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Original Research

Qualitative Evaluation of Pharmaceutical Industrial Effluents: Case of Study

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Abstract

In Algeria, there are multiple deficiencies in environmental protection. Today, in the context of the constant evolution of healthcare systems and the growing importance given to environmental preservation, the management of pharmaceutical effluents has become one of the major challenges for the pharmaceutical industry. However, often the interests of companies, especially private ones, do not align with environmental priorities, despite the existence of a range of procedures and legislative mechanisms. This can lead to the creation of safe and sustainable action plans to prevent, reduce, and/or eliminate pollution, harmful effects, and nuisances. Unfortunately, this regulation is widely underestimated and neglected in their actual daily practices and actions. Furthermore, awareness and preventive information on environmental concerns are very limited; regulatory mechanisms are fragmented; safety culture and environmental education are disparate, and monitoring and tracking means are limited. The objective of this work is to assess the environmental impact of the activities of an Algerian pharmaceutical industry in order to reflect on environmental concerns and open national discussions on the harmful effects produced by various companies and the strict application of current regulations. This assessment is based on the evaluation of the value of physico-chemical analysis of sewage discharges from a pharmaceutical industry during manufacturing, research and development processes, as well as waste disposal. The analysis results indicate that the physico-chemical properties of the discharged sewage were within the limits allowed by standards regarding heavy metals. However, the analyses of DOB_5, DCO, and the concentration of suspended solids (SS), oils and fats significantly exceed the standardized values. This study aims to raise awareness among stakeholders to implement procedures and legislative measures, potentially leading to the development of safe and sustainable action plans, or even fostering a culture of continuous improvement and lasting prevention.

Keywords: pharmaceutical industry, environmental risks, assessment, effluents, prevention and harmfulness

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Introduction

Actually, in the context of the constant evolution of healthcare systems and the growing importance given to environmental preservation, the management of pharmaceutical effluents has become one of the major challenges for the pharmaceutical industry. The majority of sewage retains pollutants that contribute to eutrophication, persisting even after undergoing secondary treatment and subsequent discharge into watercourses [1]. Therefore, continuous, permanent, and sustainable improvement in the management of these effluents for the well-being, health of society and the environment is essential and becomes everyone's concern [2]. Every enterprise, through the simple exercise of its activities, generates an impact on its natural and human environment [3-5]. This relatively new phenomenon, called environmental risk, is still not widely considered by entrepreneurs today. Often, the interests of businesses, especially private ones, do not align with environmental priorities, and many prioritize legal, economic, competitive, and industrial aspects. These risks are widely underestimated, overlooked in their reality, and in their daily actions. Consequently, the risks generated by the constant interaction between human activities and the environment are numerous [6-8], of very diverse natures, and often catastrophic in their consequences. For this reason, the nature of the activities of many companies can, at any time, be a source of pollution or damage to biodiversity. Nowadays, the modern concept of the risk of environmental harm, which lies at the heart of the missions of states, is based on a broad understanding of the environment, in line with the use of the term in public policies for management. Therefore, regulatory contexts require industrial operators who operate classified installations for environmental protection subject to authorization to identify, analyze, and assess accidental risks in their various components [9-11].

Among the suspected industries, the pharmaceutical industry stands out, generating liquid waste that is harmful to the ecosystem [12-16]. These liquid wastes can have significant consequences on the environment and public health, despite the crucial role that this industry plays in the health and well-being of the population by developing medicines and pharmaceutical products.

The liquid rejections of the pharmaceutical industry refer to effluents produced during manufacturing, research and development processes, as well as waste disposal. These rejections may contain active pharmaceutical substances such as active pharmaceutical ingredient (API), degradation products, excipients, and other chemical components. They can also be contaminated with solvents, heavy metals, and other potentially hazardous substances. As a result, physico-chemical alterations refer to changes in the characteristics of environments, such as salinity, acidity, or water temperature, etc. Beyond a certain threshold, these modifications become toxic to both humanity and organisms living in the environment. They can lead to the contamination of water resources, aquatic ecosystems, and surrounding soils [15-19].

Hence, our task consists of evaluating the environmental impacts of the pharmaceutical industry activities of an Algerian company with the aim of reflecting on environmental concerns and initiating national debates on the harmful effects produced by different companies, as well as ensuring strict compliance with existing regulations. This evaluation is based on well-defined criteria, namely the chemical analysis of effluents produced during manufacturing, research and development processes, as well as waste disposal. This study aims to raise awareness among stakeholders to implement procedures and legislative measures, eventually enabling the development of safe and sustainable action plans, and fostering a culture of improvement and sustainable prevention.

The Impact of Pharmaceutical Industrial Effluents

Industrial effluents from the pharmaceutical industry can have a significant impact on the environment due to the presence of active pharmaceutical ingredients (API) and other chemicals used in the manufacturing process. Here is a detailed description of the environmental impacts of pharmaceutical industrial effluents, as shown in Table 1.

Table 1. Environmental impacts of pharmaceutical industrial effluents.

Impact	Effects	References
Water resources contamination	Pharmaceutical effluents can pollute water sources such as rivers, lakes, etc., leading to the presence of API in the aquatic environment.	[20-23]
Effects on biodiversity	Certain API present in pharmaceutical effluents may exert toxic effects on biodiversity, especially on delicate aquatic organisms such as algae, crustaceans, and mollusks.	[24-27]
Presence in the soils	Pharmaceutical effluents discharged in sanitation may contaminate soil, affecting quality and agriculture, posing environmental concerns.	[15, 27-29]
Effects on human health	The impact of pharmaceutical effluent APIs on human health is unclear. Concerns arise over chronic low-dose exposure.	[30-35]

Methodology

Method Evaluation

The proposed methodology is found on evaluating the environmental impacts on both human health and the ecosystem. Its objectives include instigating contemplation on environmental concerns, promoting national discourse regarding the detrimental effects generated by various companies, and underscoring the crucial need for rigorous adherence to prescribed regulations. This research is fundamentally based on evaluating the significance of physico-chemical analysis of sewage discharges from a pharmaceutical industry located in Constantine province. In the course of our research, we collected four samples from effluents at the factory's discharge point throughout the year 2022, with the goal of assessing the composition and characteristics of this sewage. This evaluation is based on the chemical analysis of effluents produced during the manufacturing, research and development processes, as well as during waste disposal. Sample collection was done quarterly. This research work is an opportunity to inform and raise awareness among stakeholders, authorities, and the public about the harmful effects caused by effluents from pharmaceutical industries. This allows raising awareness among those concerned and authorities about the harmful effects of pharmaceutical effluents, in order to develop legislative procedures and devices that could potentially lead to the creation of safe and sustainable action plans. The aim is to prevent, reduce, and/or eliminate pollution, harm, and disturbances, and possibly engage in a culture of continuous improvement and sustainable prevention.

Physicochemical Analysis

The results highlight the physicochemical properties of the sewage discharged by the industry in question. They were obtained through a series of rigorous tests and analyses aimed at assessing the composition and characteristics of this sewage. These analyses have identified several key parameters, such as the concentration of chemical oxygen demand, biological oxygen demand, pH levels, the content of heavy metals, and the possible presence of specific contaminants. These parameters are essential for assessing the potential environmental impact of these discharges on the surrounding aquatic ecosystems. Table 2. below illustrates the results of these analyses.

For more precision, we present the various values determined after the chemical analysis of the different samples.

Hydrogen Potential (pH): The pH of water plays a crucial role both in human health and in the environment. Here are the detailed effects of water pH on health and the environment [37- 38], namely:

– **Effects on Human Health**: Skin and Eye Irritation: Water with an extremely low (acidic) or high (alkaline) pH can cause skin and eye irritations in individuals exposed to it.
– **Digestive System Effects:** Regular consumption of water with abnormally high or low pH can have harmful effects on the digestive system, particularly by disrupting the body's acid-base balance.
– **Nutrient Absorption:** Inappropriate water pH can influence the absorption of nutrients in the digestive system, which can have an impact on overall health.
– **Environmental Effects:** Aquatic Ecosystems: Extreme pH levels can disrupt aquatic ecosystems,

Table 2. Summary table of physicochemical analyses (source ONEDD) [36].

Parameters	Units	Limit Values*	Sample 1	Sample 2	Sample 3	Sample 4	Analysis Standards
Temperature	ºC	**30**	13	16	30	28	**Instrumental**
pH	-	**6,5-8,5**	6,7	7,21	6,57	7,08	**Instrumental**
COD1[1]	mg/L	**130**	**4416**	**450**	**5280**	**390**	**ISO 6060 de1989**
BOD_5[2]	mg/L	**40**	**470**	**320**	**1450**	**200**	**Oxytop**
MES[3]	mg/L	**40**	**44**	**5**	**57**	**20**	**ISO : 11923 de 1997**
Oils and fats	mg/L	**30**	5,8	**37**	**56**	12	**JIS 0102.24.2**
Cadmium	mg/L	**0,25**	<0,03	<0,03	<0,03	<0,03	**ISO 8288-1986F**
Copper	mg/L	**1**	<0,2	<0,2	<0,2	<0,2	**ISO8288-1986F**
Lead	mg/L	**0,75**	<0,2	<0,2	<0,2	<0,2	**ISO 8288-1986F**
Nickel	mg/L	**0,75**	<0,2	<0,2	<0,2	<0,2	**ISO 8288-1986F**
Iron	mg/L	**5**	1,3	2	3	1,2	**FDT 90-112**
Zinc	mg/L	**5**	0,05	0,06	0,05	0,06	**ISO 8288-1986F**
Chromium	mg/L	**0,75**	**<0,2**	**<0,2**	**<0,2**	**<0,2**	**ISO 8288-1986**

COD1[1] : Chemical Oxygen Demand; **BOD_5[2]:** Biochemical Oxygen Demand; MES[3] : Total Matter Suspended affecting the survival and development of plants, fish, invertebrates, and other aquatic organisms.

– **Soil Acidification:** Acidic waters can lead to soil acidification, which can hinder plant growth and nutrient availability for living organisms.
– **Imbalance in Terrestrial Ecosystems:** Surface water acidification can result in the leaching of toxic metals such as lead, aluminum, and mercury, which can have detrimental effects on terrestrial wildlife and flora. The analysis results are as follows, shown in Fig. 1.

Finding: The obtained results indicate an average pH value of 6.89. It is noteworthy that all pH values consistently fall between 6.5 and 8.5, making them compliant with the standards governing industrial effluent discharges.

Biochemical Oxygen Demand (BOD_5): Biochemical Oxygen Demand (BOD_5) in water can have significant effects on the environment and health. BOD_5 is a measure of the amount of dissolved oxygen required for the biological degradation of organic materials present in water. When BOD levels are high, it indicates a heavy load of organic matter in the water, which can lead to several negative consequences [39-41], namely:

– **Environmental effects:** The health of a watercourse is reflected in its biodiversity and appearance, which are directly impacted by the presence of sufficient oxygen and minimal excess organic nutrients. A well-oxygenated watercourse provides an ideal environment for the proliferation of various aquatic species. The release of water with a high Biochemical Oxygen Demand (BOD_5) index into watercourses causes several detrimental effects, specifically the consumption of ecosystem oxygen for pollutant degradation and the increase in organic sediments.

Oxygen depletion and the accumulation of sediments at the bottom of a watercourse are two major factors associated with watercourse eutrophication. The proliferation of algae due to excessive presence of phosphorus and nitrogen is not the sole cause. Therefore, the treatment of organic matter associated with BOD_5 in sewage discharged into the environment is crucial for maintaining its health.

Health effects: The presence of high levels of BOD_5 (Biochemical Oxygen Demand) in water can indicate the presence of organic matter from contaminating sources such as domestic or industrial sewage. This organic matter can promote the growth of pathogenic bacteria, viruses, and parasites, which can increase the risk of waterborne diseases for populations consuming this contaminated water.

It is important to note that the specific effects of BOD_5 on the environment and health can vary depending on the nature of the organic matter in the water, the concentration of BOD_5, and the specific characteristics of the ecosystem and the affected population. The analysis results are as follows, shown in Fig. 2.

Finding: Fig. 2. illustrates the results of the samples taken and the measurements of the parameter BOD_5 (Biochemical Oxygen Demand over 5 days) expressed in milligrams per liter (mg/L). The samples collected are numbered from P1 to P4, and their respective results are presented. The BOD_5 analyses show that all the samples exceed the upper limit of 40 mg/L.

Chemical Oxygen Demand (COD): COD (Chemical Oxygen Demand) in water can have significant effects on the environment and health. COD is a measure of the amount of oxygen required for the chemical breakdown of organic matter present in the water. Elevated levels of COD can indicate the presence of organic pollutants in the water, which can lead to several harmful consequences [39,42-44], namely:

– **Environmental effect:** An increase in Chemical Oxygen Demand (COD) can lead to a decrease in dissolved oxygen in the water, which may result in a deterioration of water quality and the death of aquatic organisms. Additionally, the degradation of organic matter can lead to the release of toxic substances or degradation products that can harm aquatic life and disrupt ecosystems.
– **Health Effects:** Regarding health, the presence of high levels of Chemical Oxygen Demand (COD) in the water can indicate the presence of industrial,

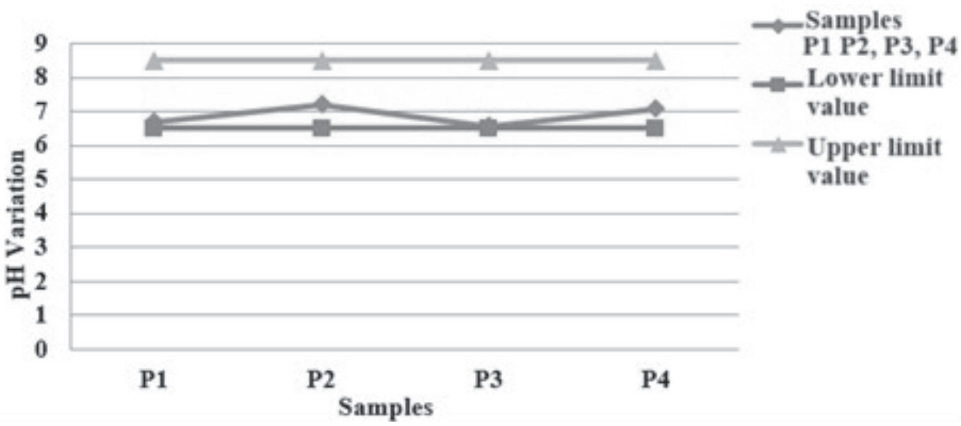

Fig. 1. pH Variation in 4 Samples.

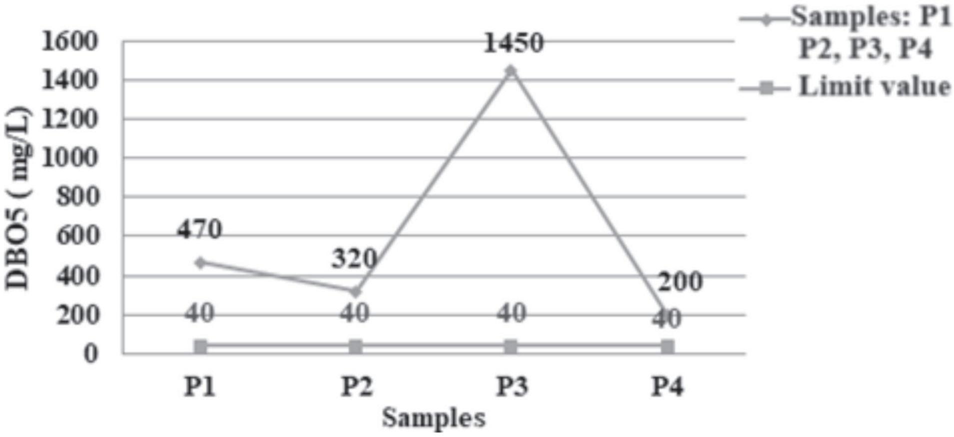

Fig. 2. Variation in BOD_5 concentration.

agricultural, or domestic chemical pollutants. These substances can be toxic to humans when ingested or with prolonged exposure. Health effects can vary depending on the type and concentration of the substances present but may include gastrointestinal issues, developmental disorders, liver problems, potential carcinogenic effects, among others.

It is important to note that the effects of the Chemical Oxygen Demand (COD) on the environment and health depend on various factors such as the concentration of substances, the duration of exposure, and the specific characteristics of the ecosystem or population in question. The analysis results are as follows, as shown in Fig. 3.

Finding: According to the data collected for the parameter COD (Chemical Oxygen Demand) illustrated in Fig. 8., it is clear that samples 1, 2, 3, and 4 significantly exceed the upper limit of 130 mg/L. Therefore, it is essential to implement suitable measures to decrease the COD levels in samples that exceed the acceptable limits.

Suspended matter (MES): Suspended matter are solid or semi-solid particles suspended in water, such as sediment particles, organic debris, plant material, or particles of industrial or agricultural origin. Their presence in the water can have effects on the environment and health [45-46], namely:

– **Environmental effects:** A high concentration of MES can lead to water turbidity, reduce light penetration, and disrupt the photosynthesis of aquatic plants. This can result in decreased oxygen production and disturb the ecological balance of aquatic ecosystems. Additionally, TSS can accumulate in seafloors or watercourses, altering the habitats of aquatic organisms and reducing biodiversity.

– **Health effects:** Suspended matter MES can transport chemicals, pathogens, or pollutants in water. This can lead to contamination of drinking water or water sources used for crop irrigation. Consuming water with high levels of SS and associated contaminants can pose risks to human health, such as gastrointestinal disorders, infections, or illnesses related to exposure to toxic substances. The analysis results are as follows, Fig. 4.

Finding: Fig. 4. represents the results of various samples in relation with the measurement parameter, which is the total matter suspended concentration

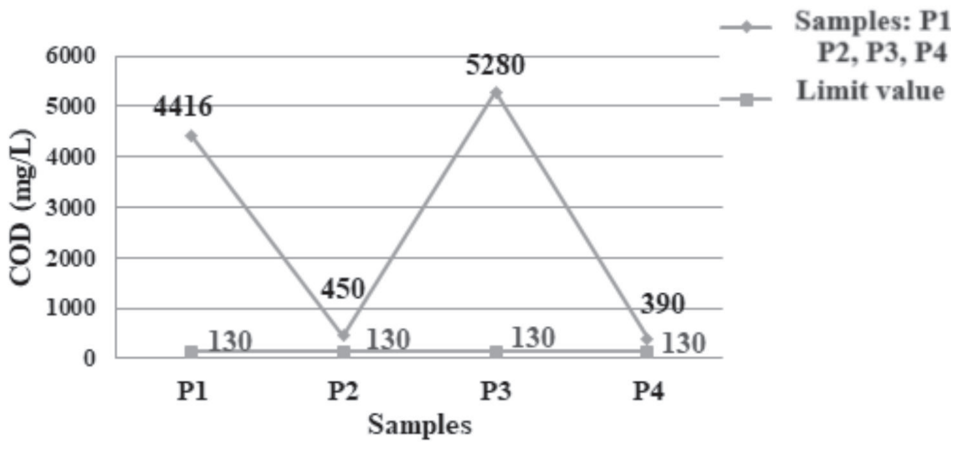

Fig. 3. Variation in COD concentration.

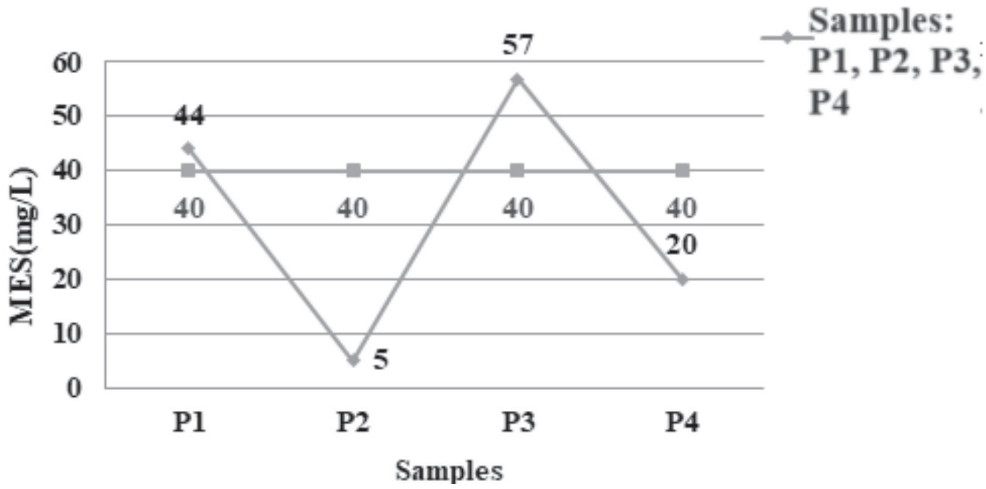

Fig. 4. Variation in suspended matter concentration.

(MES), expressed in milligrams per liter (mg/L). The MES sample results show that samples P1 and P3 exceed the upper limit of 40 mg/l, while samples 2 and 4 fall below this limit.

Oils and Fats: In addition to causing clogs and unpleasant odors in pipelines, they lead to the suffocation of bacteria responsible for purifying water and a proliferation of microorganisms harmful to health, resulting in significant consequences for aquatic environments [47-48]. They lead to massive mortalities of species, but they also have less visible effects: eutrophication of environments, toxic effects in the short or long term, diseases, or endocrine disruptions.

Finding: Fig. 5. represents the results of various samples based on the measured parameter, which is the concentration of oils and fats, expressed in milligrams per liter (mg/L). The analysis results of the oil and fat samples indicate that samples P2 and P3 exceed the standard set by the World Health Organization (WHO) at 30 mg/L, while samples P1 and P4 are below this limit.

Heavy Metals: Heavy metals present in water are harmful to health. They are persistent, disrupt ecosystems, degrade soils, surface waters, forests, and crops, and accumulate in the food chain [49-52]. Some are carcinogenic and have effects on bones, kidneys, cardiovascular system, and are neurotoxic, etc. They are significant contaminants in ecosystems and food chains. Moreover, they are non-biodegradable. The analysis results are as follows:

– **For cadmium:** Cadmium is unequivocally recognized as a potent human carcinogen by the International Agency for Research on Cancer (IARC), placing it in Group 1 of their classification. This classification underscores the severe threat it poses to human health. Prolonged exposure to cadmium, commonly found in industrial settings and tobacco smoke, has been linked to a heightened risk of cancer development. As a result, there is a pressing need for stringent regulations and preventive measures to limit cadmium exposure in various occupational and environmental settings.

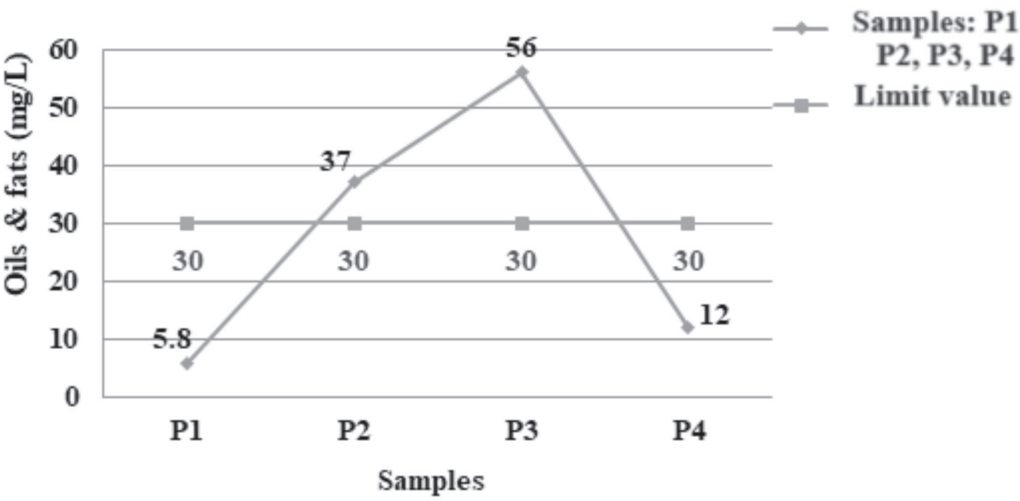

Fig. 5. Variation in oils and fats concentration.

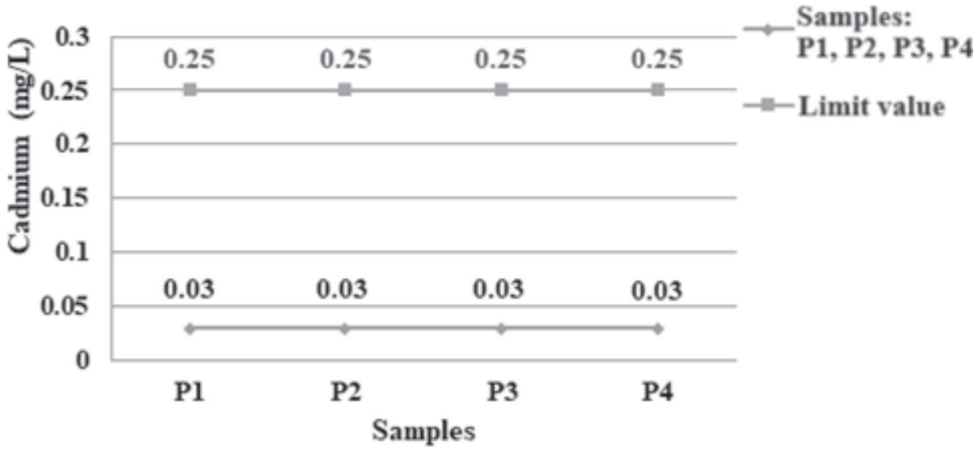

Fig. 6. Cadmium concentration variation.

The acknowledgment of cadmium's carcinogenicity by IARC emphasizes the urgency of safeguarding individuals from this hazardous substance to safeguard public health. [53-54].

Findings: Fig. 6. represents the results of the various samples based on the measured parameter, which is the cadmium concentration expressed in milligrams per liter (mg/L). The samples are numbered from P1 to P4, along with their corresponding results. Upon analyzing the results, it is evident that all samples show a cadmium concentration below the limit value, 0.25 mg/L.

– **For copper:** Even in small quantities, copper consumption can have detrimental effects on health. Nausea, vomiting, and diarrhea are common symptoms associated with copper poisoning. Therefore, it is crucial to be cautious about copper exposure, as even minimal intake can lead to these adverse health issues. To safeguard one's well-being, it is essential to be aware of the potential sources of copper in daily life and take necessary precautions to minimize exposure. Being mindful of copper consumption is paramount in maintaining good health and preventing these uncomfortable and harmful symptoms [55-56].

Findings: Fig. 7. illustrates the outcomes of different copper samples, presenting their measured copper concentration in milligrams per liter (mg/L). The results indicate that the copper concentration in all samples is below the standard-defined limit of 0.25 mg/L. This compliance with the specified threshold highlights the adherence to the required quality standards, ensuring the safety and purity of the samples tested.

– **For lead:** Lead is a hazardous heavy metal known for its detrimental impact on health. It profoundly affects blood pressure and kidney function in adults, and hampers reproduction and children's development. Especially alarming is its effect on young children, where it impairs the central nervous system, leading to decreased IQ points and attention disorders even at low levels of exposure. High doses of lead can cause severe conditions like encephalopathy and neuropathy, posing a life-threatening risk to both adults and children. Furthermore, lead exposure is linked to distressing digestive issues such as lead

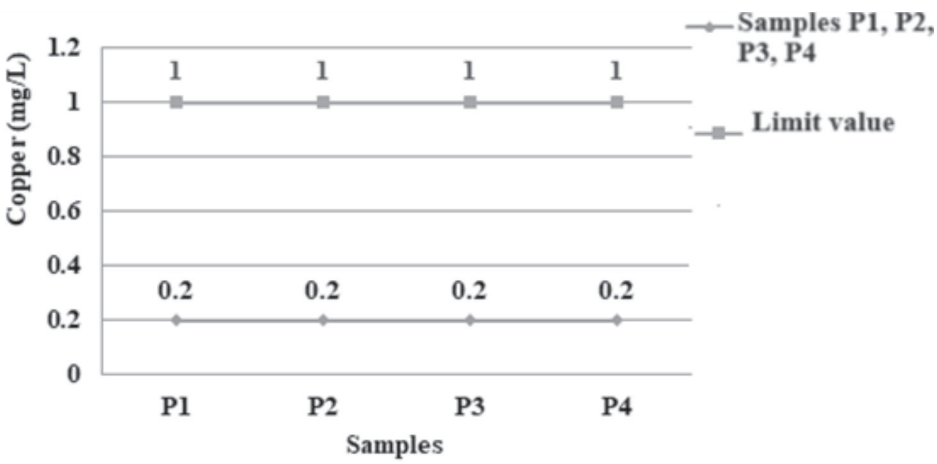

Fig. 7. Copper concentration variation.

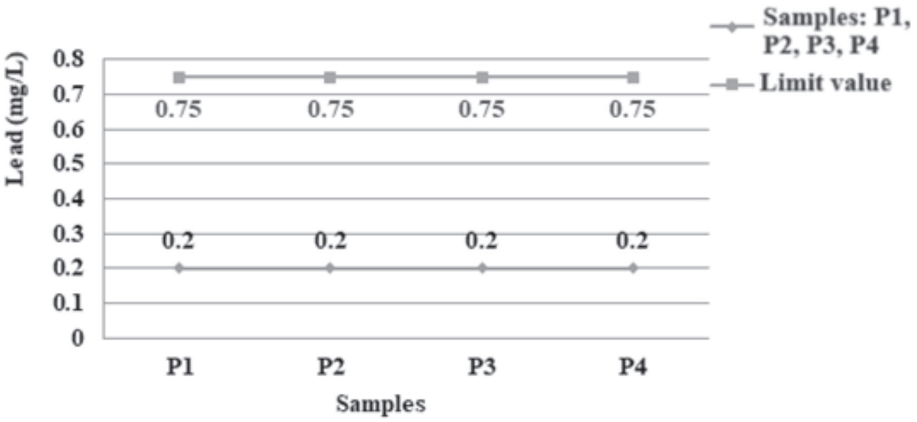

Fig. 8. Lead concentration variation.

colic and abdominal pain. Limiting lead exposure is imperative to safeguard health. Awareness of its pervasive consequences is vital, urging communities to take immediate action to reduce exposure and protect individuals, particularly the vulnerable population of children, from the devastating impact of lead contamination. [57-58].

Findings: Fig. 8. displays results from various samples based on the measured parameter, which is lead concentration expressed in milligrams per liter (mg/L). The specified lead limits are 0.75 mg/L. According to the results, it is evident that all samples exhibit lead concentrations below the limit set by the World Health Organization (WHO) standard.

– **For nickel:** In the case of nickel exposure, it's crucial to note that being in contact with nickel compounds raises the likelihood of developing lung and nasal cavity cancer, as well as lung fibrosis. This risk is substantiated by mechanistic data indicating an indirect genotoxic mode of action. Consequently, nickel and its compounds are classified as threshold carcinogens according to research studies [59-60]. This categorization underscores the importance of minimizing exposure to nickel-containing substances, given their potential to trigger serious health conditions, including various forms of cancer and pulmonary fibrosis.

Findings: Fig. 9. depicts the outcomes of different samples, categorized by the measured parameter: iron concentration, expressed in milligrams per liter (mg/L). In this case, the Nickel concentrations in samples P1, P2, P3, and P4 consistently remain below the 5 mg/L limit. This graphical representation underscores the adherence of these samples to the specified standard, indicating a favorable outcome. The graph provides a clear overview of the data, showcasing the compliance of the samples with the predetermined threshold. The data illustrates that these samples exhibit iron concentrations well within the acceptable range, highlighting the effectiveness of the studied system or process. Such adherence to the specified limit is crucial in ensuring the quality and safety of the examined substance. This visual representation serves as a valuable reference, emphasizing the importance of maintaining iron levels within the prescribed limits for various applications, thereby enhancing overall comprehension and awareness.

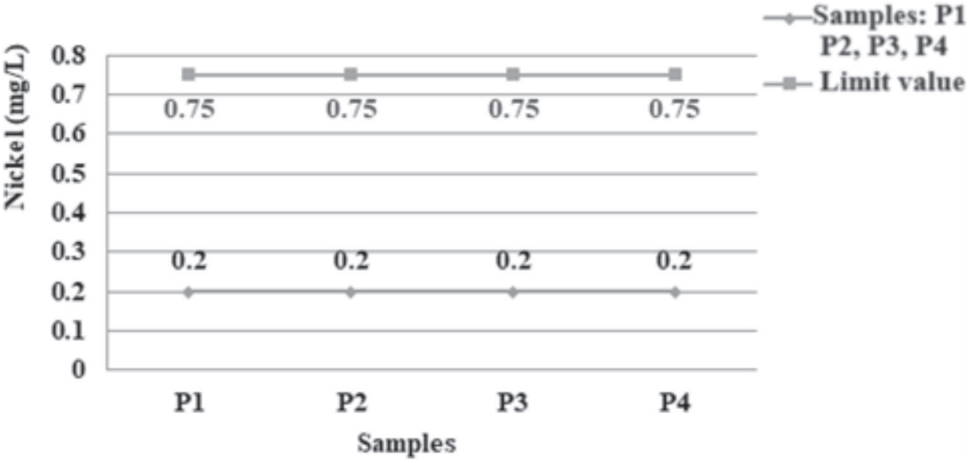

Fig. 9. Nickel concentration variation.

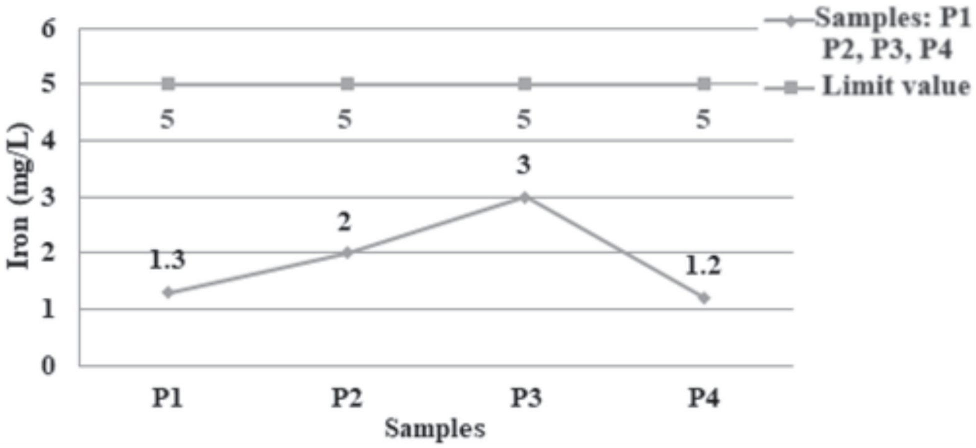

Fig. 10. Iron concentration variation.

– **For iron:** Plants, air, and water require careful consideration. It is strongly advised to prevent the introduction of this chemical into the environment due to its persistent nature. Proactive measures must be taken to safeguard our surroundings. Allowing this substance to infiltrate our environment could have detrimental consequences, underscoring the urgent need for stringent control. Preserving the delicate balance of our ecosystem demands meticulous attention to prevent potential harm [61-62].

Findings: Fig. 10. provides a visual representation of the results obtained from a variety of sample sets, each evaluated with respect to a specific metric: the concentration of iron, measured in milligrams per liter (mg/L). It is of significance to observe that the concentrations of iron in samples P1, P2, P3, and P4 consistently maintain levels below the 5 mg/L threshold throughout the course of this analysis. This observation underscores the stability and reliability of the measurements, suggesting that the iron content in these particular samples consistently adheres to safety standards, remaining well within acceptable limits.

– **For zinc:** Vigilance is paramount in managing zinc intake, given that elevated levels may result in adverse effects like headaches, nausea, vomiting, decreased appetite, and abdominal cramps. Moreover, the presence of water-soluble zinc in soil presents a potential hazard as it can contaminate groundwater, as substantiated by references [59-60]. Preventing health complications arising from excessive zinc consumption requires careful attention. The environmental implications of water-soluble zinc on groundwater quality emphasize the importance of responsible handling and disposal practices.

Findings: Fig. 11. illustrates the outcomes derived from diverse water samples in relation to the measured variable – zinc concentration, quantified in milligrams per liter (mg/L). Notably, all water samples subjected to analysis exhibited exceptionally low zinc levels, falling well below the established limit of 5 mg/L. This data underscores the consistently minimal presence of zinc in the tested water sources, indicating that the zinc content poses no concerns or risks in terms of water quality. It also emphasizes the effectiveness of measures, highlighting the successful maintenance of zinc levels within the stipulated safety boundaries.

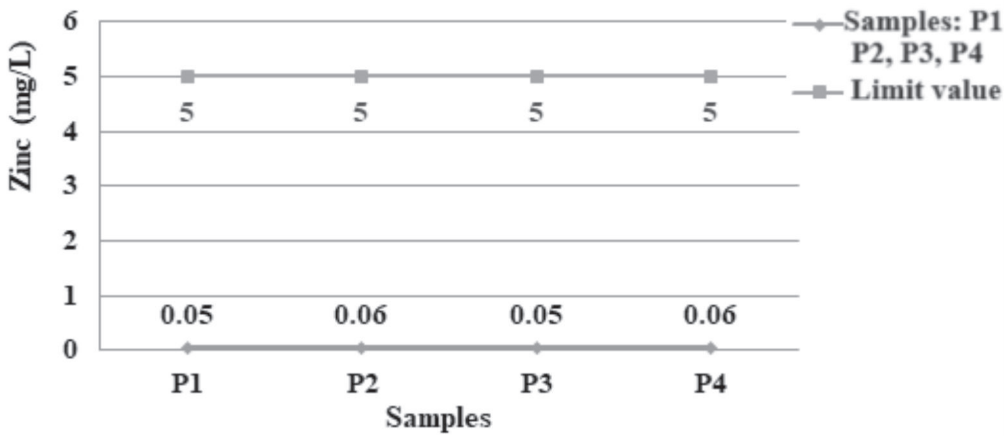

Fig. 11. Zinc concentration variation.

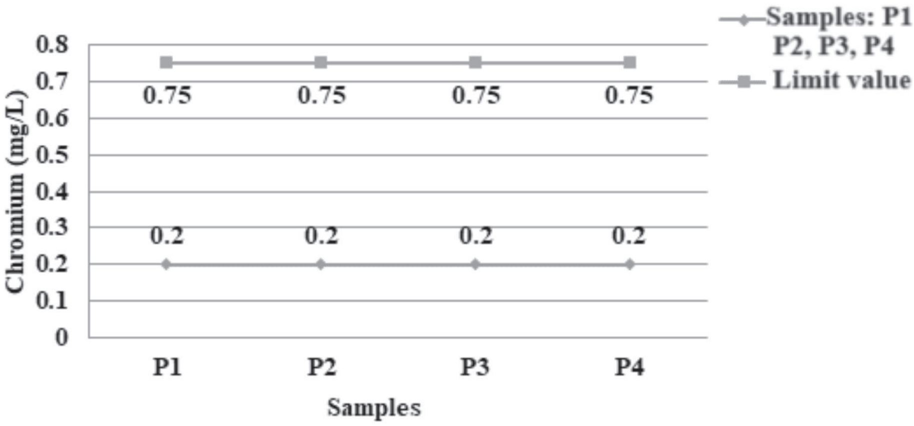

Fig. 12. Chromium concentration variation.

– **For Chromium:** In the context of chrome, it is classified as a potential carcinogen for human health, with documented concerns regarding its adverse impact on the environment, as supported by references [63-66]. This designation highlights the risks associated with chromium exposure, both in terms of its health effects and potential harm to the natural surroundings, as per the referenced sources.

Findings: In Fig 12., we can observe a graphical depiction of diverse sample results, each correlating with the measured parameter: the concentration of chromium expressed in milligrams per liter (mg/L). Notably, the outcomes of these chromium samples consistently show that the chromium concentration remains comfortably below the established limit of 0.2 mg/L across all sampled instances. This data underscores the safety and adherence to regulatory standards in chromium levels for the given samples, indicating a minimal presence of this element in the examined substances.

Conclusions

The rejection of sewage has a significant impact on the environment and human health. These rejections, coming from various sources such as pharmaceutical industries, often contain potentially dangerous contaminants for human life and human health, also harmful to the environment. Henceforth, effluents released by these industries must undergo treatment to comply with discharge standards. When sewage is discharged into aquatic ecosystems, it can alter water quality, disrupt biological balances, and compromise local biodiversity. Chemical substances found in sewage, such as heavy metals, industrial chemicals, and persistent organic compounds, can accumulate in living organisms, leading to adverse effects on their health and reproduction.

Furthermore, sewage from pharmaceutical industries can contaminate drinking water sources, thereby exposing populations to health risks. The contaminants present, such as pathogens, pharmaceuticals, and toxic chemicals, can cause illnesses in humans, including gastrointestinal infections, respiratory issues, and long-term toxic effects. So it is important to note that the effects of heavy metals can vary depending on the type of metal, its concentration, the duration and route of exposure, as well as individual sensitivity. The most vulnerable populations, such as children and pregnant women, are particularly sensitive to the effects of heavy metals on health. It is therefore essential to require industrial companies to implement effective sewage treatment measures to minimize the negative impacts on the environment and health. This includes the use of advanced treatment technologies such as reverse osmosis, membrane filtration, and biological processes to remove contaminants from sewage before they are discharged into ecosystems.

Additionally, strict regulations and appropriate environmental standards must be established and enforced to control industrial and municipal sewage discharge. Enterprises and public authorities should also promote source reduction, reuse, and sewage recycling to minimize the quantity of contaminants generated. Finally, by adopting a comprehensive approach to sewage management, with a focus on environmental and human health protection, we can safeguard our aquatic ecosystems, guarantee access to clean and safe water, and build a sustainable future for generations to come.

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Conflict of Interest

The authors declare no conflict of interest.

References

1. BULLO T.A., BAYISA Y.M. Optimizing the removal efficiency of chromium from tanning plant effluent by adsorption method with activated carbon chat stems (catha edulis) using response surface methodology. Water Conser. Manag. (WCM), **6** (1), 15, **2022**.
2. SATTAR A.A. Preparation of novel hybrid (almond shell and pleurotus sajor caju) biosorbent for the removal of heavy metals (nickel and lead) from wastewater. Water Conservation and Management, **5** (1), 1, **2021**.
3. BOUZERARA R., CHAIB R., VERZEA I. Contribution to the analysis of the impact of hazardous chemicals on employee health case study: Company SARL EL CHAFEK (Algeria). Ukrainian Journal of Ecology, **12** (1), 54, **2022**.
4. BOUAZZA G., SOUABI S., MADINZI A., CHATRI E.H. Optimization of the color corresponding to the different absorbencies of tannery wastewater by response surface designs. Water Conservation & Management (WCM), **6** (2), 99, **2022**.
5. KAHOUL H., CHAIB R., VERZEA I., BELHOUR S. Impact of industrial activities on the environment. Case study: ALEMO Company, Algeria. Acta Technica Napocensis-Series: Applied Mathematics, Mechanics, and Engineering, **64** (2), **2021**.
6. ZHANG Q., WANG C. Natural and human factors affect the distribution of soil heavy metal pollution: a review. Water, air & soil pollution, **231**, pp. 1, **2020**.
7. SINGH R L., SINGH P. K. Global environmental problems. Principles and applications of environmental biotechnology for a sustainable future, pp. 13, **2017**.
8. MANISALIDIS I., STAVROPOULOU E., STAVROPOULOS A., BEZIRTZOGLOU E. Environmental and health impacts of air pollution: a review. Frontiers in public health, **8** (14), **2020**.
9. LEZZI M., LAZOI M., CORALLO A. Cybersecurity for Industry 4.0 in the current literature: A reference framework. Computers in Industry, **103**, 97, **2018**.
10. BOTTELBERGHS P. H. Risk analysis and safety policy developments in the Netherlands. Journal of Hazardous Materials, **71** (1-3), 59, **2000**.
11. BOUDIAF M., CHAIB R., FREDJ M. Assessment of potential dangers of installations at rhourde nouss station within the framework of the law 45/DG, Ouargla, Algeria. Natsional'nyi Hirnychyi Universytet. Naukovyi Visnyk, **2**, 145, **2021**.
12. ZUCCATO E., CASTIGLIONI S., FANELLI R., REITANO G., BAGNATI R., CHIABRANDO C., CALAMARI D. Pharmaceuticals in the environment in Italy: causes, occurrence, effects and control. Environmental Science and Pollution Research, **13**, 15, **2006**.
13. AUS D.B.T., WEBER F.A., BERGMANN A., HICKMANN S., EBERT I., HEIN A., KÜSTER A. Pharmaceuticals in the environment-Global occurrences and perspectives. Environmental toxicology and chemistry, **35** (4), 823, **2016**.
14. BASHIR I., LONE F.A., BHAT R.A., MIR S.A., DAR Z.A., DAR S.A. Concerns and threats of contamination on aquatic ecosystems. Bioremediation and biotechnology: sustainable approaches to pollution degradation, pp. 1, **2020**.
15. LI W.C. Occurrence, sources, and fate of pharmaceuticals in aquatic environment and soil. Environmental pollution, **187**, 193, **2014**.
16. HU J., ZHAO L., LUO J., GONG H., ZHU N. A sustainable reuse strategy of converting waste activated sludge into biochar for contaminants removal from water: Modifications, applications and perspectives. Journal of Hazardous Materials, **438**, 129437, **2022**.
17. BOTTONI P., CAROLI S., CARACCIOLO A.B. Pharmaceuticals as priority water contaminants. Toxicological & Environmental Chemistry, **92** (3), 549, **2010**.
18. KAYODE-AFOLAYAN S.D., AHUEKWE E.F., NWINYI O.C. Impacts of pharmaceutical effluents on aquatic ecosystems. Scientific African, **17**, e01288, **2022**.
19. YADAV D., RANGABHASHIYAM S., VERMA P., SINGH P., DEVI P., KUMAR P., KUMAR K.S. Environmental and health impacts of contaminants of emerging concerns: Recent treatment challenges and approaches. Chemosphere, **272**, 129492, **2021**.
20. LÓPEZ-PACHECO I.Y., SILVA-NÚÑEZ A., SALINAS-SALAZAR C., ARÉVALO-GALLEGOS A., LIZARAZO-HOLGUIN L.A., BARCELÓ D., PARRA-SALDÍVAR R. Anthropogenic contaminants of high concern: Existence in water resources and their adverse effects. Science of the Total environment, **690**, 1068, **2019**.
21. PATNEEDI C.B., PRASADU K.D. Impact of pharmaceutical wastes on human life and environment. Rasayan journal of chemistry, **8** (1), 67, **2015**.
22. BIELEN A., ŠIMATOVIĆ A., KOSIĆ-VUKŠIĆ J., SENTA I., AHEL M., BABIĆ S., UDIKOVIĆ-KOLIĆ N. Negative environmental impacts of antibiotic-contaminated effluents from pharmaceutical industries. Water research, **126**, 79, **2017**.
23. SUNDARARAMAN S., KUMAR J.A., DEIVASIGAMANI P., DEVARAJAN Y. Emerging pharma residue contaminants: Occurrence, monitoring, risk and fate assessment–A challenge to water resource management. Science of the Total Environment, **825**, 153897, **2022**.
24. NÉSTOR M. C., MARIANA C. Impact of pharmaceutical waste on biodiversity. Ecopharmacovigilance: Multidisciplinary Approaches to Environmental Safety of Medicines, pp. 235, **2019.**
25. STADLER L.B., DELGADO VELA J., JAIN S., DICK G.J., LOVE N.G. Elucidating the impact of microbial community biodiversity on pharmaceutical biotransformation during wastewater treatment. Microbial biotechnology, **11** (6), 995, **2018.**
26. HAMDHANI H., EPPEHIMER D.E., BOGAN M.T. Release of treated effluent into streams: A global review of ecological impacts with a consideration of its potential use for environmental flows. Freshwater Biology, **65** (9), 1657, **2020.**
27. DULSAT-MASVIDAL M., CIUDAD C., INFANTE O., MATEO R., LACORTE S. Water pollution threats in important bird and biodiversity areas from Spain. Journal of Hazardous Materials, **448**, 130938, **2023**.
28. ILYAS M., AHMAD W., KHAN H., YOUSAF S., YASIR M., KHAN A. Environmental and health impacts of industrial wastewater effluents in Pakistan: a review. Reviews on environmental health, **34** (2), 171, **2019**.
29. GURUMURTHY J.V., RAYUDU E.S. A study on index properties of alkaline soils treated with pharmaceutical industrial effluents. International Journal of Civil Engineering and Technology, **10** (05), **2019**.
30. PATNEEDI C.B., PRASADU K.D. Impact of pharmaceutical wastes on human life and environment. Rasayan journal of chemistry, **8** (1), 67, **2015**.

31. GARG S., CHOWDHURY Z.Z., FAISAL A.N.M., RUMJIT N.P., THOMAS P. Impact of industrial wastewater on environment and human health. Advanced Industrial Wastewater Treatment and Reclamation of Water: Comparative Study of Water Pollution Index during Pre-industrial, Industrial Period and Prospect of Wastewater Treatment for Water Resource Conservation, pp. 197, **2022**.
32. MOHAN S., SRUTHY S. Human health risk assessment due to solvent exposure from pharmaceutical industrial effluent: Deterministic and probabilistic approaches. Environmental Processes, **9** (1), 18, **2022**.
33. SARAVANAKUMAR K., DE SILVA S., SANTOSH S.S., SATHIYASEELAN A., GANESHALINGAM A., JAMLA M., WANG M.H. Impact of industrial effluents on the environment and human health and their remediation using MOFs-based hybrid membrane filtration techniques. Chemosphere, **307**, 135593, **2022**.
34. OKORO H.K., OROSUN M.M., ORIADE F.A., MOMOH-SALAMI T.M., OGUNKUNLE C.O., ADENIYI A.G., NGILA J.C. Potentially toxic elements in pharmaceutical industrial effluents: a review on risk assessment, treatment, and management for human health. Sustainability, **15** (8), 6974, **2023**.
35. BIELEN A., ŠIMATOVIĆ A., KOSIĆ-VUKŠIĆ J., SENTA I., AHEL M., BABIĆ S., UDIKOVIĆ-KOLIĆ, N. Negative environmental impacts of antibiotic-contaminated effluents from pharmaceutical industries. Water research, **126**, 79, **2017**.
36. ACHOUR B., BENMERKHI M. Sécurité hydrique et rejets des eaux usées: Etude de cas d'une industrie pharmaceutique: Mémoire de Master II, Filière Hygiène et Sécurité Industrielle, Spécialité Hygiène et Sécurité Industrielle de l'université Constantine1, Frères Mentouri, Algérie juin **2023.**
37. CREMER J., ARNOLDINI M., HWA T. Effect of water flow and chemical environment on microbiota growth and composition in the human colon. Proceedings of the National Academy of Sciences, **114** (25), 6438, **2017.**
38. MARAMBIO-JONES C., HOEK, E.M. A review of the antibacterial effects of silver nanomaterials and potential implications for human health and the environment. Journal of nanoparticle research, **12**, pp. 1531, **2010**.
39. PRAMBUDY H., SUPRIYATIN T., SETIAWAN F. The testing of chemical oxygen demand (COD) and biological oxygen demand (BOD) of river water in Cipager Cirebon. In Journal of Physics: Conference Series **1360** (1), 012010, **2019**.
40. TAO H., BOBAKER A.M., RAMAL M.M., YASEEN Z.M., HOSSAIN M.S., SHAHID S. Determination of biochemical oxygen demand and dissolved oxygen for semi-arid river environment: application of soft computing models. Environmental Science and Pollution Research, **26** (1), 923, **2019**.
41. XU J., JIN G., MO Y., TANG H., LI L. Assessing anthropogenic impacts on chemical and biochemical oxygen demand in different spatial scales with bayesian networks. Water, **12** (1), 246, **2020**.
42. LI J., LUO G., HE L., XU J., LYU J. Analytical approaches for determining chemical oxygen demand in water bodies: a review. Critical reviews in analytical chemistry, **48** (1), 47, **2018**.
43. GEERDINK R.B., VAN DEN HURK R.S., EPEMA O.J. Chemical oxygen demand: Historical perspectives and future challenges. Analytica Chimica Acta, **961**, 1, **2017**.
44. SALIH S.Q., ALAKILI I., BEYAZTAS U., SHAHID S., YASEEN Z.M. Prediction of dissolved oxygen, biochemical oxygen demand, and chemical oxygen demand using hydrometeorological variables: case study of Selangor River, Malaysia. Environment, Development and Sustainability, **23** (5), 8027, **2021**.
45. ZENG J., HAN G., WU Q., TANG, Y. Heavy metals in suspended particulate matter of the Zhujiang River, southwest China: contents, sources, and health risks. International Journal of Environmental Research and Public Health, **16** (10), 1843, **2019**.
46. JOLLIET O., ANTÓN A., BOULAY A.M., CHERUBINI F., FANTKE P., LEVASSEUR A., FRISCHKNECHT R. Global guidance on environmental life cycle impact assessment indicators: impacts of climate change, fine particulate matter formation, water consumption and land use. The International Journal of Life Cycle Assessment, **23**, 2189, **2018**.
47. ABUBAKAR A.M., SILAS K., AJI M.M. An elaborate breakdown of the essentials of biogas production. Journal of Engineering Research and Sciences, **1** (4), 93, **2022**.
48. SOMERVILLE C., COHEN M., PANTANELLA E., STANKUS A., LOVATELLI A. Small-scale aquaponic food production: integrated fish and plant farming. FAO Fisheries and aquaculture technical paper, **589**, I, **2014**.
49. AWASTHI G., NAGAR V., MANDZHIEVA S., MINKINA T., SANKHLA M.S., PANDIT P.P., SRIVASTAVA S. Sustainable amelioration of heavy metals in soil ecosystem: Existing developments to emerging trends. Minerals, **12** (1), 85, **2022**.
50. CHIARELLI R., ROCCHERI M.C. Marine invertebrates as bioindicators of heavy metal pollution. repository. embuni.ac.ke, **2014**.
51. MATHUMITHA C., MOHAN RAJ V., SANGEETHA R., SUSAN G., RAGUMARAN M. A review on the effect of heavy metal contamination and its impact on the environment. Intern. J. Zool. Invest, **7** (2), 762, **2021**.
52. SHAH S.B. Heavy metals in the marine environment - an overview. Heavy Metals in Scleractinian Corals, pp. 1, **2021**.
53. GENCHI G., SINICROPI M. S., LAURIA G., CAROCCI A., CATALANO A. The effects of cadmium toxicity. International journal of environmental research and public health, **17** (11), 3782, **2020**.
54. MEZYNSKA M., BRZÓSKA M. M. Environmental exposure to cadmium – A risk for health of the general population in industrialized countries and preventive strategies. Environmental Science and Pollution Research, **25**, 3211, **2018**.
55. POHANKA M. Copper and copper nanoparticles toxicity and their impact on basic functions in the body. Bratisl. Lek. Listy, **120** (6), 397, **2019**.
56. KUMAR V., PANDITA S., SIDHU G.P.S., SHARMA A., KHANNA K., KAUR P., SETIA R. Copper bioavailability, uptake, toxicity and tolerance in plants: A comprehensive review. Chemosphere, **262**, 127810, **2021**.
57. RAHMAN Z., SINGH V.P. The relative impact of toxic heavy metals (THMs) (arsenic (As), cadmium (Cd), chromium (Cr) (VI), mercury (Hg), and lead (Pb) on the total environment: an overview. Environmental monitoring and assessment, **191**, 1, **2019**.
58. OBIORA S.C., CHUKWU A., CHIBUIKE G., NWEGBU, A.N. Potentially harmful elements and their health implications in cultivable soils and food crops around lead-zinc mines in Ishiagu, Southeastern Nigeria. Journal of Geochemical Exploration, **204**, 289, **2019**.

59. GENCHI G., CAROCCI A., LAURIA G., SINICROPI M.S., CATALANO A. Nickel: Human health and environmental toxicology. International journal of environmental research and public health, **17** (3), 679, **2020**.
60. HARASIM P., FILIPEK T. Nickel in the environment. Journal of Elementology, **20** (2), **2015**.
61. GEVERA P.K., CAVE M., DOWLING K., GIKUMA-NJURU P., MOURI H.A review on the occurrence of some potentially harmful elements in the natural environment and their health implications: examples of fluoride, iron and salinity in the South-Eastern Kenya region. Practical Applications of Medical Geology, pp. 637, **2021**.
62. LEI C., SUN Y., TSANG D.C., LIN D. Environmental transformations and ecological effects of iron-based nanoparticles. Environmental Pollution, **232**, 10, **2018**.
63. OBIORA S.C., CHUKWU A., CHIBUIKE G., NWEGBU A.N. Potentially harmful elements and their health implications in cultivable soils and food crops around lead-zinc mines in Ishiagu, Southeastern Nigeria. Journal of Geochemical Exploration, **204**, 289, **2019**.
64. TEHRANI G.F., RUBINOS D.A., KELM U., GHADIMI S. Environmental and human health risks of potentially harmful elements in mining-impacted soils: A case study of the Angouran Zn–Pb Mine, Iran. Journal of Environmental Management, **334**, 117470, **2023**.
65. PRASAD S., YADAV K.K., KUMAR S., GUPTA N., CABRAL-PINTO M.M., REZANIA S., ALAM J. Chromium contamination and effect on environmental health and its remediation: A sustainable approaches. Journal of Environmental Management, **285**, 112174, **2021**.
66. COETZEE J.J., BANSAL N., CHIRWA E.M. Chromium in environment, its toxic effect from chromite-mining and ferrochrome industries, and its possible bioremediation. Exposure and health, **12**, 51, **2020**.