IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Assessment of Physico-Chemical Parameters and Heavy Metal Contamination in Petroleum Refinery Samples

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Abstract

The discharge of contaminant effluents from industries and municipalities into water bodies has led to serious environmental stress, raising concerns about human health, environmental sustainability, and conservation. Industrial effluents carry harmful chemicals and heavy metals, such as Pb, Ni, Cr, Zn, Cd, Fe, Co, and Cu, posing a significant threat to life. This research focuses on assessing the physico-chemical parameters and heavy metal contamination in a petroleum refinery effluent. Four agricultural waste precursors - coconut shell, corn cob, rice husk, and sugarcane bagasse - were employed as activated carbon for the remediation process. The study evaluated the removal efficiency of physico-chemical parameters, including alkalinity, pH, acidity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), and turbidity. Additionally, heavy metals such as chromium, cadmium, copper, nickel, lead, and zinc were investigated. The findings revealed significant removal efficiencies for the physico-chemical parameters using the different activated carbon precursors. Coconut shell activated carbon demonstrated removal percentages of 43% for BOD, 90% for COD, and 79% for turbidity. Similarly, corn cob activated carbon exhibited removal efficiencies of 59%, 90%, and 85% for BOD, COD, and turbidity, respectively. Rice husk and sugarcane bagasse activated carbons recorded removal percentages ranging from 80% to 93% for BOD, COD, and turbidity. This research underscores the potential of utilizing agricultural waste precursors as activated carbon for effective remediation of petroleum refinery effluent. The findings contribute valuable insights to the development of sustainable and eco-friendly approaches to address water pollution. However, further optimization and exploration of different effluents and contaminants are necessary to unlock the full potential of these agricultural waste-derived activated carbons for broader environmental applications.

Key Words: Refinary, physico chemical, agriculture waste

Introduction

Wastewater pollution, characterized by the presence of organic compounds, inorganic substances, and heavy metals, poses a significant threat to the environment. The indiscriminate use of fertilizers, pesticides, and unchecked waste disposal exacerbates the problem. Industries, including oil refineries, contribute to the discharge of harmful pollutants into water bodies, disrupting aquatic ecosystems. Heavy metals like lead, chromium, and mercury are particularly hazardous. This urgent need for safe and cost-effective heavy metal removal has led to the exploration of activated carbon as an efficient adsorbent. This introduction emphasizes the critical importance of sustainable wastewater treatment to protect the environment and human well-being.

Activated carbon, a versatile material used for various applications, can be classified based on particle size into three main types: Powdered Activated Carbon (PAC), Granular Activated Carbon (GAC), and Activated Carbon Fibers (ACF). PAC consists of particles smaller than 0.1 mm, while GAC ranges from 0.6 to 4 mm in size. PAC is commonly used in wastewater treatment, flue gas stream purification, and the food and pharmaceutical industries. GAC, with its larger particle size, is used in both liquid and gas phase applications and can be regenerated and reused multiple times. On the other hand, ACF is made from pyrolyzed carbons and heat-treated in an oxidizing atmosphere, and its unique isotropic nature makes it a valuable material.

Activated carbon possesses diverse pore sizes and surface characteristics, making it an effective adsorbent. Various analytical methods, such as X-ray analysis and spectroscopy, help determine its porosity and surface properties. Activated carbon finds wide applications in water and wastewater treatment, air purification, chemical industries, and gas-phase processes. It is highly utilized for adsorbing pollutants from both aqueous and gas phases. However, heavy metal contamination remains a significant environmental concern, as these toxic compounds cannot be biologically degraded and pose health risks to humans. Traditional methods for heavy metal removal are costly and inefficient. To address this, research focuses on utilizing low-cost agricultural biomass, like neem bark, oil palm shell, rice husk, and others, to produce cost-effective activated carbon for heavy metal remediation. This study aims to investigate the potential of such cheap adsorbents to treat heavy metal-contaminated wastewater.

Materials and Methods

The materials and methods used in this research involved the collection of agricultural biomass, such as coconut shell, sugarcane bagasse, corn cobs, and rice husk, from various sources. Oil refinery wastewaters were obtained from the Indian Oil and Petroleum Company Ltd. The activated carbon (AC) preparation process included sun-drying, grinding, and carbonizing the precursors in a muffle furnace. Impregnation with different chemicals and heating at various temperatures were performed to enhance the adsorptive properties of the activated carbon. The final products were characterized using Fourier Transform Infrared (FTIR) spectroscopy, X-ray diffraction, and Atomic Absorption Spectrophotometer to analyze surface chemistry, crystalline structure, and heavy metal content, respectively. Yield and bulk density of the activated carbon were also calculated. Wastewater samples were collected and analyzed for various parameters, including BOD, COD, turbidity, pH, alkalinity, acidity, total suspended solids, total dissolved solids, and heavy metals. The experimental procedures for BOD and COD determination involved incubation and titration methods, respectively. The acidity and alkalinity of the samples were determined through titration with appropriate indicators. The total dissolved and suspended solids were assessed through evaporation and filtration. These methods allowed the researchers to evaluate the effectiveness of the agricultural-based activated carbon in removing pollutants from wastewater.

RESULTS AND DISCUSSIONS

OIL REFINERY EFFLUENT

The physico-chemical characteristics of the effluent as analyzed in the laboratory were presented in the table below.

Table 1.Physico-chemical parameters of oil refinery effluent

S.no.	Parameter	Value
1	pH	9-10
2	Acidity	4 mg/L
3	Alkalinity	344 mg/L
4	Turbidity	93 NTU
5	BOD	75 mg/L
6	COD	620 mg/L
7	Total Solid (TS)	1400 mg/L
8	TDS	1000 mg/L

Table 2. ACTIVATED CARBON CHARACTERIZATION.

The various properties the activated carbon produce such as bulk density, yield, moisture content, ash content etc. are described in the below table.

S/N	Parameters	Coconut shell	Corn Cobs	Rice Husk	Sugarcane
1	Bulk density (g/cm3)	**0.667**	**0.444**	**0.400**	**0.333**
2	Yield (%)	**91.55**	**91.94**	**77.10**	**84.44**
3	Iodine number (mg/g)	**1397**	**1129**	**1312**	**1128**
4	Ash content (%)	**8.45**	**8.06**	**22.90**	**15.56**
5	Moisture content (%)	**<1**	**<1**	**<1**	**<1**
6	Particle size (µm)	**>150**	**>150**	**>150**	**>150**

Table 3.Heavy Metals in oil refinery effluent.

Heavy metals as obtained from the effluent after analysis are given in the table below.

S.No.	PARAMETER	VALUE
1	Cadmium (Cd)	0.015
2	Chromium (Cr)	0.210
3	Copper (Cu)	0.740
4	Lead (Pb)	0.030
5	Nickel (Ni)	0.304
6	Zinc (Zn)	1.130

Table 4. Physico-chemical effluent characteristics after treatment (600°C)

The effluent treatment for various physico-chemical parameters using the different activated carbons (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) at different impregnation ratios and temperature of 600°C are as presented in the underneath

		Coconut Shell			Corn Cobs			Rice Husk			SC Bagasse		
S/N	**Parameter**	**CS 1**	**CS 1.5**	**CS 2**	**CC 1**	**CC 1.5**	**CC 2**	**RH 1**	**RH 1.5**	**RH 2**	**SB 1**	**SB 1.5**	**SB 2**
1	pH	8	8	7.9	7.8	7.9	8	7.0	6.7	6.5	6.7	6.8	6.9
2	Alkalinity	120	100	100	200	240	200	100	80	64	120	100	60
3	Turbidity	27	23	20	15	13	14	11	9	9	8	8	8
4	BOD	0	0	0	0	7.5	7.5	5	0	2.5	5	0	0
5	COD	384	352	352	320	320	256	96	192	192	224	256	128
6	TS	1000	1000	1000	1000	1000	800	800	600	600	800	800	600
7	TDS	900	700	800	800	800	800	700	800	600	600	700	600
8	TSS	100	300	200	200	200	200	100	0	0	200	100	0

Table 5.Heavy metal effluent characteristics after treatment (600ºC).

The wastewater treatment for various heavy metal parameters using the different activated carbons (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) at different impregnation ratios and temperature of 600ºC are as presented in the below.

		Coconut Shell		Corn Cobs		Rice Husk			SC Bagasse				
S/N	**Parameter**	**CS 1**	**CS 1.5**	**CS 2**	**CC 1**	**CC 1.5**	**CC 2**	**RH 1**	**RH 1.5**	**RH 2**	**SB 1**	**SB 1.5**	**SB 2**
1	**(Cd)**	0.011	0.0006	0.0003	0.0014	0.0006	0.0003	0.0009	0.0003	0.0001	0.0012	0.0007	0.00
2	**(Cr)**	0.0294	0.0252	0.0189	0.0294	0.0392	0.0189	0.0315	0.0252	0.0210	0.0399	0.0294	0.021
3	**(Cu)**	0.126	0.111	0.081	0.096	0.074	0.037	0.074	0.052	0.030	0.089	0.067	0.044
4	**(Pb)**	0.0018	0.0012	0.0003	0.0045	0.0027	0.0021	0.0027	0.0012	0.0003	0.0015	0.0006	0.00
5	**(Ni)**	0.073	0.072	0.055	0.055	0.040	0.033	0.058	0.043	0.031	0.055	0.040	0.031
6	**(Zn)**	0.237	0.226	0.181	0.124	0.091	0.057	0.147	0.113	0.091	0.102	0.079	0.045

Table 6. Physico-chemical effluent characteristics after treatment (550ºC)

The effluent treatment for various physico-chemical parameters using the different activated carbons (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) at different impregnation ratios and temperature of 550ºC are as presented in the below.

		Coconut Shell			Corn Cobs			Rice Husk			SC Bagasse		
S/N	**Parameter**	**CS 1**	**CS 1.5**	**CS 2**	**CC 1**	**CC 1.5**	**CC 2**	**RH 1**	**RH 1.5**	**RH 2**	**SB 1**	**SB 1.5**	**SB 2**
1	pH	8.19	8.19	8.17	8.29	8.36	8.31	7.0	7.29	6.56	7.00	6.99	6.50
2	Alkalinity	120	120	112	208	240	240	80	120	64	100	80	60
3	Turbidity	27	29	22	13	14	13	9	10	9	9	9	8
4	BOD	0	0	0	0	0	0	0	0	0	5	5	2.5
5	COD	416	416	416	416	416	416	352	416	416	416	416	416
6	TS	800	800	600	1200	1200	1100	700	700	600	1000	1000	900
7	TDS	700	700	600	900	900	900	700	700	600	900	900	900

Table 7.Heavy metal effluent characteristics after treatment (550ºC).

The wastewater treatment for various heavy metal parameters using the different activated carbons (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) at different impregnation ratios and temperature of 550ºC are as presented in the below.

		Coconut Shell			Corn Cobs			Rice Husk			SC Bagasse		
Seria	**Parameters**	**CS 1**	**CS 1.5**	**CS 2**	**CC 1**	**CC 1.5**	**CC 2**	**RH 1**	**RH 1.5**	**RH 2**	**SB 1**	**SB 1.5**	**SB 2**
1	**Cadmium (Cd)**	0.0020	0.0017	0.0014	0.0029	0.0020	0.0015	0.0021	0.0017	0.00075	0.0023	0.0018	0.0014
2	**Chromium (Cr)**	0.0399	0.0357	0.0252	0.0798	0.0672	0.0630	0.0462	0.0420	0.0357	0.0525	0.0462	0.0357
3	**Copper (Cu)**	0.163	0.148	0.111	0.215	0.163	0.133	0.148	0.104	0.089	0.133	0.118	0.096
4	**Lead (Pb)**	0.0036	0.0030	0.0018	0.0090	0.0069	0.0060	0.0045	0.0039	0.0030	0.0030	0.0027	0.0018
5	**Nickel (Ni)**	0.103	0.088	0.064	0.094	0.088	0.079	0.097	0.091	0.076	0.082	0.067	0.058
6	**Zinc (Zn)**	0.339	0.294	0.226	0.215	0.170	0.136	0.237	0.192	0.124	0.226	0.181	0.136

Table 8. Physico-chemical effluent characteristics after treatment (500ºC)

The effluent treatment for various physico-chemical parameters using the different activated carbons (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) at different impregnation ratios and temperature of 500ºC are as presented in the below.

		Coconut Shell			**Corn Cobs**			**Rice Husk**			**SC Bagasse**		
S/N	**parameter**	**CS 1**	**CS 1.5**	**CS 2**	**CC 1**	**CC 1.5**	**CC 2**	**RH 1**	**RH 1.5**	**RH 2**	**SB 1**	**SB 1.5**	**SB 2**
1	pH	8.2	8.17	8.0	8	8.1	7.9	7.4	7.2	7.0	7.0	6.8	6.9
3	Alkalinity	112	112	116	200	200	240	76	76	72	76	68	76
4	Turbidity	22	22	20	29	28	31	7	7	5	7	5	7

5	BOD	5	7.5	7.5	5	5	7.5	2.5	0	0	5	7.5	7.5
6	COD	480	512	512	480	512	512	320	320	352	320	384	352
7	TS	700	700	600	900	900	900	700	700	700	900	900	900
8	TDS	400	700	700	600	700	800	600	600	600	800	800	800
9	TSS	300	200	100	300	200	100	100	100	100	100	100	100

Table 9.Heavy metal effluent characteristics after treatment (500°C)

The wastewater treatment for various heavy metal parameters using the different activated carbons (Coconut Shell, Corn Cob, Rice Husk and Sugarcane Bagasse) at different impregnation ratios and temperature of 500°C are as presented in the below.

		Coconut Shell			Corn Cobs			Rice Husk			SC Bagasse		
S/N	**Parameter**	**CS 1**	**CS 1.5**	**CS 2**	**CC 1**	**CC 1.5**	**CC 2**	**RH 1**	**RH 1.5**	**RH 2**	**SB 1**	**SB 1.5**	**SB 2**
1	**Cadmium (Cd)**	0.003	0.0023	0.0015	0.0024	0.0021	0.0018	0.0023	0.002	0.0012	0.0027	0.0021	0.0017
2	**Chromium (Cr)**	0.042	0.042	0.0315	0.084	0.078	0.0714	0.055	0.050	0.042	0.048	0.044	0.038
3	**Copper (Cu)**	0.222	0.185	0.148	0.222	0.163	0.148	0.170	0.133	0.096	0.163	0.148	0.111
4	**Lead (Pb)**	0.0045	0.0039	0.0024	0.0096	0.0084	0.0063	0.0057	0.0048	0.0036	0.0042	0.0036	0.0027
5	**Nickel (Ni)**	0.122	0.109	0.076	0.106	0.097	0.091	0.097	0.082	0.064	0.088	0.073	0.061
6	**Zinc (Zn)**	0.339	0.305	0.283	0.226	0.192	0.158	0.294	0.226	0.158	0.215	0.170	0.147

Conclusion:

Based on the research conducted, it can be concluded that the physico-chemical parameters of the effluent sample have slightly deviated from the acceptable range. The presence of heavy metals such as cadmium, chromium, copper, lead, nickel, and zinc in the effluent is a cause for concern, as they often exceed the regulated limits. These findings suggest that the effluent requires treatment to bring its physico-chemical properties within the acceptable range and to reduce the concentration of heavy metals for safe disposal or discharge. The use of activated carbon derived from agricultural residues appears to be a promising option for the treatment of industrial effluent due to its favorable sorption properties and surface functional groups that enhance cation binding. However, further studies and optimization may be necessary to ensure efficient and effective treatment of the effluent.

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