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Ground Water Remediation Using Flash Graphene Produced from Banana Peels: Batch Mode

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ABSTRACT

Remediate groundwater (GW) contaminants (anions, T.D.S, Cr_6) to utilize (GW) for irrigation purposes, and implement experimental findings using adsorption technology to minimize pollutants concentration in (GW). Banana peels activated carbon (BPAC) modified to flash as-synthesized graphene (FG) adsorbent. Synthesization of (FG) by transmutation (BPAC) into graphene in a burst of light through an electro-flash reactor technique producing (5gm) of (FG) each time by exposing (BPAC) to manual circuit break of (8 - 10) shocks in the reactor. The adsorption process in batch mode remediates the (GW) samples stabilizing one parameter either (FG) dosage, agitation speed, PH value, or contact time for each experiment and varying the others. Characterization of (FG) The samples' composition is analyzed using an FTIR spectrometer, SEM, and XRD analysis. Adsorption capacity improved by creating a high internal pores structure with a powerful capacity of adsorption due to its functional surface area. (0.717 m^2/gm), and Remediation conducted for (T.D.S, SO_4, NO_3, and Cr_6) values to be proportion to Iraqi's and FAO standards of irrigation water.

1. INTRODUCTION

Water is a natural resource in need of preservation for the help of the living including human beings, plants as well as animals in their survival. Water has a paramount importance in areas of agricultural use, the economy, and some uses within the industrial sector [1]. Groundwater is an indispensable resource for economic development and human survival [2], and nearly 95% of the entire freshwater found on this planet is held in aquifers [3]. Irrigation water from the groundwater is a critical factor in the effectiveness of crops, yields of the crops, as well as the quality of the irrigated crops [4].

However, the problem with groundwater resources is that they are very much sensitive to natural anthropogenic factors. One side effect of over-exploitation of the groundwater in aquifers is the depletion of source resources; the other is the direct contamination caused by industrial wastewater disposal, landfill leachate, and spillage of toxic substances, and agricultural activity can negatively affect water quality in the ground. This causes a significant threat to both humans and the environment [3]. Groundwater contamination is a global issue and can be very costly to restore. They include: Many remedial approaches are applied to the problem [5].

Different treatment technologies have been applied to the treatment of groundwater. These treatment technologies include physical, chemical, and biological technologies with varying levels of effectiveness. Some of the physical treatment processes applied to groundwater include volatilization, ultrafiltration or filtration, incineration, and adsorption [6]. Carbonaceous materials that have been studied by different groups in the area of water treatment include activated carbon, graphene, and graphene-based adsorbents including graphene oxides, reduced graphene oxides, and carbon nanotubes [7].

Graphene is a honeycomb-structured mineral that is composed of carbon molecules in sp2 that cross-pollinate and connect with other carbon molecules [8]. Graphene is notable for its superior performance and budget-friendly production and processing methods and other factors such as its being environmentally safe and not capable of existing on its own without the presence of other materials. The confirmed preceding form of graphene is the graphite crystal which is present in the interbedded coal seams or the metamorphic formations like schist and gneiss [9].

Some of these applications arise from graphene's two-dimensional structure and related band structure, making it very useful in many applications. Since its discovery, scientists have remained particularly interested in graphene and its materials for composites due to its odd electrical and mechanical applications, in addition to its odd magnetism., and mobility of charge carriers [10].

The synthesis of graphene is possible in multiple ways. However, all methods of graphene creation are partitioned. There are two basic methods: The two approaches that are widely used are the top-down and the bottom-up approaches. The bottom-up strategy entails approaches such as chemical vapor impregnation [8]. Flash Graphene Method is considered one of the most advanced methods of graphene creation; it involves the passage of an electric current through a carbon-based material. This procedure transforms the amorphous carbon into graphene by using the energy with the help of the

electrical discharge [11]. All of these make graphene a common substance and its uses in the environment require to be evaluated. More so this article looks at the current advances in the field of graphene use and some of the relevant applications not forgetting its impacts such as contaminant removal and detection. along with its recent advancements [8].

The analysis of the adsorption mechanism has given evidence that the process of adsorption was primarily chemical in nature and involved the exchange of ions [6]. Figure 1 shows the whole remediation process in this research.

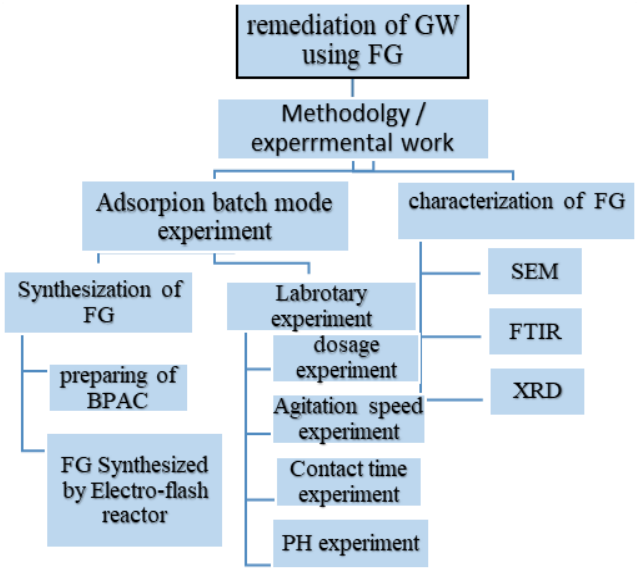


Figure 1. GW remediation using synthesized FG

2. METHODOLOGY/EXPERIMENTAL WORK

2.1 Synthetization of flash graphene

An adsorption technique was used to eliminate contaminants (anions, T.D.S, and Cr_6) present in real groundwater samples; various initial concentration values were tested in the laboratory to be compatible with Iraqi's standards for irrigation use. Flash graphene synthesized from activated carbon that was derived from banana peel was considered to be food waste that lacked monetary value. Preparing activated carbon and then crushing it into powder form, the powdered (BPAC) is used to synthesize the flash graphene, which is then used as an adsorbent for contaminants in groundwater samples.

Table 1. The materials used in the experimental part

Name	Chemical Formula	Molecular Weight (gm/mol)	Manufacturing Company
Acetic acid	CH3COOH	60.052	FENGDA/China
Sodium hydroxide	NaOH	39.99	LOBA Chemie/India
Banana peels	-	-	Locally Available

2.1.1 Materials

All materials used for the remediation of groundwater samples are listed in Table 1. The row banana peels were personally collected and used as raw material.

2.1.2 Equipment

Table 2 contains a list of the equipment used for characterizing and preparing the banana peel-activated carbon and the flash graphene used in the adsorption experiments.

Table 2. Laboratory equipment

Name	Manufacturing Company
Electrical balance	Precisa 205 A, Switzerland
Digital pH meter	China
Platform shaker	Julabo Labortechnik Gmbh, Germany
Furnace	SAFTHERM, China
Electro-flash reactor	Locally Manufactured
Mixer grinder	China
Glasswares	China
Conical flask	China
Pipette	China

2.2 Preparation of the banana peels activated carbon

For activated carbon preparation, banana peels were collected in Figure 2(a). After being washed with distilled water in order to remove surface debris, the peels was dried in the sun for three days. The dried banana peels were cut into small pieces of 2*2 cm as in Figure 2(a), and then physical activation was achieved where banana peels were carbonized and activated for 2hrs using a furnace at 250℃ using (1) l/min of CO_2 and (1) l/min of N_2 one hour for each, as shown in Figure 2(b).

Activated carbon of banana peels small pieces were ground into powder using a mixer grinder (Figure 2(c)). After activation to 0.25 mm size, the samples were carbonized at the mentioned temperature then left to cool to room temperature then the samples were first washed with distilled water and filtered several times before drying it in a hot air oven at 50℃ for one day.

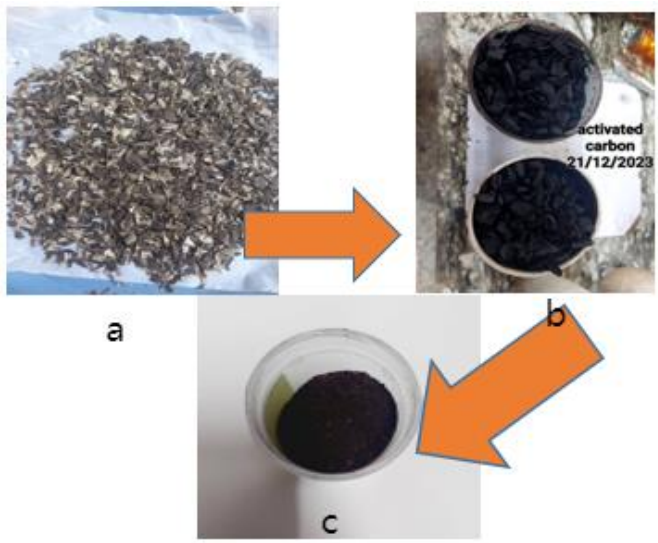


Figure 2. Sample of prepared (BPAC): (a) dried banana peels, (b) activated carbon, and (c) crushed activated carbon

Physical parameters of the adsorbent were measured and listed in Table 3. The data in the table were collected from the Petroleum Development and Research Center, which is part of the Ministry of Oil. The crushed activated carbon was prepared to synthesize the flash graphene.

Table 3. Physical properties of BP, Ac, and FG

Properties	Banana Peels	Activated Carbon	Flash Graphene
Surface area (m^2/g)	0.5519	0.5415	0.717
Bulk density (gm/cm^3)	0.4905	0.4412	0.4333
Real densities, (gm/cm^{-3})	1.4442	1.3902	1..335

2.3 Synthetization of flash graphene

Flash graphene is synthesized from crushed banana peel activated carbon by turning the activated carbon into graphene in a burst of light through a technique when graphene can literally be made using an electro-flash reactor, which is a device consisting of two electrodes of high voltage electricity in contact with Cooper wire inside Pyrex tube where the activated carbon placed inside the tube.

Electro-flash reactor consists of an electrical source and a circuit breaker CB1 (Figure 3). It's utilized to link the capacitor cabinet and the power source. The power supply has a 220 V AC in addition, to 10 circuit breakers that render simpler to turn on and off and; a circuit breaker that renders simpler to turn on and off. It's been proven that the construction of individual capacitor banks is possible.

A power source for LED luminaires has been used to charge capacitors, the power source supplies the necessary (460×4) voltage for charging the capacitor through the use of a resistor. Once the capacitor is charged, CB1 is turned off, this leaves the bank charged and ready to be released.

In as much as the intended voltage is attained across the capacitors then the release of the fund can be done. To this end, flexible output cables are connected to a test probe that has two copper metallic electrodes [12].

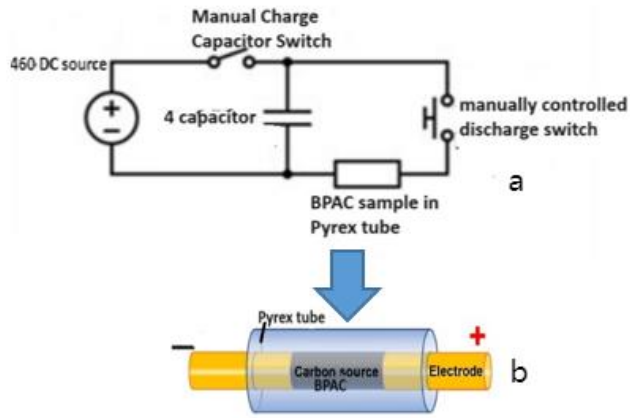


Figure 3. (a) Electro-flash reactor [13], (b) Pyrex tube [14]

The activated carbon of the 5 gm-weight sample was placed into the Pyrex tube with the Cooper wire in the tube and the two ends of the wire in touch with two electrodes where the discharge duration is input in 2 seconds between each burst of light done by manual circuit break for (8-10) times blow on the switch as shown in Figure 4. The activated carbon is converted into graphene (Figure 5).

2.4 Characterization and qualification techniques of flash graphene

The solid adsorbent has been characterized and analyzed using a variety of techniques. The analytical techniques whereby the objective materials' characteristics were analyzed include fourier transforms infrared spectroscopy (FTIR), Scanner electron microscopy (SEM), and X-ray diffraction (XRD).

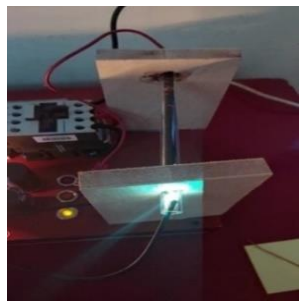


Figure 4. Flash graphene

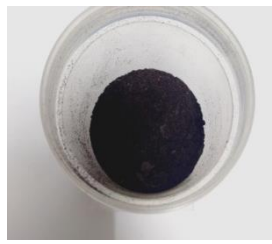


Figure 5. Sample of synthesized by a burst of light flash graphene

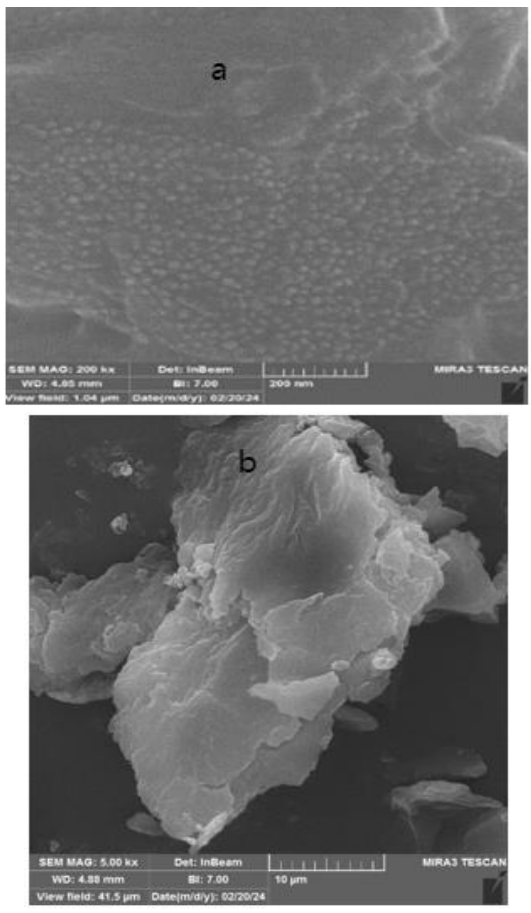


Figure 6. SEM micrographs of graphene (a) seeds of spherical particles and (b) layers of FG shells form on top of seeds

2.4.1 Scanner Electron Microscopy (SEM)

SEM serves to observe graphenes' shape. SEM imaging has benefits like recognizing impurities, graphene flaps, and problems during the manufacturing process [15]. Figure 6 shows the rough, very porous, and defined surface morphologies of the adsorbents, which are suitable for adsorption [16], and demonstrates 2D nucleation and growth of graphitic crystals on the surface of graphitic nanoparticles bed. Crystal and ultimately form a continuous shell of graphitic layers, the scale SEM images of FG in Figure 6(a) is 200 nm and Figure 6(b) is 10 µm [14].

2.4.2 X-ray diffraction (XRD)

Is a technique that does not adversely affect the structural integrity of materials, and instead provides information about their crystallographic structure and properties [17].

The X-ray deviation pattern (XRD) of synthesized graphene is shown in Figure 7. A broad peak around a 2θ°angle of 10.1 degrees, as in Figure 7 [17]. The 2θ values at 28.5° and 40.7° exhibit a sharp C(022) peak along with a weak C(101) peak that is indicative of the presence of statically supported graphene. The statically supported graphite is characterized by a two-dimensional graphite structure that is misaligned with the layers by translation or rotation, the interlayer spacing is also displayed. approaches that of crystalline graphite (0.335 nm) [18].

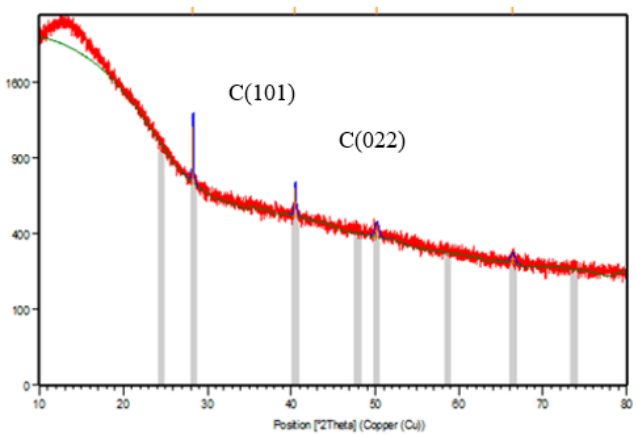


Figure 7. X-ray diffraction (XRD)

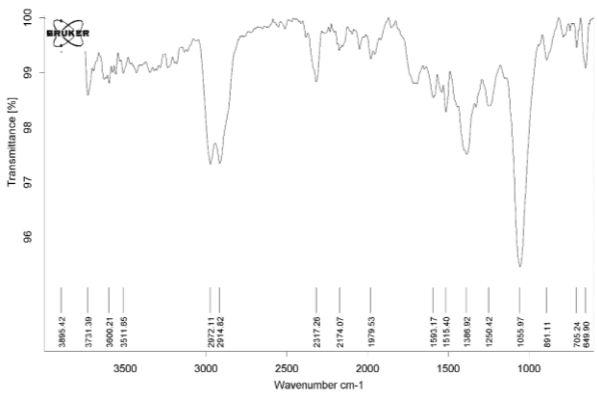


Figure 8. FTIR of flash graphene

2.4.3 FTIR spectroscopy (FTIR)

FTIR analysis is a method for recognizing chemical groups in flash graphene. The structures of the flash graphene were characterized by several analysis techniques. FTIR spectra of flash graphene are shown in Figure 8. Over a spectral range of 4500-600 cm^{-1}, the FTIR spectra have been obtained in reflectance mode at a resolution of 4 cm^{-1}. We could determine which molecular functions were responsible for the adsorption found at 1600 to 1400 cm^{-1}, the peak at 2300 could be due to carbonyl (C=O), while the peak at 891cm^{-1} due to polyacrylamide molecule (C-H), and the other adsorption brand at 3000 cm^{-1} due to hydroxyl groups. These groups stretch vibration from the FG structure.

3. ADSORPTION EXPERIMENTS (LABORATORY EXPERIMENT/BATCH MODE)

The remediation of GW depends on the adsorption performance of flash graphene to reduce concentration of the pollutant (i.e., anions, T.D.S, Cr_6) from the GW samples was investigated. The remediation was obtained by making one of the affected parameters (dosage, PH, time, and rpm) steady and verifying the others in each test (Table 4). To select the best performance of exact parameter values which were chosen Constructively on the literature review of former adsorption's batch mode experiments in scientific research, these values remediate the GW samples for lowest pollutant concentration.

Table 4. Adsorption batch mode for variable and steady parameters

Variables Parameters	Vales	Constant Parameters
Dosage	0.5, 1, 1.5, 2, 2.5, 3	2 hrs, 200 rpm, PH 7
PH	5, 7, 10	2 hrs, 1.5 gm, 200 rpm
Time	1, 2, 3, 4	200 rpm, PH 7, 1.5 gm
Rpm	100, 150, 200, 250	1.5 gm, PH 7, 2 hrs

The experimental work investigated the remediation of groundwater for irrigation purposes and Land Reclamation, the source of groundwater samples was from AL-Raeed research station wells located in the surrounding area of the station. The AL-Raeed research station is a research station one of the Iraqi Water Resources Ministry institutions, that specializes in studying and developing methods and modern techniques for field irrigation, it is located (20) kilometers western side of Baghdad at Abu-Ghareeb and the whole area of the station, researches laboratory building and reclaimed agricultural lands location extend on (64) acre, these lands including also many wells for irrigation and agricultural experiments work purposes.

The GW samples were collected in a Sterile bottle of (2)L, and after the water pumping started at a continuous period for (3h) and they were kept in a Refrigerated dark box then delivered to the station laboratory, all tests conducted after (48 h) or less after collection.

GW samples from Al-Raeed station were initially examined at the station laboratory as shown in Table 5, for anions, Cr_6, and T.D.S values, and compared with Iraqi's standards for river preserving system and FAO's standards for irrigation water.

All laboratory tests to remediate (anions, T.D.S, Cr_6) for groundwater samples treated with flash graphene by

adsorption experiment (batch mode) achieved by the National Center for Water Resources Management.

Table 5. GW initial values of anions, Cr_6, and T.D.S

Groundwater of AL-Raeed Research Station		Iraqi's Standards for River Preserving System	FAO's Standards for Irrigation Water
Pollutants		Pollutant Values (ppm)	
T.D.S	5390	-	2000
SO_4^{-2}	1321	400	200
Cl^{-1}	991	350	250
NO_3	10.1	30	30
Cr_6^{+}	0.04	0.1	0.1

3.1 Effect of adsorbent dosage

Each experiment of adsorption tests was carried out by adding different dosages of flash graphene sorbent to (6) conical flasks of (100ml) ground.

Water sample with constant time, rpm, and PH values and at room temperature for each (6) sample. The various weighted amounts of 0.5, 1, 1.5, 2, 2.5 and 3 gm. respectively adsorbent were taken and put inside 6 conical flasks of 100 ml of groundwater sample in these conical flasks, for 2 hours and at 200 rpm. As shown in Table 6. The remediation results of this experiment are represented in Table 7.

Table 6. Dosage parameters experiment

Material	Dosage (gm)	Parameters		
		PH	Contact Time	RPM
Flash graphene	0.5 1 1.5 2 2.5 3	7	2 hrs	200

Table 7. Anions, T.D.S, Cr_6 values in dosage experiment

Dosage of Adsorbent (gm)	Pollutant Values (ppm)				
	T.D.S	SO_4^{-2}	Cl^{-1}	NO_3	Cr_6^{+}
0.5	2726	1152	525	9.39	0.0191
1	3458	634	504	5.24	0.035
1.5	2144	653	444	5.33	0.023
2	4487	902	852	5.39	0.035
2.5	4900	749	943	5.58	0.031
3	5060	768	980	5.69	0.011

And the results of this experiment are represented graphically as in Figure 9.

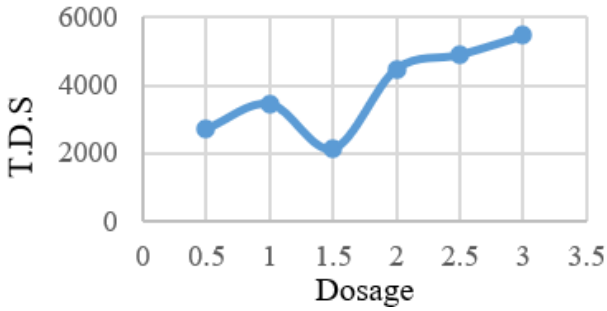
3.2 Effect of agitation speed (rpm)

Table 8. Anions, T.D.S, Cr_6 values with variable agitation speed

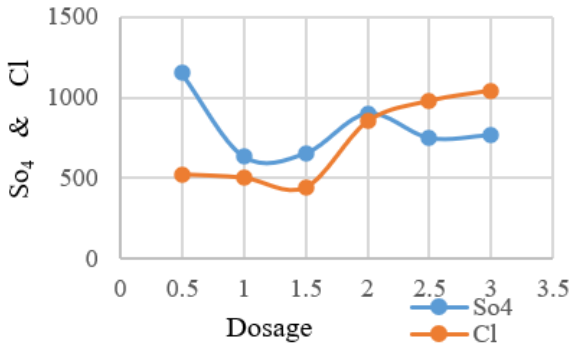
Agitation Speed(rpm)	Pollutant Values (ppm)				
	T.D.S	SO_4^{-2}	NO_3^{-1}	Cl^{-1}	Cr_6^{+}
100	3570	595	3.21	504	0
150	2381	580	2.69	72	0
200	2144	633	5.33	444	0.023
250	4004	1290	5.11	525	0

GW samples of (100) ml and (1.5) gm of flash graphene dosage, PH value (7) and (2) h. The contact time for the 4 samples with 100, 150, 200, and 250 rpm was conducted for each sample. The test results for each adsorption experiment for variable rpm value are listed in Table 8.

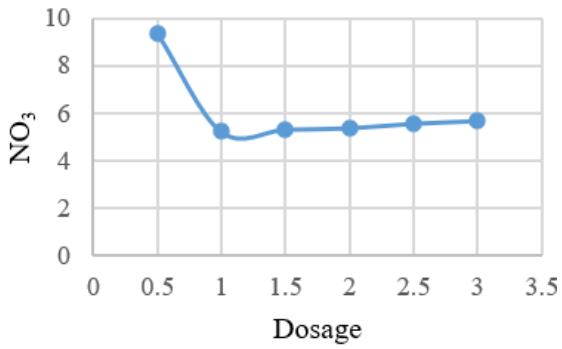
The results in Table 8 are represented graphically shown in Figure 10.



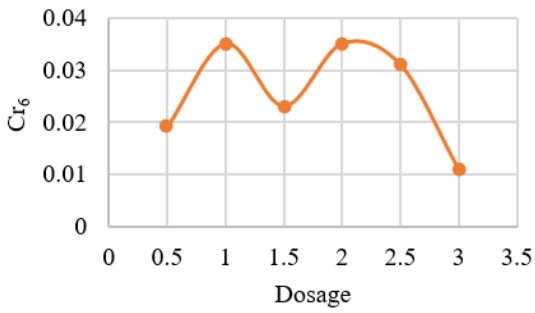
(a) T.D.S with different dosages



(b) SO_4 & Cl with different dosages

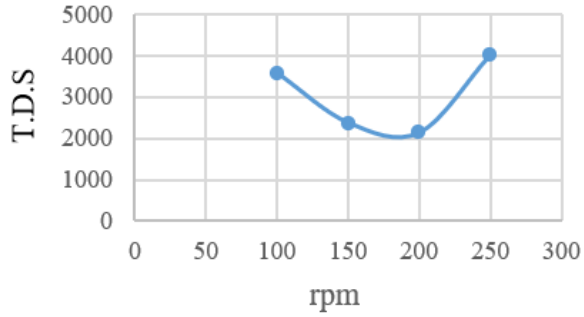


(c) NO_3 with different dosages

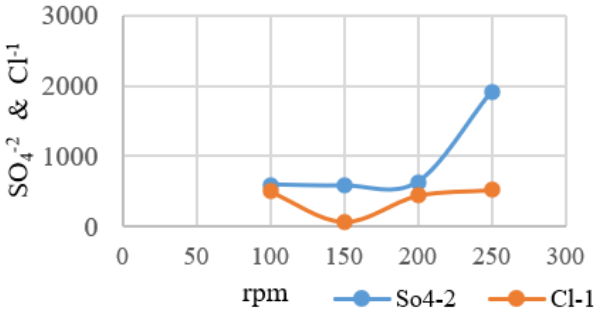


(d) Cr_6^{+} with different dosages

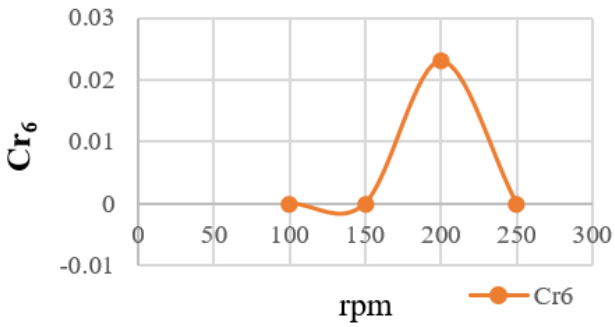
Figure 9. Effect of variable amounts of dosage to remediate



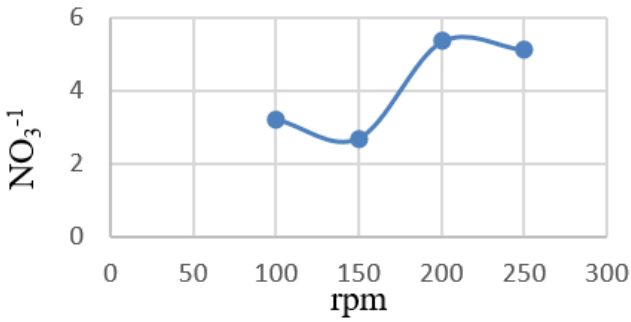
(a) T.D.S with agitation speed



(b) SO_4^{-2} & Cl^{-1} with agitation speed



(c) Cr_6 with agitation speed



(d) NO_3^{-1} with agitation speed

Figure 10. Effect of variable rpm to remediate

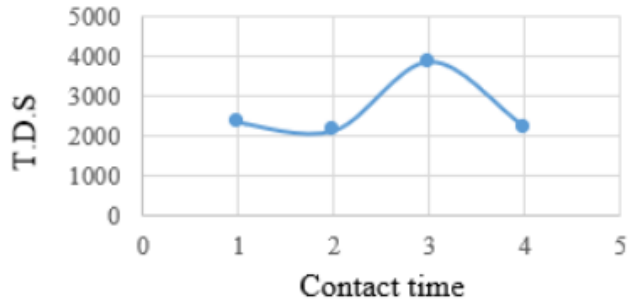
3.3 Contact time effect

The adsorption experiment to obtain the effective time to remediate the groundwater sample was completed by adding (1.5) gm flash graphene to each (4) conical flasks containing ml of groundwater. These samples were then kept in a shaker and vibrated at (150) rpm and PH =7 at room temperature. The 4 samples of constant parameters (rpm, PH, and dosage) were prepared at 4 different times 1, 2, 3, and 4h. Each of the 4 samples of constant parameters (rpm, PH, and dosage) was prepared at 4 different times 1, 2, 3, and 4h. Each sample was prepared in a separate conical flask, as shown in Table 9.

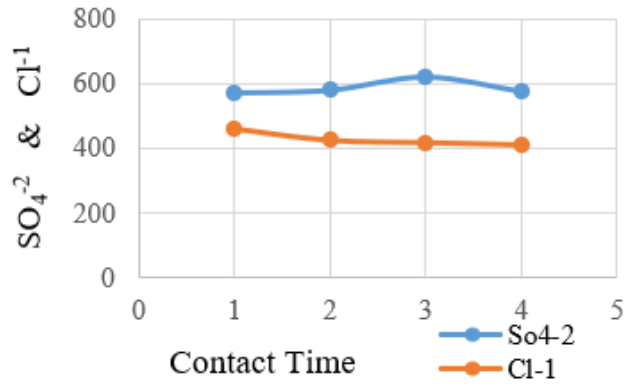
Table 9. Anions, T.D.S, Cr_6 values for different contact times

Contact Time (h)	Pollutant Values (ppm)			
	T.D.S	SO_4^{-2}	Cl^{-1}	Cr_6^{+}
1	2342	572	462	0
2	2144	580	426	0
3	3857	620	419	0
4	2227	576	412	0

The results of this experiment are represented graphically in Figure 11.



(a)T.D.S with different contact time



(b) SO_4^{-2} and Cl^{-1} with different contact time

Figure 11. Effect of different contact times to remediate

3.4 Effect of solution PH values

Table 10. Anions, T.D.S, Cr_6 values for variable PH values

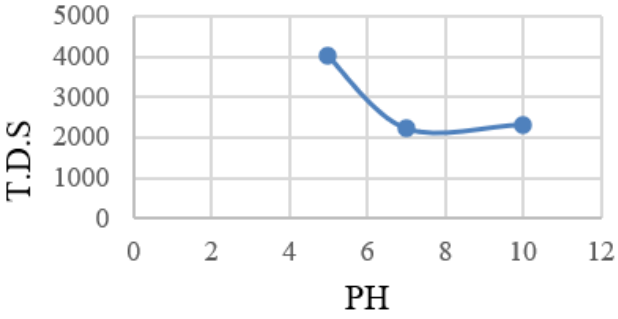
PH	T.D.S	SO_4^{-2} ppm	Cl^{-1} ppm	NO^{-3} ppm	Cr_6 ppm
5	4004	1920	88	5.11	0
7	2221	787	72	2.69	0
10	2323	634	56	3.21	0

A sample of 1.5 gm as an adsorbent dose of flash graphene was added to (3) samples of 100 ml ground water, pH values verified for each sample as 5, 7, and 10, and were taken for solutions prepared. Constant dosage (1.5) gm, contact time (4 h), and (150) rpm were taken for each of the 3 conical flasks.

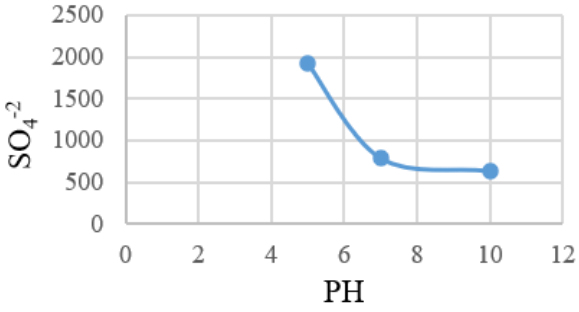
By adding the necessary amounts of 1 N acetic acid (CH_3COOH) to maintain an acidic nature and 1 N NaOH to

maintain a basic nature, the varying PH values were maintained in the flask, as shown in Table 10.

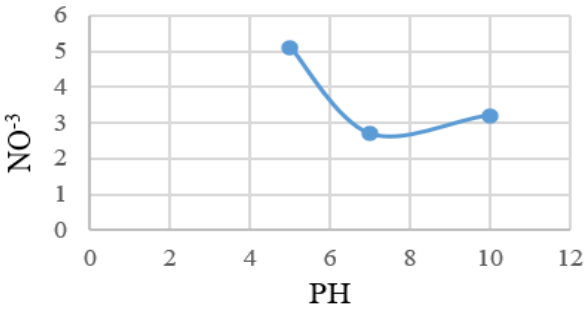
The result is represented graphically in Figure 12.



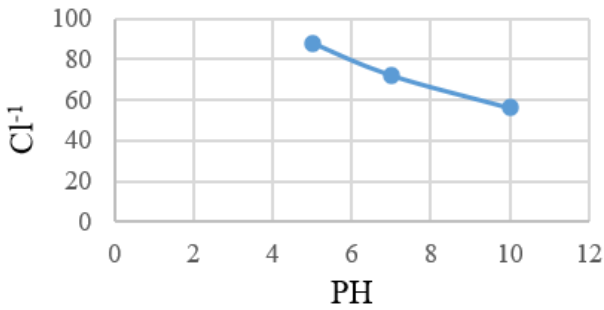
(a) T.D.S with different PH levels



(b) SO_4^{-2} with different PH levels



(c) NO^{-3} with different PH levels



(d) Cl^{-1} with different PH levels

Figure 12. Effect of variable PH values to remediate

4. RESULTS AND DISCUSSION

4.1 Adsorption process

Flash graphene offers a significant effect in the adsorption process to remediate GW contaminants compared with other adsorbents, due to, Its large specific area, superior mechanical strength, chemical stability, great flexibility, and low weight are only a few of its many remarkable qualities [7]. The majority of these materials serve either catalytic or electronic purposes. The largest essential and widely used application of amorphous carbon is in environmental remediation [10].

The two main elements that significantly affect a solute's ability to adsorb on an adsorbent are pore density and surface chemistry. Adsorption is the process by which particles with opposing charges interact to form a number of bonds, including hydrogen bonds, ion exchange, dipole-dipole interactions, van der Waals forces, and electrostatic bonds [19].

It found that Cr_6 was removed from the aqueous solution using an indirect reduction process that made use of the π electrons on the carbocyclic six-membered ring. GW also contains a few inorganic anions, such as Cl^{-1}, SO_4^{-2}, and NO_3^{-} Massive quantities of these anions, which are the purpose of groundwater contamination, need to be eliminated. Due to the negative charge of anions, their adsorptive removal was by graphene [20].

By the experimental work, the number of anions (SO_4^{-2}, NO_3^{-1}, and Cl^{-1}), T.D.S, and Cr_6 were remediate in the groundwater samples to the lowest concentrations. The tests at adsorption batch mode using synthesized flash graphene prepared from banana peels activated carbon were investigated the influential parameters to adsorbate the pollutants on the adsorbent, and they were implemented with flash graphene dosage weight 1.5 gm/100 mL of groundwater sample for 4h. And solution PH equal to 7 with 150 rpm agitation speed as in Table 8.

4.2 Characterization

An FTIR spectrum was performed to identify the functional groups in charge of the adsorption process. FTIR spectra reveal that graphene exhibits several indicators of oxygen-derived species; functional groups are visible inside the structure; a large band ranging from 2800 to 3000 cm^{-1} is attributed to carboxyl COOH groups establishing hydrogen bonds, for instance [21].

The 1979 cm^{-1} peak is thought to be caused by C=O stretching in alkyl esters (−COOR) and/or carboxylic acids (−COOH). However, the peak at 1625.48 cm^{-1} is caused by carboxylate (COO−) and its asymmetric C=O and/or C=C stretching. Finally, broadband can be seen around 1055.97 cm^{-1}, suggesting that symmetric C–O stretching of COO− could result in the peak at 1386.92 cm^{-1}. This may be caused by the O-H deformation and C-O stretching of polysaccharide structures. These small peaks are characteristic of cellulose, as is the (648.34-580.93) cm^{-1} peak that is linked to out-of-phase ring stretching [22].

The bands at 1410 and 1102 cm^{-1} are related to the emergence of C–N and CH_2 groups, which may have been added to graphene's surface through treatment with 1-methyl-2-pyrrolidinone. The stretching mode of the amide-type C-O bond introduced by sulfuric acid and hydrogen peroxide (oxidation reagent) is responsible for the band at 1631 cm^{-1}. The stretching of CH_3 groups from the organic solvent of 1-methyl-2-pyrrolidinone is linked to the band at 2925 cm^{-1}.

The bands at 795 and 643 cm^{-1} reflect the C–H and N–H bending [10]. The GW contaminant (anions, T.D.S, and Cr_6^{+}) adsorption is assigned by a decrease in peak displacement, indicating a structural alteration caused by the corresponding functional groups. The outcomes of loading hydroxyl and

carbonyl group bands migrated to lower displacement, indicating that they play a crucial role in the adsorption of the ions.

Scanning electron microscopy (SEM) characterization for flash graphene was tested. The surface of graphene is significantly highly expanded and its structure and inhomogeneous have a lot of folds and the number of defects is not so abundant.

4.3 GW remediation for irrigation purposes

The groundwater of the site wells (GW of AL-Ra'aed research station's wells) initially tested fell within the category of moderate and unsuitable levels for groundwater (anions and Cr_6^+) and category of unsuitable levels for groundwater (T.D.S) for irrigation purposes compared with the Iraqi's and FAO's standards. Therefore, the untreated GW used for irrigation will damage the crops and reduce production.

The outcomes of adsorption batch mode experiments at the effective parameters results and according to the minimum values of the contaminants concentration (anions, T.D.S, Cr_6^+) which is reached to (0 mg/L) of Cr_6^+, whenever compared with the Iraqi's and FAO's standards show that the remediated GW by this laboratory experiment results can be useful to approve the advantage of using flash graphene as a good adsorbent in one of GW remediation methods to prevent the damage of crops and production.

5. CONCLUSION

Synthetization of the flash graphene process by electro-flash reactor technology improves the prospective environmental benefits of using agricultural waste by concentrating on maximizing the process parameters for obtaining flash graphene from various carbonaceous materials and effectively expanding. provides a graphene synthesis route that is quicker than other synthesis methods and economically successful for upscaling.

Graphene has been proven as a functional material that can be used in many potential applications, for instance, the adsorption batch experiment using flash graphene conducted to search for the removal of anions, cations, and heavy metals on graphene, and remediate groundwater.

The parameters studied in this research could be extended to include in future research other parameters involved in ameliorating the remediation prosses for GW and wastewater as well to be used in irrigation purposes such parameters as temperature, and more values for Ph level.

Additional research is required to fully comprehend how larger-scale graphene synthesis affects the environment. Thankfully, graphene is found in vast quantities in coal and occurs naturally as crystalline aggregates of graphite. As the use of graphene grows, more thorough research on the preservation and degradation of larger-scale graphene synthesization ought to be done in academia and industry.

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NOMENCLATURE

Greek symbols

μm	Micrometer
π	Pi

Subscripts

Ac	nanoparticle
AC	fluid (pure water)
BPAC	nanofluid
CB1	Circuit break 1
FAO	Food and Agriculture Organization
FG	Flash graphene
FTIR	Fourier transform infrared spectroscopy
GW	Groundwater
LED	Light-emitting diode
ppm	Part per million
RPM	Revolution per minute
SEM	Scanner Electron Microscopy
T.D.S	Total dissolved solids
V	Volte
XRD	X-ray diffraction
Nm	Nanometer