Classification of industrial wastewater discharged into effluent pits, an approach toward a sustainable recycling: case study of a water treatment facility in Morocco

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Abstract. Most water treatment facilities collect industrial wastewater in separated effluent pits. This discharge strategy has been proposed by several previous research as a solution to the problems of untreated wastewater being withdrawn further into open sea or rivers, which aims to prevent the pollution of water supplies. However, this solution might also have far-reaching ecological and environmental negative consequences. In this research we have assessed the effluent's Physico-chemical characterization over the duration of one year, utilizing a specific statistical methodology for a water treatment plant located in Morocco that used effluent pits for retaining its wastewater. Effluents collected by the water treatment plant are tested in two effluent pits to determine the effects of the direct evaporation and storage, the results of this study reveal a significant increase in the Physico-chemical characteristics of these effluents kept inside effluent pits, which may be attributed to an uptick in water pollution in case of any accidental release or spill. Regression and correlation Explanatory variables from a statistical analysis have been assessed to determine which effluent variables were indeed strongly connected to each other. Effluent recycling is proposed to minimize the likelihood of environmental and ecological concerns. ***Keywords*:** Wastewater, pollution, ecological, environmental, Physico-chemical, evaporation

1 Introduction

The persistent loss and degradation of natural resources, especially water, continue to be major problems in the modern day. There seems to be a great deal of debate about water reuse and disposal, which necessitates the strictest regulations, because of the growing demand for potable water across the world [1]. Conventional water sources represent a significant portion of Morocco's water supply. New, non-traditional water resources have grown rapidly, with the goal of minimizing the wasteful reuse of already-existing water supplies and protecting the planet from further depletion of its natural resources [2]. Nowadays, wastewater treatment is an essential necessity for protecting our planet's limited natural resources. To achieve this goal, many strategies have been developed to deal with the issue of wastewater management and to lessen the pollution of water supplies. Many different types of chemical compounds, liquids, and solids fluids are employed in the production process, and the resulting effluent waste contains considerable substances that are detrimental to the environment, people, and marine organisms [3]. In addition, the freshwater used for water treatment facilities in such industries cannot be recycled because of stringent restrictions; so, the hazardous impacts must be reduced to safeguard the environment and ecosystems [1].

The effluent contains a variety of harmful substances, including bacteria, heavy metals, biodegradable organics and Micropollutants [4]. There is significant environmental damage caused by these substances. Among these unfavourable effects include heavy metal poisoning, irritation, bacterial infections, and nutritional enhancement. Reduced oxygen levels can lead to the discharge of harmful materials and the enrichment of nutrients. Effluent that is discharged into various water sources must be addressed properly to prevent these unintended and potentially harmful effects [5]. Releasing industrial effluent into big ponds wherever it evaporates slowly in the sun is an effective method of water purification. There are several countries that use them to treat their brine. While there are many positive aspects to evaporation ponds, there are also potential ecological and environmental concerns. Effluent spills from evaporation ponds/ effluent pits, for example, might cause serious ecological damage. While effluent pits are open water surfaces, they also bring wildlife; nevertheless, if the effluent accumulated into an evaporation pond [4] or effluent pits is poor quality and exceeds the legal limits, this could also result in a rise in the deaths among some creatures [6]. We'll illustrate how problematic it became for all industries especially water treatment plants that release their effluent into the effluent pits or evaporation ponds by studying the wastewater from one industrial

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plant located in Morocco. In this research, the physicochemical variables of effluent pollutants were analysed. Statistical modelling was utilized to determine the most common correlations between the physicochemical properties.

2 Material and methods

Fig. 1. Location map of the study area

2.1 Collection and Physicochemical Examination

The From October 2021 to September 2022, a Sigma SD900 Portable Sampler has been utilized to gather the set of data from the water treatment facility.

In an approved external water analysis laboratory, Physico-chemical and bacterial studies of the wastewater were conducted using standard and applicable protocols. Special packaging was used to take samples by the external laboratory given the presence of hydrocarbon remnants mostly in effluent from the water treatment facility. The samples were gathered at two effluent pits and analyzed the next day. Established Procedures for the Assessment of Wastewater were applied in accordance with standard procedures for the assessment of effluent. Through using the procedures outlined below, the following physical, chemical, and bacterial studies were assessed:

- Heavy metals (Lead, Chromium, Nickel, Zinc, Mercury, Iron) were analyzed using NF 90-112.
- Organic pollutants (BOD and COD) were analyzed using NM 03.7.054 v 2013.
- Bacteria (Salmonella, Escherichia coli and Spores of anaerobic micro-organisms sulphite-reducers at 37°C (clostridia)) were analyzed using NM ISO 1925 v 2012.
- pH, Electrical conductivity (EC), and total suspended solids (TSS) were analyzed using NM ISO 10523 v 2012, NM ISO 7888 v 2001, and NM EN 872 v 2013.
- Phenol index (C_6H_6O) was analyzed using NF 90-109.
- Sulphate (SO_4) were analyzed using NM ISO/TR 896.

2.2 Description of the study area

To ensure that we have a representative sample over the four seasons, we collected wastewater samples from the effluent pit at a water treatment facility in Morocco, the period was from October 2021 to September 2022. The following map (figure 1) shows the exact location of the study area:

2.3 Correlation and Regression analysis

The cleanliness of the effluent in the evaporating basin may be evaluated with the use of regression and correlation techniques. Analytical instruments were used for correlation and regression analysis. In this investigation, we used the Pearson correlation formula to determine the degree of association between the physicochemical properties of untreated wastewater and their respective environmental impacts. Pearson's coefficient of correlation (r) may be calculated with the help of the formula (Equation 1) [7].

$$r = \frac{N\,\Sigma xy - \Sigma x\,\Sigma y}{\sqrt{[N\sum x^2 - (\sum x)^2][N\sum y^2 - (\sum y)^2]}} \quad (1)$$

Where:
r= Pearson correlation coefficient
N= value in each data set number
$\sum x$ = sum of x scores
$\sum y$= sum of y scores
$\sum x^2$ = sum of x squared scores
$\sum xy$ = sum of products paired scores
$\sum y^2$ = sum of y squared scores

In statistical analysis, the least-squares regression technique is employed to foretell whether dependent variables might evolve over time.

Using the least-squares method necessitates paying attention to the path of the maximum match in addition to the other sample points.

Users sometimes use regression analysis (Equation 2) to investigate the interplay of both the regression model and a number of potential predictors [8]:

$$y = ax + b \quad (2)$$

Where:
Y= Dependent
x=Independent
a= Intercept
b= constant

The goal of this statistical analysis is to find out how various effluent characteristics are connected and associated.

Correlation statistical analysis is used to determine the significance and direction of the relationship between the two variables. Only when the magnitude of the correlation coefficient (r) is close to 1, it indicates that there is a strong link between the two variables being analyzed. Values of -1 and +1 indicate a negative and positive association, respectively.

As the correlation value drops closer to zero, the strength of the link between the variables in question decreases. In the end, the significance of the link was calculated based on the p-value. If somehow the p-coefficient is far

less than 0.05 or even less than 0.01, then the correlation is substantial. If the p-coefficient is more than 0.05, then the association is not substantial. Importance is tested at the 0.05 and 0.01 levels (2-tailed analysis) [9-10].
The choice of this statistical analysis (correlation and regression methodology) is also used to characterise the association between two or many effluent variables.
Moreover, this statistical methodology further creates a method for predicting one effluent variable by considering the value of a second variable while a mathematical model describing a relationship, and this will be more useful when analysing the dependence of wastewater parameters in order to identify the most characteristics responsible for increasing the wastewater pollution.

3 Results and discussion

3.1 Outcomes of Effluent characterization

3.1.1 Heavy metal concentration results and regulations

As displayed in the table 1 and figure 2, the results of a year's worth of heavy metals in the water treatment plant effluent were summarized. The heavy metal in this study was determined by averaging the following factors (Lead, Chromium, Nickel, Zinc, Mercury, and Iron).

Table 1. Heavy metals characterization results

Parameter	unit	10/21	11/21	12/21	01/22	02/22	03/22	04/22	05/22	06/22	07/22	08/22	09/22
Lead	mg/l	0.12	0.15	0.10	0.25	0.34	0.22	0.41	0.11	0.23	0.19	0.24	0.32
Chromium	mg/l	0.82	1.10	0.98	0.75	0.56	0.97	1.09	1.01	0.14	0.23	0.18	1.03
Nickel	mg/l	0.14	1.23	1.89	2.01	0.78	0.98	1.23	1.78	1.65	1.26	1.14	1.81
Zinc	mg/l	0.88	0.14	0.32	0.45	0.11	0.22	0.45	0.32	0.17	0.28	0.36	0.14
Mercury	mg/l	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01
Iron	mg/l	1.02	1.1	0.98	0.86	0.92	1	0.87	0.93	1.01	1.05	0.97	1.04
Total Heavy Metal	mg/l	0.50	0.62	0.71	0.72	0.45	0.57	0.68	0.70	0.54	0.50	0.48	0.73

The following graph (figure 2) shows the total heavy metals findings during one year. Industrial effluents and soil were analyzed to determine the acceptable concentrations of Lead, Chromium, Nickel, Zinc, Mercury, and iron according to the guidelines set forth by the World Health Organization (WHO), Morocco (Decree N°3286.17 related to the discharges into surface or groundwater Moroccan), the World Bank and the United States Environmental Protection Agency (EPA).

Based on the result above, and in order to figure out if the pollution levels in the effluent pits were over the locally and globally acceptable criteria, the concentrations of heavy metals in the field samples were contrasted with these limit values.
When almost all of these components (heavy metals) are present in the effluent, the toxicity of the wastewater and the difficulty of treating it are greatly increased.

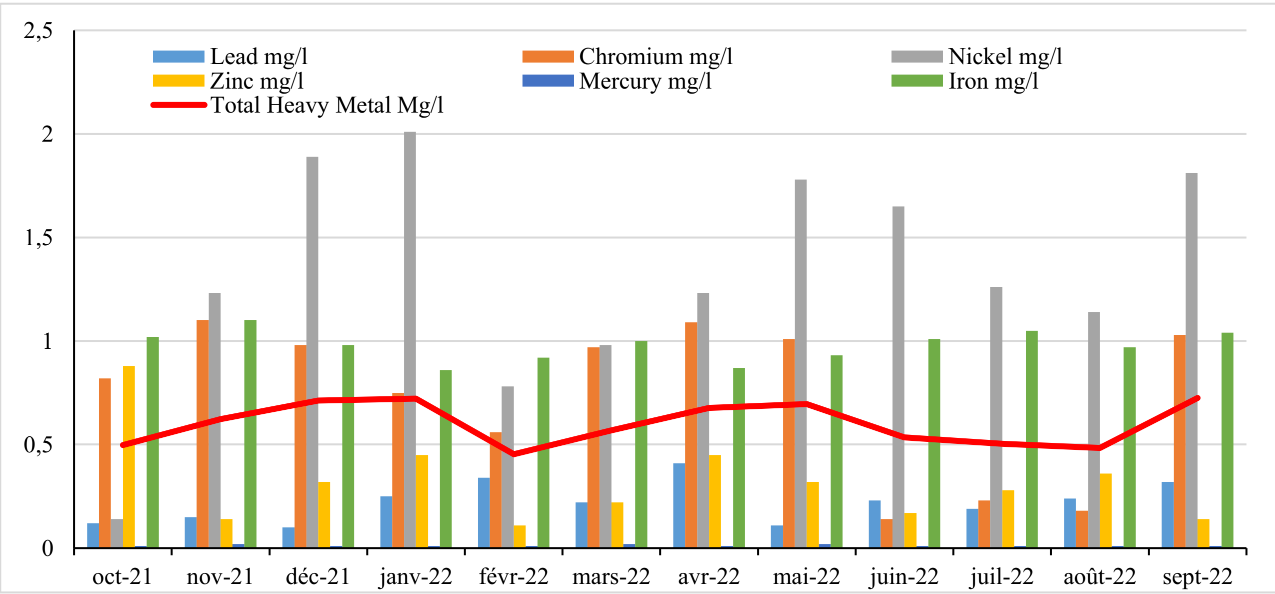

Fig. 2. Heavy Metals characterization results during one year

Sampling results show that the average concentration of heavy metals is between 0.45 and 0.73 mg/l; this range does not yet exceed the limit value fixed by international regulations which is 1 mg/l, but it is close; by increasing the residence time of effluents in the evaporation or effluent pits could increase the average concentration of heavy metals and cause it to exceed the limit value. There may be an accumulation of hazardous pollutants in the effluent because of its prolonged storage in sewage pits, which might explain this phenomenon. But on the other side, because it lacks a recognised metabolic role, mercury is regarded as being among the most toxic components for human intake. According to reports, the structure and processes of mercury that is consumed affect the poisoning effects. Consuming its chemical variants might result in sudden abortion, genetic abnormalities, and digestive issues [11].

3.1.2 Bacteriological results

The results of the bacteriological testing of the effluents pit over a year are shown in figure 3.

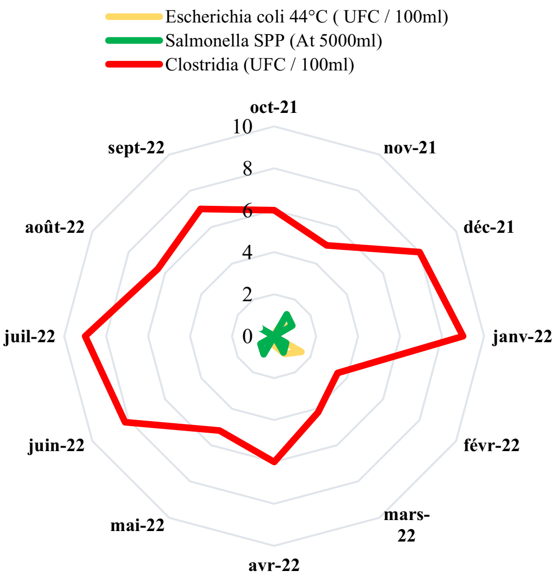

Fig. 3. Bacteriological results during one year

These findings indicate that there may be faecal contamination of the effluent, as the bacteria count in the wastewater that is dumped into the effluent pit tends to rise with time.
Despite the fact that the appearance of Escherichia coli in effluent pits had also been considered to be a sign of faecal contamination, an increasing body of research suggests that there could be a specialised component of Escherichia coli strains may be able to replicate and persist in environments other than those provided by the bowel flora, such as those found in both tropical and temperate zones [12].
Disease bacteria such as those belonging to the Salmonella category might be spread to aquatic ecosystems as a result of water pollution. This makes simultaneous testing for Salmonella's occurrence, concentration, and resistant pathogens in effluents and surrounding waters essential for gauging the associated health hazards [13].
In spite of the fact that a few different bird species have been spotted congregating near the effluent pit's surface water, this discovery raises the possibility that birds are responsible for dispersing a significant number of Escherichia coli strains into the surrounding environment, which poses a potential ecological problem.

3.1.3 Physico-chemical results

The findings of a year's duration of chemical analysis of the effluent from the water treatment facility are presented in Table 2.

Table 2. Physico-chemical characterization results

Parameter	unit	Limit	10/21	11/21	12/21	01/22	02/22	03/22	04/22	05/22	06/22	07/22	08/22	09/22
pH	pH unit	5.5-9.5	7.88	7.8	7.14	7.22	7.92	7.98	7.78	7.65	7.85	7.15	7.79	7.81
BOD_5	mg O_2/l	100	30	86	**114**	**109**	98	**106**	**132**	**119**	**123**	87	95	79
COD	mg O_2/l	500	189	215	260	**514**	**564**	**602**	478	**546**	328	378	342	303
EC	mS/cm	2.7	**21**	**26**	**24**	**32**	**35**	**28**	**21**	**19**	**32**	**29**	**24**	**23**
TSS	mg/l	100	32	98	**102**	**145**	**128**	**202**	96	**103**	**100**	95	**108**	**111**
C_6H_6O	mg/l	0.5	**1.4**	**1.3**	**1**	**1.8**	**1.5**	**1.4**	**1.5**	**1.7**	**1.3**	**1.2**	**1.1**	**1.3**
SO_4	mg/l	600	**3600**	**3800**	**4125**	**4214**	**3963**	**3500**	**3158**	**5210**	**4896**	**3875**	**3200**	**3341**
Heavy Metals	mg/l		0.50	0.62	0.71	0.72	0.45	0.57	0.68	0.70	0.54	0.50	0.48	0.73

In table 3, six characteristics of effluents (EC, BOD_5, DCO, TSS, C_6H_6O, and SO_4) exceed the limit value set by Moroccan legislation for wastewater release into the environment [14].
The maximum EC value of 35 mS/cm analysed in February 2022 is more than the limit value of 2.7 mS/cm.
The maximum BOD_5 value of 132 mg O_2/l analysed in April 2022 is more than the limit value of 100 mg O_2/l.
The maximum COD value of 602 mg O_2/l analysed in March 2022 is more than the limit value of 500 mg O_2/l.
The maximum TSS value of 202 mg/l analysed in March 2022 is more than the limit value of 100 mg/l.
The maximum C_6H_6O value of 1.8 mg/l analysed in January 2022 is more than the limit value of 0.5 mg/l.
The maximum SO_4 value of 5210 mg/l analysed in May 2022 is more than the limit value of 600 mg/l.
The above graphs (figure 4) show how the Physico-chemical characteristics of non-compliant wastewater correspond to maximum statutory requirements on an annual basis:

Fig. 4. Physico-chemical characteristics of non-compliant effluent vs the limit values

3.2 Indicators of Correlation

Table 3 is a year-to-date summary of the correlation matrix outcomes during two seasons.

The pH value has a very weak correlation with all parameters. BOD_5 correlates positively with COD and TSS. This correlation could be seen as an underestimation of the BOD_5 level when nutrients are low in the effluent. But if this nutrient is too high, nitrogen fixation will develop, and the BOD will be inflated.
To destroy organic compounds in the existence of non-biodegradable or partially degradable chemicals, bacteria must undergo a lengthy adaptation process.

The correlation between COD and TSS and C_6H_6O is high, but the correlation between COD and EC, SO_4, and heavy metals are inconsequential.

The occurrence of TSS and the chemical stability of organic molecules in the effluent pit may explain the high COD levels.
EC is substantially and positively correlated with TSS, but very weakly with C_6H_6O, SO_4, and heavy metals. The dissolution of organic compounds in the wastewater of the effluent pit may be used to explain the high value of EC, which is related to the increase in TSS; EC is increased whenever there is a significant amount of contaminants.
Whereas heavy metals have a poor relationship with pH and EC, they have a positive relationship with BOD_5, COD, TSS, SO_4, and C_6H_6O.
Heavy metals in wastewater may result in the production of hydrogen, which reacts with oxygen progressively.
Heavy metals cause sedimentation and TSS release in wastewater when present in greater concentrations. Moreover, heavy metals may give wastewater in the effluents pit an unpleasant odour.
Heavy metals, therefore, have a detrimental influence on aquatic creature development and can seriously disrupt microbiological treatment facilities for wastewater. According to its entrance into the food system through bioaccumulation and biosorption, heavy metal pollution poses serious dangers to vegetation developing upon these soils, with the eating of certain vegetation by animals and people having significant negative effects [15].
It is also recognised that heavy metals affect soil ecology. Vegetation that thrives in these conditions is often affected by heavy metal contamination like the soil. Several of these effects involve reduced germination rate and lipid productivity, reduced enzymes and plant development, suppression of chloroplasts, significantly reduced seedling, reduced chlorophyll generation, and reduced plant development, which can all be brought on by Lead, Chromium, Nickel, Zinc, Mercury, Iron respectively [16].

Table 3. Correlation matrix outcomes

	pH	BOD_5	COD	EC	TSS	C_6H_6O	SO_4	Heavy Metals
pH	1							
BOD_5	-0.178	1						
COD	0.085	**0.554**	1					
EC	-0.078	0.169	0.303	1				
TSS	0.060	**0.494**	**0.719****	**0.448**	1			
C_6H_6O	0.106	0.168	**0.621****	0.097	0.213	1		
SO_4	-0.240	0.348	0.172	0.174	-0.034	0.336	1	
Heavy Metals	-0.370	0.376	0.036	-0.387	0.137	0.269	0.154	1

The biological reduction of contaminants from the effluent is known as the biological eradication of heavy metals in polluted water. This is a screening method that makes use of the adaptability of plants and bacteria. Ex-situ and in-situ applications are two options for microbial treatment.
COD, SO_4, and TSS all have a favourable connection with C_6H_6O; however, it has a sporadic association with pH, EC, and DBO_5. The presence of C_6H_6O residue in the effluent may indicate that enough contaminants, such as oils and greases, have been discharged into the effluent.
The quantity of accidental C_6H_6O in wastewater is related to the presence of pollutants and a high COD.
In contrast to its very weakly negative associations with pH and TSS, SO4 exhibits strong positive associations with COD, DBO_5, EC, and C_6H_6O.
Measurements of sulphates are widespread. An excessive sulphate content could be a sign of contaminated industrial effluent.
Continuing to follow meaningful relations across effluent properties were found by statistical analysis:
When compared to TSS and C_6H_6O, the COD significantly correlated positively (r=0.720, p0.05). The TSS development in the effluent pit may be the cause of an increase in COD, and when compared to DBO_5, the COD significantly correlated positively (r=0.554, p0.05).

3.3 Indicators of Regression

The regression analysis of effluent properties was carried out using descriptive statistics.
The last square of the regression system created using effluent characteristics and statistical significance correlations is shown in Table 4.

Table 4. Least square of the regression relation for the most correlated effluent parameters

Y : Dependent	X : Independent	Correlation (r)	R^2	a	B (constant)	Regression equation (Y=ax+b)
BOD_5	COD	0.554	0.307	0.104	57.17	BOD_5= 0.104 COD +57.17
BOD_5	TSS	0.495	0.244	0.339	60.89	BOD_5= 0.339 TSS+ 60.89
COD	TSS	0.719	0.517	2.623	104.7	COD= 2.623 TSS+ 104.7
COD	C_6H_6O	0.621	0.386	385.88	-137.33	COD= 385.88 C_6H_6O -137.33
EC	TSS	0.448	0.200	0.057	19.8	EC = 0.057 TSS + 19.8

The graphs below (figure 5) depict linear relationships among effluent Physico-chemical variables:

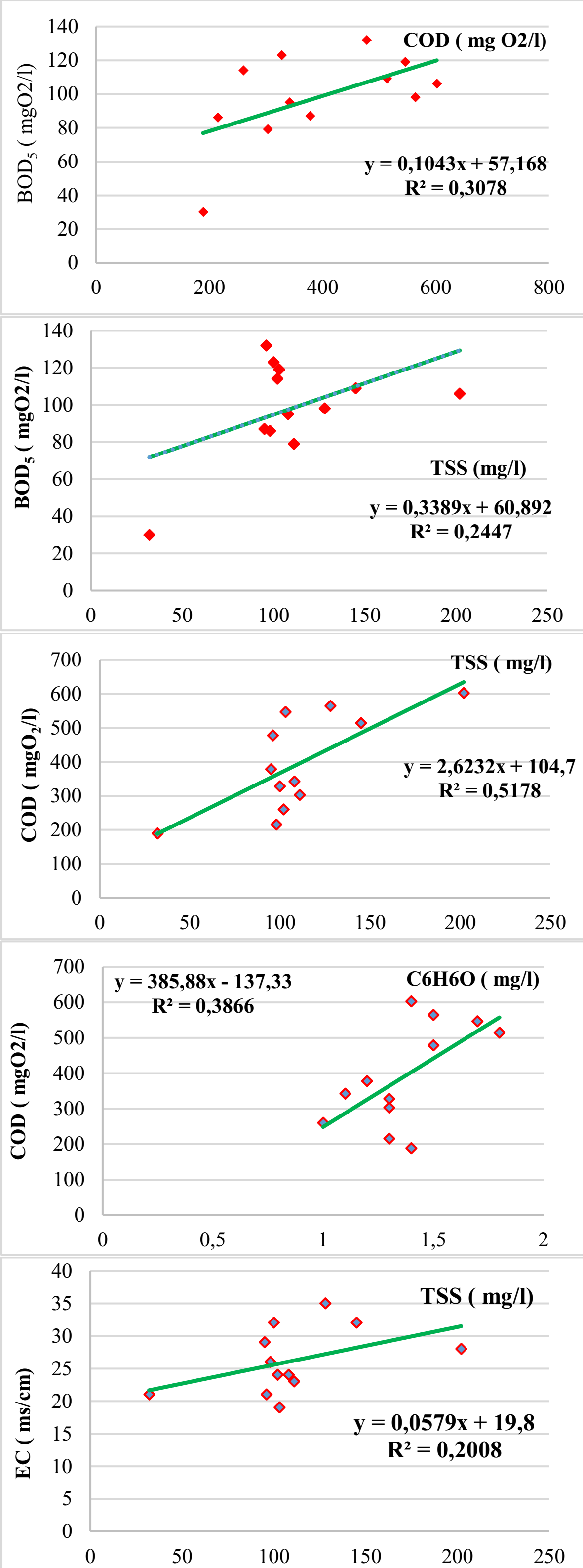

Fig. 5. Regression linear plots between effluent parameters.

Linear and positive correlations between BOD_5 and COD and TSS were seen in the scatter plots. The correlation coefficient (R) and square root (R2) coefficients for those connections were calculated using linear regression.

The graph (figure 4) shows that COD and TSS are dependent on the BOD_5 and that raising the BOD_5 level also raises the COD and TSS levels. Scatter plots showed a linear and positive relationship between COD with TSS and C_6H_6O. We used linear regression to determine the strength of such associations by calculating their respective correlation coefficients (R) and square roots (R2). The graph demonstrates that the levels of TSS and C_6H_6O are directly proportional to the concentration of COD and that increasing the COD also increases the concentrations of C_6H_6O and TSS. The same for EC and TSS which have a linear and positive relationship, so raising the EC level in effluent also raises the TSS level.

4 Discussion

Results from analyzing the Physico-chemical and bacteriological characteristics of effluent discharged into effluent pits reveal that wastewater storage under direct sunlight has a negative effect on these types of industrial effluents, as shown by a rise across several effluent characteristics that are above the limit values set by international standards. Ecological and environmental harm may result from this phenomenon so every industry should carefully develop an environmental risk assessment for further remedy [17]. Sun evaporation effects in the effluent, which elevate the water content and salinity, explain the huge impact of DBO_5 on COD and TSS formation in the effluent. The significant value of EC, which is connected to the growth of many biochemical parameters, may be attributable to degradability in effluent pits wastewater; EC is increased in the presence of a high concentration of organic pollutants.
Since some biomolecules are slight or not bioresorbable, organisms must adjust for a considerable time before being able to alter the organic substances. This is why the appearance of peroxidation sturdiness of organic materials, especially in the effluent pits, and the appearance of TSS may be the reason for the excessive COD and DBO_5 findings. Typically, the appearance of Escherichia coli in effluent pits has been interpreted as proof of microbial contamination. However, accumulating data indicates that certain Escherichia coli pathogens may even be able to reproduce and remain in environments other than those made available by the bowel flora, including those discovered in both tropical and temperate regions. Before and after effluents are dumped into the effluent pit, they should be subjected to stringent monitoring, and the sewage treatment process must apply effective processes to eliminate all bacterial pathogens. The influence of heavy metals on the soil environment is also recognized. Heavy metal contamination for substances such as soil may commonly influence organisms that flourish in these conditions. Among these effects, which may be caused by Lead, Chromium, Nickel, Zinc, Mercury, and Iron in both environments, are including significantly reduced seedling growth and lipid content, reduced enzymes and enhanced plant, inhibition of plastids, significantly lower seedling, decreased chlorophyll production, and

decreased plant evolution. The occurrence of C_6H_6O in the effluent may indicate that enough contaminants, such as oils and greases, have been discharged into it. The scatter plots shown in the regression analysis revealed straight and strong relationships between most of the parameters, demonstrating that most variables are interdependent and that increasing the level of one parameter enhances the level of the others, particularly between COD and TSS.

Based on the analysis and findings, we can conclude that dumping garbage into an effluent pit is not a sustainable option since it has significant detrimental effects on the environment, ecosystem, and natural resources.

When the results are compared to other recent ones, we can draw the conclusion that releasing wastewater into effluent pits or evaporation ponds can be viewed as a temporary solution, particularly during the construction phase of industrial plants. However, in order to make it sustainable, the wastewater released should be recycled so as to avoid such environmental and ecological issues. We thus suggest that industries, particularly power plants, recycle this wastewater using sustainable methods. This may assist businesses in inflating the price of water use.

5 Conclusion

The results of this study that investigated the physical, chemical and bacteriological characteristics of the discharged effluents by water treatment plants showed that effluent quality degraded when it was allowed to stagnate or was held in dedicated effluent pits. Therefore, several physical, chemical and bacteriological parameters—including electrical conductivity, total suspended solids, Phenol index, Sulphate, heavy metals, chemical and biological oxygen demand COD, BOD_5—increase significantly as a result of wastewater storage. There will be an increase in water pollution as a result.

Obtained from the annual wastewater quality measurements from a water treatment facility, this research identified the most important relationships between pH, BOD_5, COD, EC, TSS, C_6H_6O, SO_4, and heavy Metals.

Heavy metals are known to have an effect on soil ecology, and it is also known that many heavy metals have elevated concentrations even when they are below the limit value. Heavy metal pollution of a substrate like soil has a significant impact on the vegetation that thrives in these environments. Chloroplast suppression, decreased enzyme activity, stunted plant growth, and slower germination are just a few of the negative outcomes.

The biological oxygen demand COD and the total suspended solids of industrial effluent produced by the water treatment plant activities have a significant link with the majority of the remaining effluent characteristics, as demonstrated by the findings of the relationship between variables. The greatest significant connections between COD and TSS, as well as between COD and C_6H_6O, are seen in the wastewater.

In accordance with the results of this research, there is a relationship between the various physical and chemical features of industrial effluent. In contrast, the measured values for chemical and biological oxygen requirements, electrical conductivity, Total suspended Solids, phenol index and sulphates are all higher than the allowed limits for wastewater quality features in the study area. Reusing or recycling wastewater through various technical processes is proposed as a means of control to avert environmental and ecological disasters.

6 Acknowledgements

The Laboratory of Biotechnology and Materials, Faculty of Sciences, Agadir, IBN ZOHR, Morocco, is supporting this research. The authors are grateful for the insightful and helpful feedback offered by editors and assigned reviewers on a previous version of this work.

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