 1, and R^2 (conductivity) = 0.99, respectively. Because the coefficient values are near to 1 [37].

3.2.2. Estimated parameter

With *p*-values of 0.0433 and 0.0148, respectively, the adsorbent dosage and temperature parameters were statistically significant in the treatment of suspended material in the dairy wastewater effluent (Table 4). The *p*-values for the remaining parameters for suspended solid, and *p*-values for all parameters of the treatment of COD and conductivity, were higher than 0.05 indicating that they were not statistically significant [38].

3.2.3. Mathematical model

Based on the ANOVA and the examination of the estimated parameter (Table 4). The mathematical equations to describe the variations in the studied responses according to the factors given by the JMP software are:

$$Y_1 = 848.75 + 29.75X_1 + 190X_2 - 50.25X_3 + 294X_1X_2 - 51.75X_1X_3 - 210.5X_2X_3 \quad (1)$$

$$Y_2 = 376.25 - 55X_1 - 32.5X_2 - 161.25X_3 - 18.75X_1X_2 + 30X_1X_3 \quad (2)$$

$$Y_3 = 5.626 + 0.028X_1 - 1.324X_2 + 1.514X_3 + 0.114X_1X_2 + 0.021X_1X_3 - 1.066X_2X_3 \quad (3)$$

where Y_1, Y_2 and Y_3 are the COD, TSS and conductivity responses respectively.
X_1, X_2, and X_3 are the factors of adsorbent dose, pH, and temperature respectively.

3.2.4. Prediction profiler

Fig. 8 depicts an interaction profiler that demonstrates how to interpret interaction outcomes. The interaction profiler shows interactions between adsorbent dosage and pH, adsorbent dose and temperature, and pH and temperature for COD, TSS and conductivity responses. For example, the more non-parallel the two levels appear to be, the more probable there is a significant interaction between them. For example, in the TSS response, the pH and temperature lines or levels are practically parallel, indicating there is likely no significance [39].

Table 3
Experimental design matrix with experimental values for commercial activated carbon effluent treatment using COD, SS, and conductivity as responses

Run	Experimental value			Physico-chemical parameters		
	Adsorbent dose (mg/L)	pH	Temperature (°C)	COD (mg O_2/L)	SS (mg O_2/L)	Cond. (µS/cm)
1	10	3	25	685	640	4.29
2	30	3	25	312	500	4.45
3	10	10	25	950	605	3.92
4	30	10	25	1649	405	3.79
5	10	3	40	1161	250	9.78
6	30	3	40	477	245	9.28
7	10	10	40	480	230	4.4
8	30	10	40	1076	135	5.1

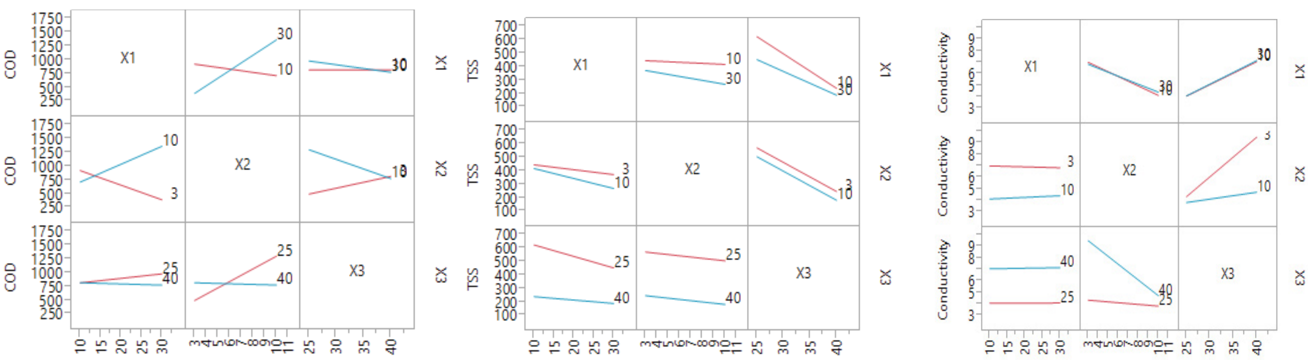

Fig. 8. Prediction profiler for significant predictors of dairy effluent treatment by reducing COD, TSS, and conductivity using commercial activated carbon.

3.2.5. Parameters optimization

Optimization is a crucial step in the experimental design methodology; it is used to find the best experimental conditions (the values taken by the influencing factors) for the response. The graphs in Fig. 9 show the full factorial design's optimal conditions.

The three responses study aims to have a minimal COD, TSS, and conductivity after treatment by adsorption of dairy wastewater on commercial activated carbon. As a result, the commercial activated carbon dose has a positive influence on COD, a negative effect on TSS, and essentially no effect on conductivity. Both COD and conductivity are negatively affected by the pH of the solution [40–41]. *T*°C has a negative effect on both COD and TSS reactions, but a good effect on conductivity, according to the effect profile. As a result of the experimental design software's findings, the best conditions for the adsorption of dairy wastewater COD, TSS and conductivity by commercial activated carbon are adsorbent dose = 10 g/L, pH = 10 and *T* = 40°C [42].

4. Conclusion

The effluents of the dairy sector are among the most organic matter-abundant waste streams. The city of Rabat-Salé's dairy processing plant discharges 900 m^3/J of liquid waste. They are a significant source of pollution due to their high concentration of bacteria, lactose, proteins, vitamins, and minerals, and the management of these effluents affects both producers and environmental actors. TSS (p-values = 0.0397) has p-values less than 0.05, however COD and conductivity have p-values greater than 0.05 (p-values (COD) = 0.1167; p-values (conductivity) = 0.152). In addition, the TSS as a response in the ANOVA has a p-value of less than 0.05, demonstrating that the full factorial design accurately represents the decrease of

Table 4
Full factorial design parameters' estimates from JMP for COD, TSS, and conductivity

Term	Estimate			*t* Ratio			*p*-value		
	COD (mg O_2/L)	TSS (mg O_2/L)	Cond. (µS/cm)	COD (mg O_2/L)	TSS (mg O_2/L)	Cond. (µS/cm)	COD (mg O_2/L)	TSS (mg O_2/L)	Cond. (µS/cm)
Model	848.75	376.25	5.62625	32.64	100.33	30.21	0.0195*	0.0063*	0.0211*
X_1, adsorbent dose	29.75	−55	0.02875	1.14	−14.67	0.15	0.4572	0.0433*	0.9025
X_2, pH	190	−32.5	−1.32375	7.31	−8.67	−7.11	0.0866	0.0731	0.0890
X_3, temperature	−50.25	−161.25	1.51375	−1.93	−43.00	8.13	0.3040	0.0148*	0.0779
$X_1 \times X_2$	294	−18.75	0.11375	11.31	−5.00	0.61	0.0562	0.1257	0.6510
$X_1 \times X_3$	51.75	30	0.02125	−1.99	8.00	0.11	0.2964	0.0792	0.9277
$X_2 \times X_3$	−210.5	0	−1.06625	−8.10	0.00	−5.72	0.0782	1.0000	0.1101

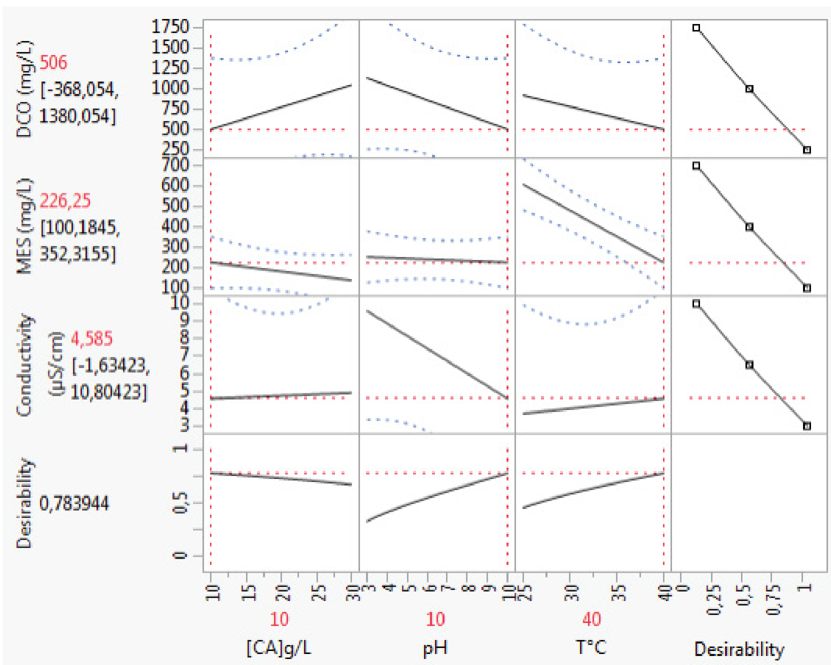

Fig. 9. Optimal conditions for the adsorption of dairy waste on the CA.

suspended solids employing commercial activated carbon as an adsorbent. The experimental and theoretical values of the three responses: COD, TSS, and conductivity, with R-square coefficients of R^2 (COD) = 1, R^2 (TSS) = 1, and R^2 (conductivity) = 0.99, respectively, demonstrate an excellent correlation between the experimental and theoretical values. Because the values of the coefficients are near to 1. The effluents investigated have an abundance of easily degradable organic waste, nitrogen, phosphate, and bacteria, all of which indicate fecal contamination. The adsorption treatment studies revealed that the commercial activated carbon utilized could remove suspended particles from raw global dairy effluent while also lowering COD and conductivity. The best COD, TSS, and dairy wastewater conductivity reduction performances by commercial activated carbon are 10 g/L of adsorbent dose, a basic medium with pH equal to 10, and at 40°C, which ensures that these parameters accommodate Moroccan norms. Despite these findings, this type of treatment remains a complete one, allowing only a modest removal of a pollutant with significant polluting potential. To ensure complete treatment, adsorption should be complemented by another physical or biological treatment that allows for the maximum reduction of pollutant load according to the norms established by the Moroccan standards project (Fig. 9).

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