

Eco-Friendly Remediation of Adsorbed Chlorsulfuron Herbicide via Walnut Shells Derived Activated Carbon

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ABSTRACT: Chlorsulfuron (1-(2-chlorophenyl) sulfonyl-3(4-methoxy-6-methyl-1,3,5-triazin-2-yl)) is the primary commercialized sulfonylurea weedicide aimed at combating several leafy weeds for the protection of many cereals and potato crops. It is used as a pre as well as a post-emergent weedicide. Due to its organic ringed structure, it poses serious environmental degradation, particularly in the lithospheric compartment. The present investigation has analyzed its adsorptive interactions with soils inherently composed of unique physicochemical attributes. In a batch equilibrium experiment, sample 2 expressed the highest adsorption coefficient $K_{d(ads)}$ with overall adsorption spanning over a range of 6.78 to 39.85 $\mu\text{g/mL}$. Adsorptive capacity analysis via Linear and Freundlich models yielded $R^2 > 0.8$ indicative of best fitting of these models to Chlorsulfuron adsorption. Statistical analysis showed a negative correlation between soil pH and $K_{d(ads)}$ ($R^2 = -0.85$) and a positive correlation with organic matter ($R^2 = 0.96$). The data was further analyzed by univariate ANOVA and its accuracy was checked through residual plots. Furthermore, the adsorbed Chlorsulfuron was remediated via the green method by utilization of walnut shells derived activated carbon in varying concentrations of 5 ppm and 7.5 ppm of Chlorsulfuron. The highest removal in 5 ppm was observed in soil 9 (85%) while in 7 ppm highest removal was observed in soil 2 (91%). Current investigation not only explored the adsorptive pattern of Chlorsulfuron but also developed a non-toxic, eco-friendly, pragmatic, and economical adsorbent for its removal.

KEYWORDS: Chlorsulfuron; Adsorption; Herbicide; Activated carbon; Walnut shells; FT-IR.

INTRODUCTION

Sulfonylurea herbicides (SUHs) are one of the significant groups of pesticides that are particularly prevalent because of their negligible toxicity towards mammalian cells in addition to an elevated herbicidal activity that has no adverse environmental impacts. SUHs are widespread because of their alleviated application rates i.e. 10 to 40 g ha^{-1} having being comprised of about 30 active substances [1-2]. Leafy weeds and annual

grasses are controlled by SUHs in a pre as well as post emergent mode [3-4]. Peculiar characteristic of SUHs in possessing lower toxicity to mammalian cells and higher toxicity to plant constituents is attributed to the enzymatic inhibition that is crucial for synthesis of branched chain amino acids; valine, leucine and isoleucine [5]. Hence, cellular division is disrupted and crop yield being affected by such weeds can flourish. Generally, SUHs

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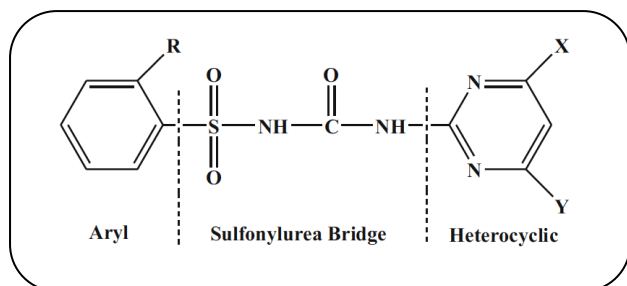


Fig. 1: General Structure of SUHs.

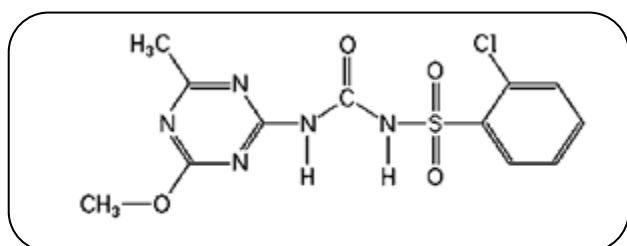


Fig. 2: Chemical structure of Chlorsulfuron weedicide.

are composed of an aryl group, the sulfonylurea bridge and a heterocyclic group that can be a symmetrical pyrimidine or atrazine group [6]. Structure of SUH is illustrated in Fig. 1. Ground as well as surficial water reserves are found with higher quantities of SUHs in places where its use is rampant due to its commendable water solubility, mobility and lower degradability [7]. Different herbicides under SUHs umbrella exhibited varied half-lives from 5-70 years depending upon herbicides' inherent qualities. However, their degradation is most often attributed to either hydrolytic or microbial degrading mechanisms which ensures the presence of metabolites for extended durations [8].

Chlorsulfuron (1-(2-chlorophenyl) sulfonyl-3(4-methoxy-6-methyl-1,3,5-triazin-2-yl)), is one of first commercialized herbicide among SUHs used as pre and post emergent for broad leaved weeds in many cereals and potato (Fig. 2). Due to its genesis being the SUHs, Chlorsulfuron also possess alleviated mammalian and environmental toxicity. Chlorsulfuron is associated with the inhibition of acetolactate synthase enzyme which is involved in amino acids production [9]. However, Chlorsulfuron when applied on crops is also partly received by underlying soil. Where it remains for years in form of either parent or daughter metabolites not only having specific positions occupied but are also percolated to lower profiles. Such behavior is governed by a myriad

of soil based factors e.g. soil organic matter presence in abundance ensures its lower mobility by developing tight interactions. Its presence in terms of years cannot be neglected since its degradation in soil is a complicated process requiring a microbial consortium and variety of suitable conditions. Similarly the photolytic or hydrolytic mechanisms will also require special conditions.

Herbicide driven contamination and environmental fate requires a thorough investigation of soils sorptive capacities upon which they are applied. In turn this phenomenon is determined via calculation of sorption co-efficients; K_d and K_f which are associated with assessment of sorption intensity. Such sorptive behavior is not only dependent upon Chlorsulfuron's physicochemical parameters but also recipient soils' characteristics. Chlorsulfuron and other SUHs are weak acids and they exist in anionic form and are adsorbed more when pH conditions of soil are lower than its pKa values that ranges between 3 to 5 [10]. Furthermore, sorption is directed by number of intermolecular forces such as Van der Waals forces, hydrogen bonding, ligand exchange, charge transfer, induced dipole and dipole-dipole interaction and chemisorption [11].

The consequent risks associated with the indiscriminate and uncontrolled use of Chlorsulfuron needs to be investigated. Since Chlorsulfuron possess a ringed structure thus it has high level persistence in soil and can cause water and soil contamination. Employment of emerging technologies for the remediation of such pollutants needs to be considered at global scale [12-13]. Remediation technologies needs to be eco-friendly in order to remove the organic pollutants. Biomass based activated carbon can be used as an environmental friendly adsorbate for removal instead of commercially available expensive activated carbon. The effectiveness of activated carbon prepared indigenously from biomass depends upon percent of carbon content [13] along with other properties including high internal surface area, resistance to degradation and negative surface charge [14]. Biomass more specifically nuts such as peanuts [15], walnuts [16], almond shells [17], date stones [18] and many other seeds [19] have high carbon content and can be effectively used as a raw material for the preparation of activated carbon [20,21].

Current study has been undertaken for evaluation of the adsorptive behavior of herbicide Chlorsulfuron

in Pakistani soils from ten different geographical locations with distinct physicochemical properties. Since Pakistan is an agrobased economy and use of SUHs is rampant for wiping out different weeds and protection of export quality crops. Despite such heavier use, the knowledge and data regarding pesticides use, fate, adverse impacts and remediation is almost nonexistent. Thus, current study has also developed a green solution for adsorptive removal of Chlorsulfuron from contaminated soils in a simplified procedure that can be adopted at larger scale.

EXPERIMENTAL SECTION

Soil sampling and Chlorsulfuron adsorption

The adsorbent utilized were soils collected from ten different geographical locations of Pakistan. The samples were collected randomly at the end of February 2017. Sampling regions exhibited an average temperature of 25 °C with no rainfall during sampling period. Sampling regions were also meticulously monitored for no previous Chlorsulfuron or any herbicidal application so that the lab based results can be used for derivation of final conclusions in single time Chlorsulfuron application. Soils were homogenized for further use and stored at ambient temperature in sterile petri dishes to be examined for their physiochemical properties (Table 1) and further experimentation through standard test methods [22]. These soil samples were labeled as S1, S2, S3, S4, S5, S6, S7, S8, S9 and S10.

Adsorption experiment was carried out by standard batch equilibrium method. For the measurement of adsorption co-efficient batch slurry method was applied, which is most commonly used in laboratories following OECD guidelines for chemical testing 1997. Different concentrations of Chlorsulfuron were obtained from stock solution in 0.1 M sodium chloride solution that acted as a background electrolyte and hence increased soil ionic strength [23]. Chlorsulfuron concentrations of 0.0, 0.25, 0.5, 0.75, 1.0, 2.5, 5.0 and 7.5 ppm were mixed with 0.5 g of each sample of soil in 15 mL centrifuge tubes and kept in orbital shaker for 24 h at room temperature. After uniform shaking, soil slurries were centrifuged at 2000 rpm for 15 minutes, the supernatants were filtered using nylon filter and analyzed by UV-spectrophotometry in the range of 190-300 nm. All experiments were done in duplicates to ensure accuracy. Linear and Freundlich

models were used to determine the adsorption capacity of Chlorsulfuron in texturally and physiochemically distinct soils.

Preparation of activated carbon

For activated carbon preparation, 500 g of walnut shells (WS) were washed for removal of any particles. WS were air dried and also dried in hot air oven at 110 °C for 48 hours for complete removal of moisture. Dried WS were ground into a fine powder first manually in pestle and mortar and then in an electrical grinder. 99.9% pure analytical grade H₂SO₄ was used for activation of WS in the equal weight by volume ratio. Acid was thoroughly mixed into WS slow and gradually with stirring to ensure better mixing inside fume hood. The reaction mixture was kept overnight to allow proper charring of acid with ground shells. To neutralize the pH of activated carbon and remove excess acid, it was thoroughly washed with cold distilled water and then with normal distilled water. Later it was soaked in a 5% sodium bicarbonate solution and left overnight. It was washed again until the pH of WS reached 7. Finally, it was kept for drying in an oven at 110 °C for 12 h for moisture removal. It was again grinded and stored in airtight glass container to be used as a green adsorbent for second phase removal followed by Chlorsulfuron adsorption [24].

FT-IR characterization

Activated carbon was analyzed using FT-IR spectrometry for investigation of active functional groups in the range of 500 to 4000 cm⁻¹, that can act as an active site for the attachment of pesticide. FT-IR spectra was obtained before preparation of activated carbon i.e. raw material (grinded walnut shells) and after preparation of activated carbon.

Removal of Chlorsulfuron by activated carbon

The removal of Chlorsulfuron in selected soil samples was performed at two concentrations of Chlorsulfuron (5ppm and 7.5 ppm). Soil, herbicide and Activated Carbon (AC) slurry was prepared by adding 0.5 g of AC. UV absorbance was checked immediately after setting up the experiment and after 3 and 6 hours. The Chlorsulfuron removal was assessed from the change in the absorbance by UV-Vis spectrophotometer and removal percentage was calculated for each soil sample.

Table 1: Physiochemical properties of selected soil samples adsorbed with Chlorsulfuron.

Samples	Location	pH	Organic matter (%)	Textural Classes			Electrical conductivity ($\mu\text{S}/\text{cm}$)	Total carbon (%)	Total N (%)
				Sand	Silt	Clay			
S1	Abbottabad	7.68	0.60	40	35	25	131.0	0.41	0.55
S2	Attock	7.32	1.25	54	36	10	143.0	1.02	1.05
S3	D.I.Khan	6.55	1.75	27	33	40	987	1.02	1.70
S4	Gilgit	7.54	1.75	47	38	15	288.0	0.64	1.70
S5	Mardan	7.50	1.10	30	48	22	231.0	0.64	1.05
S6	Rawalpindi	7.32	1.35	18	50	32	208.0	0.93	1.30
S7	Karachi	7.44	0.78	82	3.0	15	2120	0.70	0.65
S8	Pakpattan	7.22	1.99	3.0	47	50	672.0	1.02	1.20
S9	Rahim Yar Khan	8.08	1.60	55	25	20	6240	0.35	1.55
S10	Ormara	7.49	1.25	50	30	20	200.0	0.73	1.70

Data Analysis

Amount of Chlorsulfuron adsorbed $\mu\text{g}/\text{g}$ of soil is given by Eq. (1):

$$C_s = \frac{v}{m} \times C_b - C_a \quad (1)$$

Where C_s is the amount of Chlorsulfuron adsorbed, V is the Volume of solution, m is the mass of soil in grams, C_b is the equilibrium concentration of blank, and C_a is the equilibrium concentration of adsorbate.

Freundlich equation used for adsorption of Chlorsulfuron used was given by Eq. (2):

$$C_s = K_f C_e^{1/n} \quad (2)$$

Where, C_s is amount of Chlorsulfuron adsorbed $\mu\text{g}/\text{g}$, C_e is equilibrium concentration, K_f and n are constants, Equilibrium distribution constant is determined by Eq. (3)

$$K_d (\text{ads}) = \frac{C_s}{C_e} \quad (3)$$

where, K_d is the distribution constant in $\mu\text{g}/\text{mL}$, C_e is the equilibrium concentration, and

C_s is the amount of Chlorsulfuron adsorbed. K_{foc} which is Freundlich constant normalized to organic matter is given by Equation (4)

$$K_{\text{foc}} = \frac{K_f}{\% C} \times 100 \quad (4)$$

K_{OM} is given by Equation (5):

$$K_{\text{OM}} = \frac{K_d}{\% \text{om}} \times 100 \quad (5)$$

K_{OC} is given by Equation (6):

$$K_{\text{OC}} = \frac{K_d}{\% C} \times 100 \quad (6)$$

ΔG is which Gibbs free energy for adsorption in KJmol^{-1} is given by Equation (7):

$$\Delta G = -RT \ln K_{\text{OM}} \quad (7)$$

Where, R is universal gas constant, T is temperature in Kelvin, and \ln is natural log of K_{OM} .

RESULTS AND DISCUSSION

Physiochemical investigation of soils

Chlorsulfuron was applied to ten different soils in order to check the variability of adsorption in each soil. Physiochemical properties of soil samples are given in Table 1. On the basis of the investigation the pH of soil samples ranged from 6.55 to 8.08. Most samples possessed pH above 7 displaying a slight alkaline trend in all soils. Pakistani soils have been found to possess slightly alkaline pH. The Na content in soils tends to make them sodic eventually making them alkaline due to accumulation of higher amount of salts [25]. Soil organic matter in the current research ranged from 0.6 to 1.99%. The organic matter greatly influences the soil properties [26]. Soil possessing higher pH tend to carry a low organic matter percentage [27]. On the basis of textural investigation the soil sample from S7 contained the highest amount of sand content (82%). The geographical location of Karachi at the coast of Arabian sea renders the soil from this region a sandy texture [28]. The electrical

Table 2: Comparative parameters of Linear and Freundlich isotherms of Chlorsulfuron.

Samples	Location	K_d ($\mu\text{g/mL}$)	R^2	K_{OM} ($\mu\text{g/mL}$)	ΔG (KJ/mol)	K_{OC} ($\mu\text{g/mL}$)	K_f ($\mu\text{g/mL}$)	R^2	K_{foc} ($\mu\text{g/mL}$)	n_a
S1	Abbottabad	6.78	0.83	1131	-17	429	1.76	0.90	429	0.736
S2	Attock	38.3	0.89	1926	-18	3758	4.69	0.93	459	1.116
S3	D.I.Khan	13.7	0.87	786	-16	1348	2.90	0.92	284	0.860
S4	Gilgit	7.57	0.87	432	-15	398	2.55	0.92	398	1.302
S5	Mardan	22.5	0.89	2047	-18	3519	3.82	0.95	597	1.243
S6	Rawalpindi	23.3	0.84	1730	-18	2511	3.76	0.91	404	0.875
S7	Karachi	23.3	0.85	2999	-20	3341	3.77	0.92	539	0.859
S8	Pakpattan	39.8	0.90	1626	-18	308	4.78	0.94	308	0.95
S9	R.Y.Khan	11.1	0.77	698	-16	189	2.94	0.95	698	1.19
S10	Ormara	9.14	0.82	522	-15	537	2.06	0.90	121	0.712

conductivity of the soil samples ranged from 131 to 6240 $\mu\text{S/cm}$. High electrical conductivity values of soils are indicative of their saline nature [29].

Adsorption isotherms

Soils with the varied physicochemical make also exhibited a remarkably different adsorption pattern. For soils' adsorptivity determination, parameters like K_d , K_f , K_{OM} , K_{foc} , and K_{OC} have to be determined carefully. Thus present investigation has incorporated the use of Linear and Freundlich adsorption isotherms for Chlorsulfuron's adsorption in soils of different make ups. Soils' physicochemical make up played an influential role in altering the adsorption pattern of Chlorsulfuron. Linear and Freundlich adsorption parameters are shown in Table 2 while Figs. 3-4 have expressed the comparative sorption of Chlorsulfuron. Linear distribution co-efficient $K_{d(ads)}$ has ranged from 6.78- $\mu\text{g/mL}$, with highest value for S8 (39.85 $\mu\text{g/mL}$) and lowest for S1 (6.78 $\mu\text{g/mL}$). Freundlich distribution co-efficient $K_{f(ads)}$ was in complete conformity with $K_{d(ads)}$ and ranged from 4.78- 1.79 $\mu\text{g/mL}$, with highest value for S8 and lowest for S1. Results exhibits the elevating $K_{d(ads)}$ and $K_{f(ads)}$ with an increase in organic matter, organic carbon and clay content while a decrease was observed for increasing pH [30]. In the present study the maximum organic matter was found in S8 and hence the highest $K_{d(ads)}$ and $K_{f(ads)}$ values were obtained. Order of distribution constant K_d and K_f is as follows:

$$S8 > S2 > S6 > S7 > S5 > S3 > S9 > S10 > S4 > S1$$

The lowest $K_{d(ads)}$ and $K_{f(ads)}$ value in S1 can be attributed to its physiochemical properties including pH

and organic matter. A considerably high pH of 7.68 was observed in S-1 while the lowest organic matter content was found (0.6). pH and adsorption were thus found to be negatively co-related [31,32]. S1 also possessed a sandy texture and low clay content which did not provide sufficient sites for the attachment for Chlorsulfuron. Some variations in adsorption rates may be due to other physiochemical properties like S4 possessed a considerable percentage of organic matter but exhibited low value for distribution constants. This variation might be due to the presence of low clay content in S4 i.e. only 15%.

Results of present studies confirms the interaction between Chlorsulfuron and adsorbent soils to be primarily through hydrogen bonding [33] since the soils are entirely different for organic matter (range: 0.6% to 2.45%), pH (range: 7.32- 8.08) and electrical conductivity (range: 131-6240 $\mu\text{S/cm}$). Pakistani soils are lower in organic matter as reflected in present results as well, however, S2 exhibited higher organic matter and thus increased hydrophilicity while Chlorsulfuron is a hydrophobic weedicide, thus giving rise to electrostatic forces of attraction. Current findings are in complete conformity with previous results [34]. Gibbs free energy (ΔG) used for confirmation of adsorptive interaction type in terms of physisorption or chemisorption. $\Delta G < -40$ kJ/mol indicates physisorption while above it indicates chemisorption [34]. In the present study, value of ΔG ranged between -15 to 20 kJ/mol, hence it can be confirmed that Chlorsulfuron was physisorbed into soils *via* weak Van der Waal's forces and hydrogen bonding.

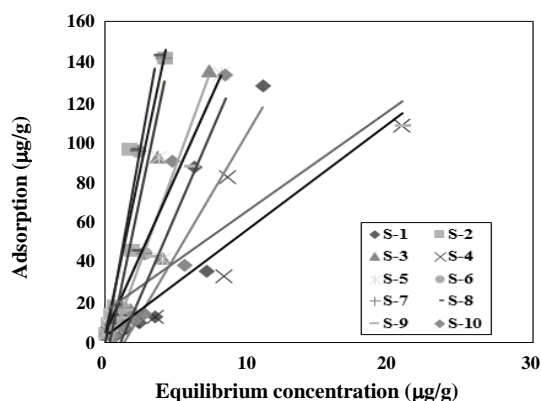


Fig. 3: Comparative Linear adsorption pattern of Chlorsulfuron.

Mobility potential of Chlorsulfuron and its relation with soil's physiochemical properties

K_{oc} is used as a mobility index to assess the leaching potential of pesticides into ground water. K_{oc} was calculated from K_d values and OC of soil samples. Organic carbon causes greater concentration of pesticides molecules onto soil particles, by this way natural aquifers can be recharged without much contamination with pesticides [34]. In the present study K_{oc} ranged from 189 to 3758 $\mu\text{g}/\text{mL}$ (Table 2), with an average of 1633 $\mu\text{g}/\text{mL}$, hence according to McCall classification [35] Chlorsulfuron shows medium to low mobility. Moreover, K_{oc} depends upon total organic matter. The soil sample having high organic matter will have greater values of K_{oc} and hence more retention time and leach less towards ground water resources. Sample S9 exhibited lowest K_{oc} value (189 $\mu\text{g}/\text{mL}$) displaying highest mobility.

Chlorsulfuron mobility into lithospheric compartment is crucial to determine since pollutants becoming part of soils are destined to leach down to underground water reserves. Though in this process, Chlorsulfuron is slowly displaced from upper soil layer to lower profiles on a geological time scale, despite this Chlorsulfuron reaching groundwater reserves pose serious toxicity. Since the remediation of surface water can be done by variety of physical, chemical and biological modes with advancements introduced every month and year, but for underground water sources remediation is expected to incur heavy costs and operational complexities. Thus, the medium to lower mobility found for Chlorsulfuron is suggestive of its use on weeds but in a controlled manner to avoid possible mentioned circumstances.

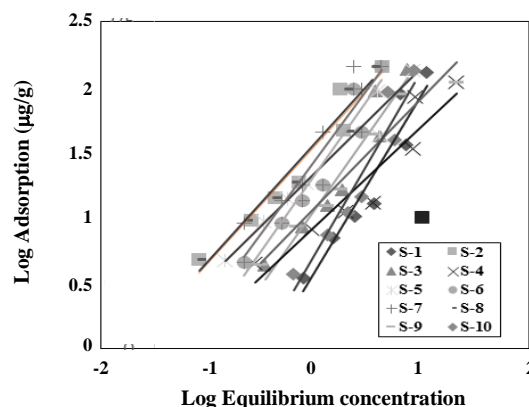


Fig. 4: Comparative Freundlich adsorption pattern of Chlorsulfuron.

Statistical Analysis

The physiochemical properties of soils and their $K_{d(ads)}$ values were evaluated statistically (Fig. 5) (Table 3). In order to analyze their relationship, regression analysis was performed, which depicted that pH was indirectly proportional to adsorption rate ($R^2 = -0.85$) while OM ($R^2 = 0.96$) and TOC ($R^2 = 0.87$) were directly proportional to adsorption. Hence, increasing OM and TOC might increase the rate of adsorption on soil while increasing pH might have inverse effect. According to the results, the soil sample with highest value of $K_{d(ads)}$ possessed the highest amount of organic matter in it. This justified the direct relation between organic matter and adsorption capacity of soil. The results were further evaluated statistically by applying univariate ANOVA in Excel and plotting residual graphs in Minitab 17 statistical software (Table 4) (Fig. 6).

FT-IR characterization

Different functional groups in activated carbon were analyzed by using FT-IR spectroscopy in the range 400 to 4000 cm^{-1} . An increase in peak positions and functional groups was observed in the sample after forming activated carbon (Fig. 7) (Table 5). These functional groups act as active sites for the pesticide attachment thus aiding in removal of Chlorsulfuron.

Removal of Chlorsulfuron by activated carbon

Chlorsulfuron contaminated soils were remediated through green adsorbent i.e. walnut shell derived activated charcoal. Chlorsulfuron removal determination was done in recipient soils through analysis after 3 and 6 h

Table 3: Linear regression & correlation for Chlorsulfuron adsorption.

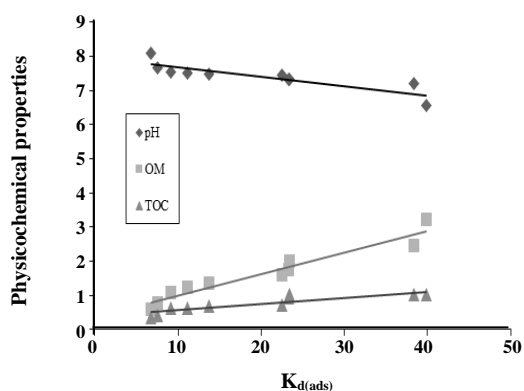
Adsorption coefficient	Property (x)	Correlation coefficient (r)	Probability level (p)	Intercept (a)	Slope (b)
$K_d(ads)$	pH	-0.85	0.0009	217	-26
	OM	0.96	0.143	-4.1	14
	TOC	0.87	0.09	-12	42

Table 4: One way ANOVA for adsorption coefficient K_d and soil physicochemical properties.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2284	3	761	20	<0.05	2.8
Within Groups	1322	36	36			

Table 5: Functional groups identified in walnut shells derived activated carbon by FT-IR.

Sr.no	Before activation by H_2SO_4		After activation by H_2SO_4	
	IR peak position	Functional Groups	IR peak position	Functional Groups
1	592.17	C-Cl stretch	590.24	C-Br stretch
2	665.46	1°,2° Amines (N-H wag)	673.18	C-Br stretch
3	802.41	C=H stretch	804.34	C-Cl stretch
4	1051.24	C=O stretch	1035.81	C-N stretch
5	1159.26	C-N stretch	1101.39	C-N stretch
6	1261.49	CH wag (-CH ₂ X)	1261.49	C-Hwag(-CH ₂ X)
7	1327.07	C-N stretch	1606.76	N-H bond 1° Amines
8	1377.22	C-N rock	1703.2	C=O stretch
9	1427.37	C-C stretch in rings	2351.3	-C≡C- stretch
10	1510.31	N-O asy stretch	2924.18	C-H Stretch
11	1745.64	C=O stretch	2962.76	C-H stretch
12	2926.11	C-H stretch	3417.98	O-H Stretch
13	3394.83	-C≡C-C:C-H stretch	---	----

**Fig. 5: Correlation of physicochemical properties of soil with K_d .**

for 5 and 7.5 ppm by UV-Vis spectrophotometer (Fig. 8). The results show that the highest removal after 3 hours and 6 hours duration in 5 ppm concentrations was from S9 (85%) (Table 6) and least removal was from S4 (47%). While in 7.5 ppm highest removal was from S2 (91%) and lowest removal was from S9 (48%) (Table 7). However, the average removal in 5 ppm concentration was 65.9% while in 7.5 ppm it was 65.3% (Figs. 9-10). Results of removal of Chlorsulfuron depicted that removal by activated carbon displayed an indirect relation with concentration of pesticide i.e. greater the concentration lower will be removal. Lesser removal

Residual plots for Kd

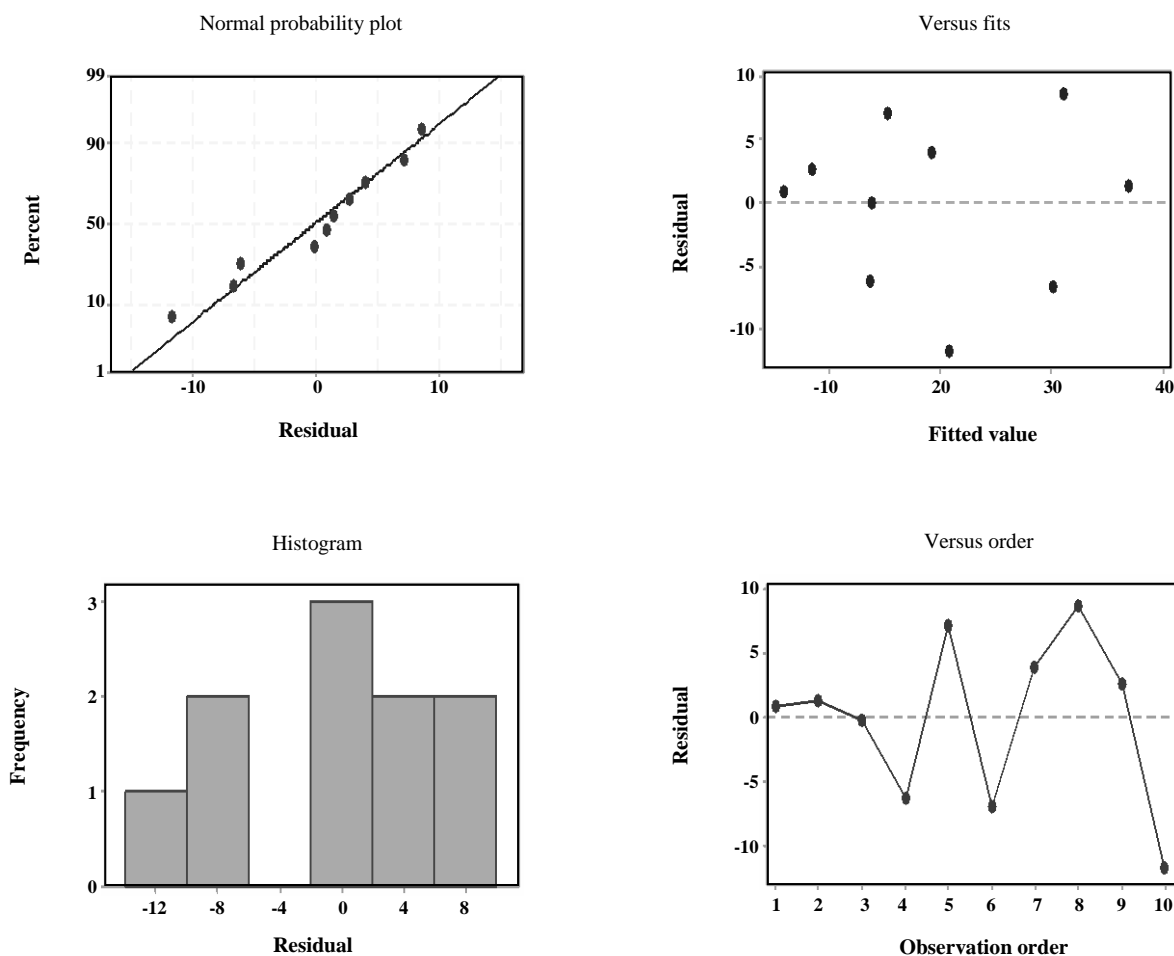


Fig. 6: ANOVA Histogram, Versus Fit, Versus Order and Normal Probability Residual plots of soil samples with physiochemical properties pH, TOC and OM while the response is K_d .

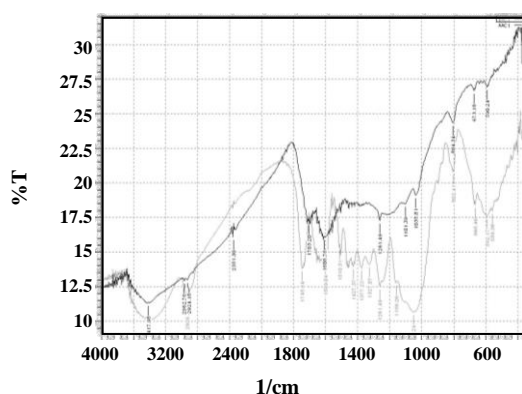


Fig. 7: FTIR spectra before and after preparation of activated carbon from walnut shells.

in high concentration is due to more molecules availability to be adsorbed on the same quantity of adsorbent (AC) as compare to the low concentration of Chlorsulfuron [36]. In the present study all soils show this trend, removal was in greater percentage in 5 ppm rather than in 7.5 ppm.

CONCLUSIONS

Soils from different regions were studied for adsorption of Chlorsulfuron along with its removal by indigenously prepared activated carbon from walnut shells. Adsorption of Chlorsulfuron to the soil is directly related to its organic matter, total organic carbon content, and clay content. High pH of soils was found to play an inverse role in the adsorption of the herbicide

Table 6: Removal results of Chlorsulfuron (5ppm).

Samples	Absorbance before addition of AC	Absorbance after 3 h	Absorbance after 6 h	Average removal	Percentage
S1	0.229	0.141	0.117	0.129	56
77S2	0.053	0.024	0.049	0.0365	68
S3	0.202	0.117	0.081	0.099	49
S4	0.175	0.116	0.051	0.0835	47
S5	0.197	0.146	0.163	0.1545	78
S6	0.079	0.067	0.02	0.0435	55
S7	0.08	0.079	0.057	0.068	84
S8	0.033	0.028	0.022	0.025	75
S9	0.105	0.097	0.083	0.09	85
S10	0.129	0.051	0.111	0.081	62

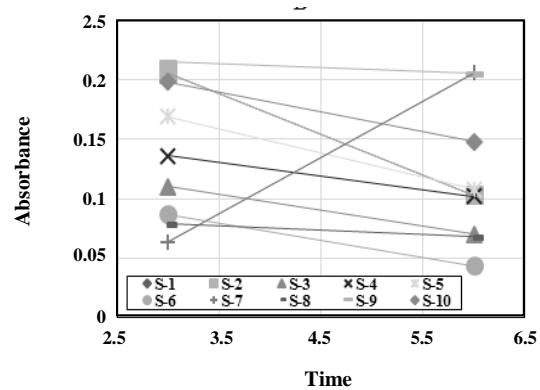
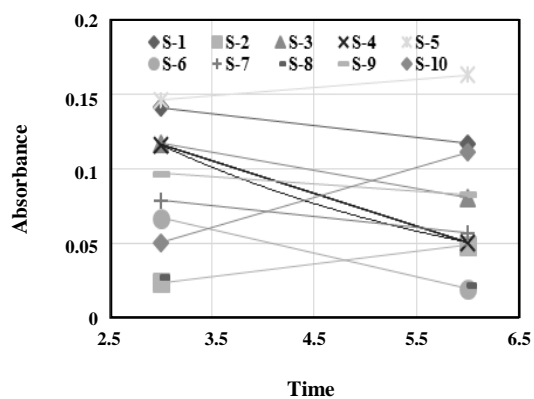
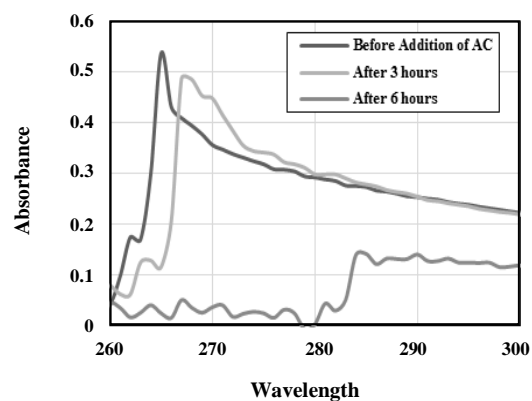
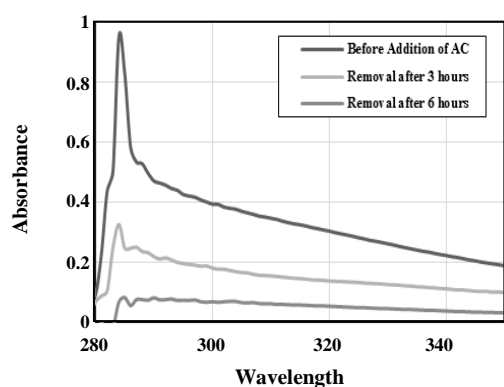
**Fig. 8: Removal graph of Chlorsulfuron (A) 5 ppm (B) 7.5 ppm.****Fig. 9: UV-Vis spectra of removal of Chlorsulfuron by activated carbon 5 ppm (A) Maximum removal (B) Minimum removal.**

Table 7: Chlorsulfuron removal from adsorbed soils (7.5ppm).

Samples	Absorbance before addition of AC	Absorbance after 3 h	Absorbance after 6 h	Average removal	Percentage
S1	0.256	0.205	0.103	0.154	60
S2	0.089	0.088	0.074	0.081	91
S3	0.158	0.11	0.07	0.09	56
S4	0.152	0.136	0.102	0.119	78
S5	0.171	0.169	0.108	0.1385	80
S6	0.115	0.087	0.044	0.0655	56
S7	0.213	0.064	0.206	0.135	63
S8	0.122	0.079	0.068	0.0735	60
S9	0.437	0.215	0.205	0.21	48
S10	0.28	0.198	0.148	0.173	61

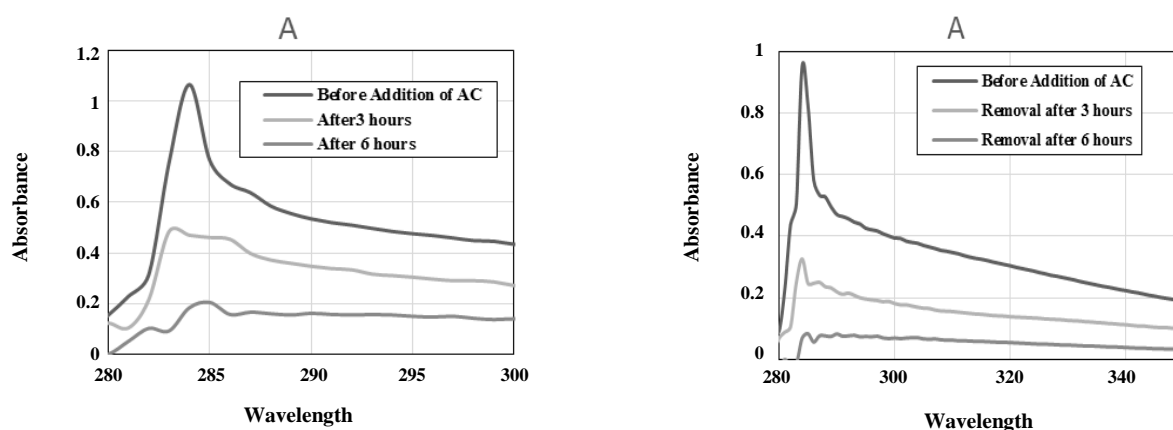


Fig. 10: UV-Vis spectra of removal of Chlorsulfuron by activated carbon at 7.5 ppm (A) Maximum removal (B) Minimum removal.

Chlorsulfuron to adsorbent soils. The research also developed an environmentally friendly method for the removal of Chlorsulfuron from the soil by using activated carbon prepared from biomass. Walnut shells based activated carbon can be used as an effective adsorbent for the number of organic pollutants. Activated carbon prepared from biomass waste such as walnuts can be effectively used rather than commercially prepared activated carbon from non-biomass sources. Current research has successfully removed the highest Chlorsulfuron quantities via prepared AC. The research utilized rudimental and uncomplicated procedure for activated carbon preparation which can easily be reproducible as well as economical.

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