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Ecologically Engineered Systems for Treating Agriculture Runoff by Integrating "Wastes" into Constructed Wetlands

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Abstract: Runoff from agricultural irrigation is contaminated and loaded with pesticides. Frequent toxic levels of pesticide detection in the ecosystem motivate scientists and engineers to diminish agrochemicals flowing into the environment. Constructed wetland, CWs, treatments are a sustainable methodology of special interest since it possess a symbiosis value. Flytek (FT) pesticide use has increased at an unprecedented rate for crop production as well as an increase in runoff loaded with Flytek. This study introduces the use of constructed wetlands based on an alum- sludge substrate for the purpose of Flytek (FT) removal performance. The system is based on an adsorption column and a sludge cake coupled with gravel acting as a carrier in order to be an adsorption bed and filtration system for Flytek removal. The structure, morphology and characteristics of the adsorption bed material "alum sludge" were characterized using X-ray diffraction spectroscopy and Scanning Electron Microscope (SEM). Additionally, Fourier-Transform infrared spectroscopy (FTIR) was explored. The experimental results revealed that a vertical flow constructed wetland is significant in eliminating the Flytek pesticide. However, the amount and height of sludge in a wetlands column affects its removal efficiency with the optimal removal (96%) being linked to the presence of sludge in 80%. Moreover, temperature, pH and the FT load showed a significant effect in removals, with the optimal operating conditions being recorded at 7.2 pH, 26 °C and 100 ppm of FT. The kinetic modeling is also investigated to validate the practical life applications and designs, and the results verified the reaction follows the pseudo 2nd-order reaction kinetic model according to the correlation coefficient factor. Furthermore, according to the isotherm model results the scheme follows the Freundlich isotherm model. Such preliminarily data of a gravel-alum-sludge-adsorption-column scheme is a good indicator in developing a constructed wetland facility being a good candidate for controlling agriculture effluent streams.

Keywords: constructed wetlands; agriculture water; pesticide treatment; removal efficiency; design optimization

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1. Introduction

Over recent decades, wetlands (CWs) have been applied as a unique cost-efficient and low energy consumption system for treating aqueous municipal wastewater streams. Recently, an interest in using CWs has increased in popularity for treating agricultural runoff. Constructed wetlands possess the advantage of wastewater remediation from agricultural irrigation systems. CWs are categorized as an ecologically engineered system because of their low energy consumption and environmental friendliness. CWs exhibit a potential to minimize and remove various agricultural chemicals simultaneously. Constructed wetlands have the ability to eliminate or reduce contamination levels of various chemicals from aqueous effluents. Worldwide, treatment wetlands were applied in different regions. For instance, in the United States of America [1], Canada [2], Ireland [3], Germany [4], Turkey [5], Australia [6], Spain [7] and China [8]. Although, CWs, in comparison to the numerous polluted aqueous effluents remediation systems, possess disadvantages categorized as a requirement of a greater land area; however, their advantages include treating wastewater together with providing an attractive place with ornamental plants for recreation [9–11] as a multifunctional role [12,13]. However, it is important to mention that this has rarely been applied to date for eliminating pesticide-containing wastewater based on an alum sludge constructed wetland.

On the other hand, due to the water purification in a drinking waterworks plant, aluminum sulfate is applied as a treatment as a primary coagulant's aid to generate high quality and sufficient drinking water prior to the domestic distribution [14,15]. The resultant by-product is a massive quantity of sludge, which is named "alum sludge". This by-product represents an environmental issue since it is a two-phase combination comprising of both solids and water. The European Union (EU) categorized such aluminum-based waste under Code 19's list of waste [16,17]. Commonly, such sludge, containing 99% water prior to it being subjected to gravity for thickening, to eliminate the excess water, could be declined to attain a sludge containing 95% water subsequent to its thickening. As a sustainable zero-waste approach, the application of alum-sludge in significant treatments is signified as an interesting utilization profit [18]. In this regard, scattered investigations [18–20] were studied and their published data dealing with the application of alum-sludge as an adsorbent material and as a substrate in constructed wetland systems. However, according to the literature cited it has not been applied, to date, in constructed wetlands based on the alum sludge for Flytek pesticide removal.

Pesticides are commonly constituted of at least one of the main groups of organic substance complexes, which trigger severe damage to the surrounding environment since their use, in massive amounts in the agricultural sector, is essential. Pesticides are applied to agriculture land to safeguard the plants and vegetables from various damage, such as an insect attack, mildew and bacteria. Such creatures could attack and cause damage to the agriculture crops. Subsequently, the excessive tendency of such pesticides to be soluble in water, chemically stable and resist biological degradation permits them to spread to the groundwater [18,21]. Consequently, searching for a novel management technology to eliminate such unwanted and harmful materials is a research topic. Among the treatments processes, adsorption possess some advantages since it is reliable, simple in operation and cost-efficient, particularly when it is based on waste or natural substances. Thus, with the daily volumes of alum sludge produced through water processing, it is good candidate to substitute chemicals for an environmentally benign world. Additionally, with the new legislation that has been asserted to prohibit the use of toxic chemical substances, using a cradle-to-cradle waste management system and use the "waste-alum sludge" for treatment is an especially is good opportunity for the constructed wetland world.

Herein, the current study is aimed at introducing the use of a gravel-alum sludge medium as a substrate for an adsorption column for preliminary data leading to a constructed wetland system. The Flytek pesticide that is widely applied in agriculture areas, and the resultant effluent, is signified as hazardous waste and is used as a model pollutant. Alum sludge characterizations are investigated using various techniques (XRD, SEM and FTIR) and tested as an adsorption medium. Four treatment trails are introduced according to the alum sludge constituent in the column. The effects of the working parameters, such as initial Flytek loading, temperature and pH of the aqueous media are investigated. Further, kinetics of the Flytek adsorption and isotherm parameters are also explored.

2. Materials and Methods

2.1. Field Sampling "Alum Sludge"

A "Alum sludge" is an inescapable so-called aluminum-rich sludge waste by-product, it was collected from the nearest water-works plant applying aluminum sulphate as a primary coagulant for water purification. The sludge was collected from the drinking water plant from the underflow channel of the sedimentation tank. Afterwards, the excess water is removed and the sludge cake is used, after natural drying, as a substrate in the adsorption column.

2.2. Adsorption Media and CW System Design

To investigate the proposed alum sludge, as a constructed wetland system, the adsorption column is prepared according to the previously reported literature [10]. Then the 100 mm column was prepared and initially filled with gravel support (10 mm in size), which was determined according to the procedures outlined by Zhao [10]. Thereafter, the lab-scale column is filled with the air-dried sludge cake. The system is connected to a reservoir comprising the aqueous effluent loaded with Flytek (FT). After the previous laboratory study [22]), the wastewater loaded into the entire system is exposed to a hydraulic loading of 0.5 m^3/m^2d to introduce a tidal flow system. The system is operated continuously and the wastewater flows in an upward-flow mode, which is released by peristaltic pumping. The illustration of the experimental tidal flow system is schematically represented in Figure 1.

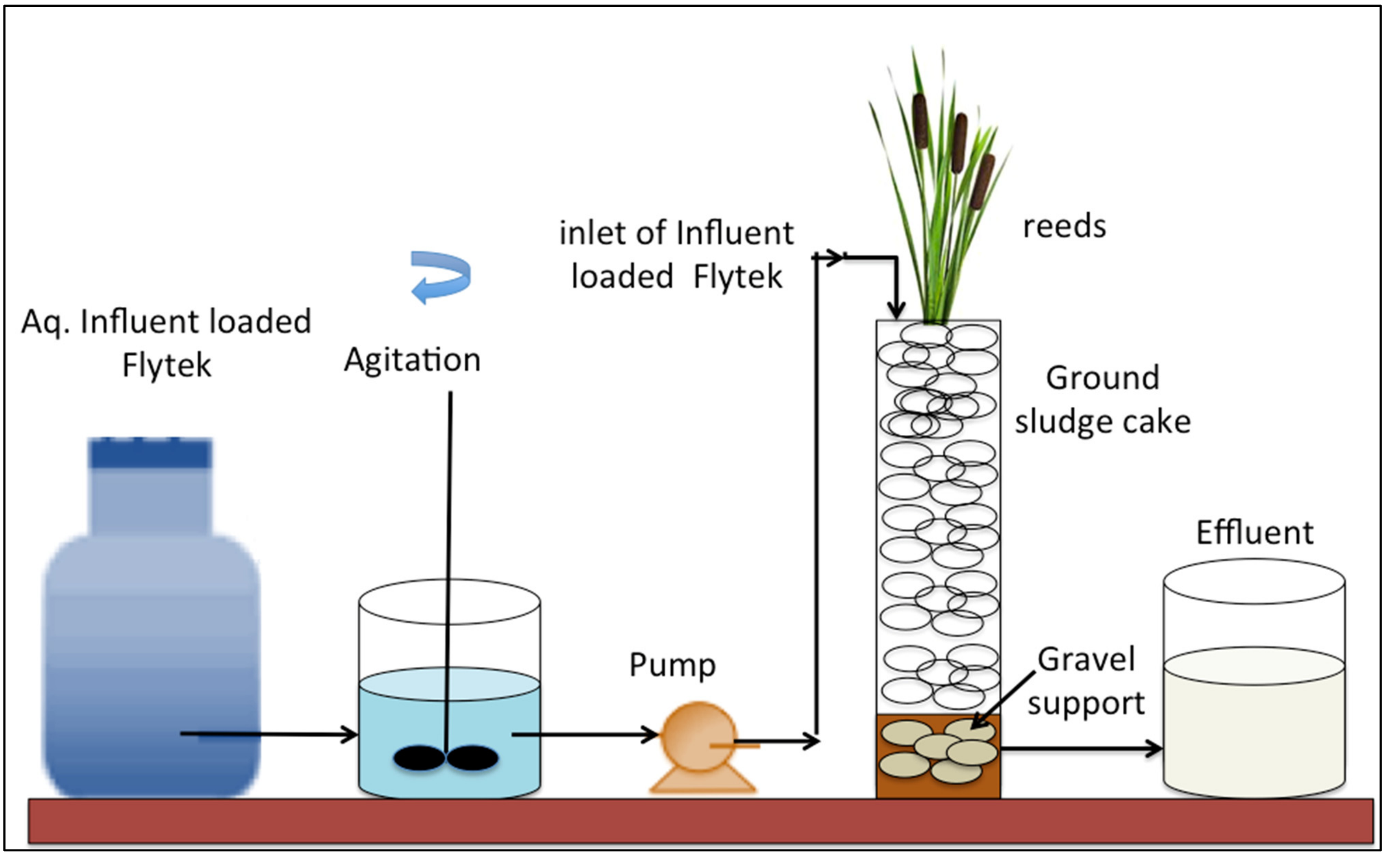

Figure 1. Systematic representation of the experimental technique.

2.3. AS "Alum Sludge" Characterization

The morphologies of the used alum sludge after drying, which is named AS cake that is the substrate in the CW column was tested and imaged using a field-emission scanning electron microscope (SEM) (model FE-SEM, Field-emission scanning electron microscope, Quanta FEG 250) with typical magnifications of ×8000 and ×60,000. The X-Ray Diffraction (XRD) was examined by the Bruker-Nonius Kappa CCD diffractometer using a CuKα radiation source at a wavelength of 1.5406 Å.

2.4. Aqueous Effluent Stream

The simulated wastewater effluent was synthetically arranged following the established protocol. A stock solution effluent (1000-ppm Flytek) was synthetically prepared and afterwards the diluted aqueous effluent was prepared as required. The original effluent, with a pH recorded at 7.2, was further adjusted using solutions of H_2SO_4 and/or NaOH (provided by Sigma-Aldrich chemicals, St. Louis, MO, USA) to attain the various pH levels as required.

2.5. Sampling and Analytical Determination

The technique of the batch methodology and sampling is used to track the concentration load of the Flytek (FT) removal through a UV-vis spectrophotometer (Unico UV-2100 spectrophotometer, Dayton, NJ, USA) by applying the maximum wavelength of FT with the initial (C_{FTo}) and the final Flytek FT (C_{FT}) being recorded. The adsorption capacity of the AS substance (qe) was explored and used to investigate the adsorption uptake. Moreover, the wastewater pH was adjusted, when needed to examine its effect though a digital pH meter (Model AD1030, Adwa instrument, Szeged, Hungary).

2.6. Prepared "Alum Sludge" Adsorption Bed Characterization

2.6.1. X-ray Diffraction Pattern

The X-ray diffraction pattern of the alum sludge cake is displayed and arranged in Figure 2. Remarkably, the diffractograms clearly demonstrate the crystalline nature of the sample that is obvious from the sharp diffraction peak patterns. The XRD of the sample signifies the peaks that are mostly characteristic of calcium aluminum, graphite and quartz phases with the predominant calcium Aluminate reflected through the most intensive peaks. The peaks of (100), (101) and (110) signifies the presence of quartz [23]. Furthermore, the XRD patterns show the peaks of (022), (112), (202) and (114) that represent the calcium aluminum and the (002), (011) and (004) that reflect the existence of graphite [24]. This reveals the importance of such material as an adsorbent medium.

2.6.2. Fourier Transform Infrared Spectroscopy:

The Fourier transform infrared (FTIR) spectroscopy of the alum-sludge cake is displayed in Figure 3. As shown in the curve of Figure 3, the bands around 3439.42 cm^{-1} are assigned to the O–H stretching vibration of the structural water. The bands for the absorption, that refers to silica, appears at 1090.55 cm^{-1}, which is attributed to the asymmetric stretching vibration of Si—O—Si. The deformation of Si–OH–HAl and Si—OH—HSi are recognized at 3846.33 cm^{-1} and 1467.65 cm^{-1}, respectively. The absorption bands at 539.97 and 3440.38 cm^{-1} are associated to the bending vibration of the H–O–H angular deformation and the OH stretching [23]. The Si—O—Si stretching vibrations attributed to the band of 789.7 cm^{-1} is linked to the stretching vibrations of the Al–Mg–OH group.

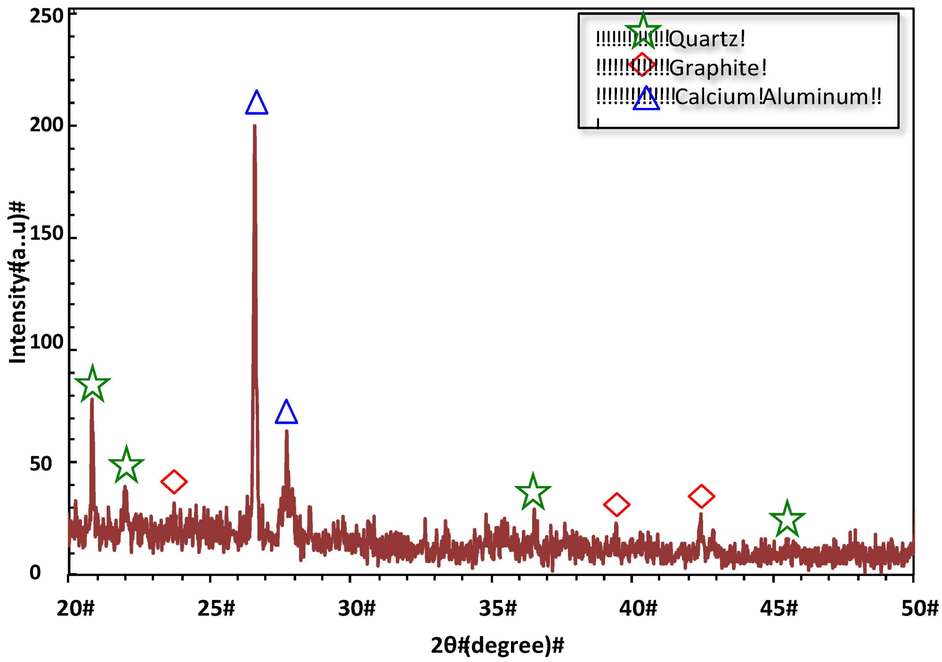

Figure 2. The XRD pattern of the alum sludge granulated bed in constructed wetland systems.

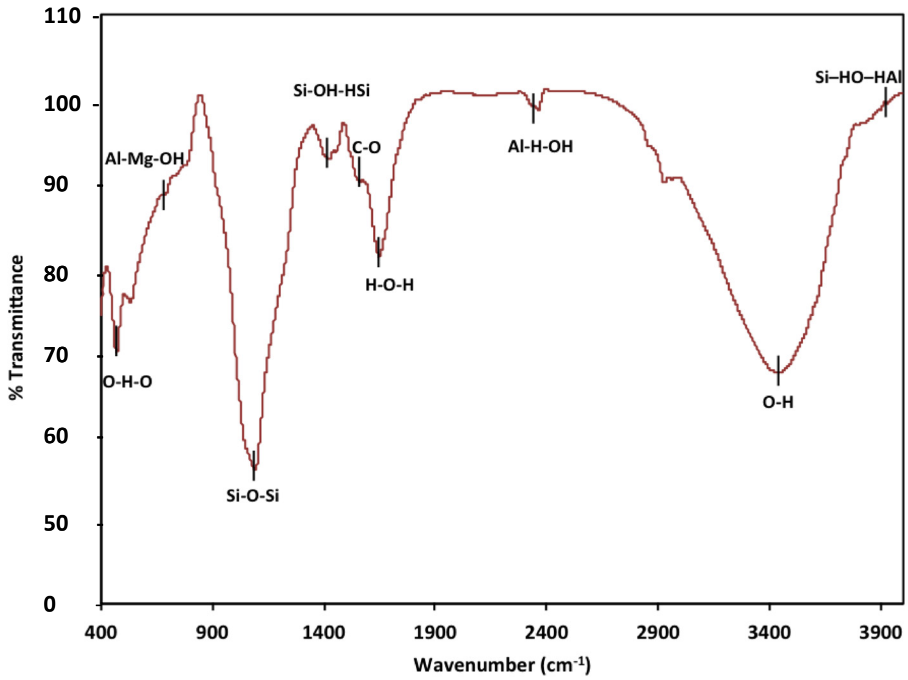

Figure 3. The FIR spectrum of the alum sludge granulated bed in constructed wetland systems.

2.6.3. Scanning Electron Microscope Images

SEM imaging was applied to explore the morphology of the adsorbent bed "alum-sludge cake" substance. The SEM micrograph (Figure 4 with different magnifications) of the AS displayed a semi-hexagonal sheet-like AS material that has a rough surface with a porous texture, which helps in the adsorption process. Moreover, it is noteworthy to mention that the inset in Figure 4 displays the ranges of the alum sludge particle size. Such particle sizes recorded at 281 nm, are considered quite small, which reflects a good adsorption, since the adsorbing surface area is increased.

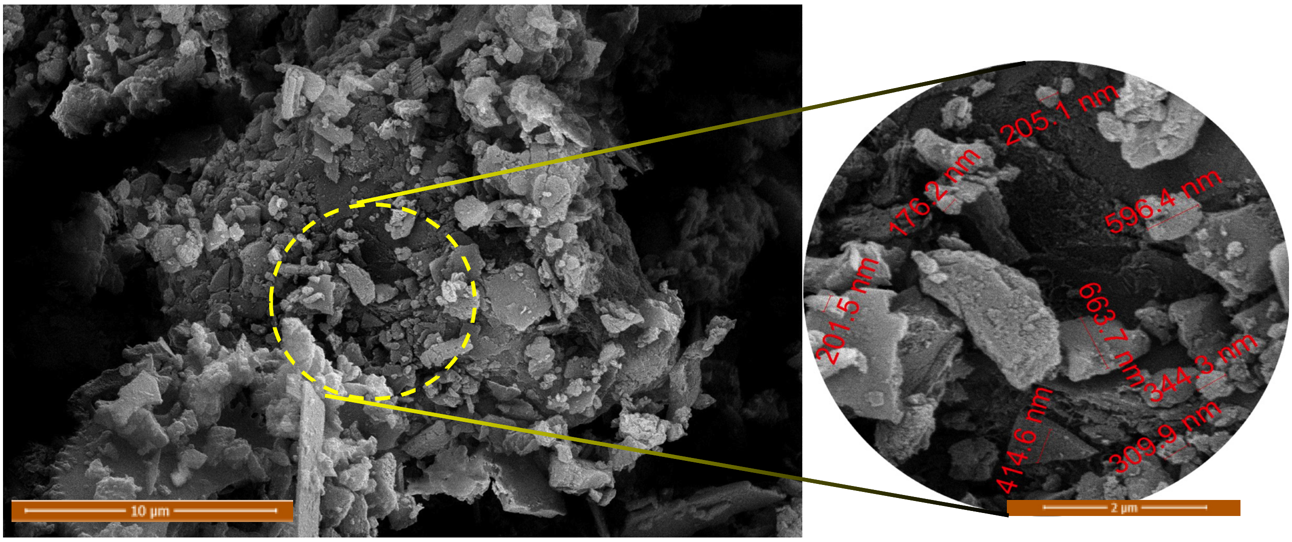

Figure 4. SEM images at different magnifications for the alum sludge granulated bed in constructed wetland systems (inset is 2 µm magnification with dimensions).

3. Results and Discussion

3.1. Flytek Removals on Alum Sludge Based Column

3.1.1. Column Studies

The effect of the alum sludge amount on the bed height breakthrough for Flytek removal is achieved, and the optimal configuration trials named: #1 (100%) Sludge CW; #2 (80%) Sludge CW; #3 (60%) Sludge CW; and #4 (40%) Sludge CW are tabulated in Table 1. Alum sludge dually represents an adsorption bed and serves as a substrate, operating as a filter medium for Flytek molecules for their loading reduction and removal. The FT efficacy is quite low due to the sludge bed reduction (60 and 40% alum sludge substrate in the column). This could be explained by the high hydraulic loading to the column. More meaningfully, the greater Flytek pesticide immobilization demonstrates the merits of using alum sludge in the adsorption column. The inclusion of supportive gravel in the column, the infiltrative substrate of the AS and the gravel surface of the columns did not verify the suggested beneficial advantages when it is increased in comparison to the sludge. Interestingly, the removal of the Flytek pesticide in the non-gravel-containing columns appeared lower than that of the joint gravel-AS columns as shown in Table 2. Such investigations support the phenomena that more contact time with the adsorbent resulted in the increased removal of the Flytek pesticide [25,26]. The highest Flytek pesticide elimination was attained for the 80% sludge bed (96% removal), which delivered excess binding sites for the absorption process of the Flytek pesticide, and the adsorbate onto the alum sludge adsorbent.

Table 1. Typical data of CW configuration column.

Trail No.	#1	#2	#3	#4
Configuration	(100%) Sludge CW	(80%) Sludge CW	(60%) Sludge CW	(40%) Sludge CW
% Flytek removal	89%	96%	72%	65%

3.1.2. Determination of Equilibrium Time

Initially, prior to the design of the adsorption matrix of the alum-sludge based substrate, it is essential to examine the isotherm equilibrium time. In this regard, the time-profile of the Flytek adsorption (200-ppm) using a gravel-alum sludge substrate was exhibited at room temperature and is displayed in Figure 5 as influent and effluent wastewater into and out of the adsorption column. The majority of the Flytek is adsorbed (93%) within 650 min. This could be due to the presence of favorable adsorption materials, such as aluminate, silica and graphite and the porous structure of the alum sludge bed as confirmed by the XRD and SEM images in Figures 2 and 3, respectively. The presence of graphite supports and helps the adsorption system since its presence is significantly influenced in the adsorption uptake. Graphite acts as an effective media since it possess hydrophobic interactions [16,27,28]. This data confirms the significance of the porous adsorbent media besides the presence of effective adsorption materials. A similar investigation was recorded in the previous work by eliminating the polymer effluent wastewater matrix [29,30]. Noticeably, there is no more FT uptake with the prolonging effect of the time of adsorption since the available active species and pores of the AS substance is saturated and fully occupied with the FT molecules.

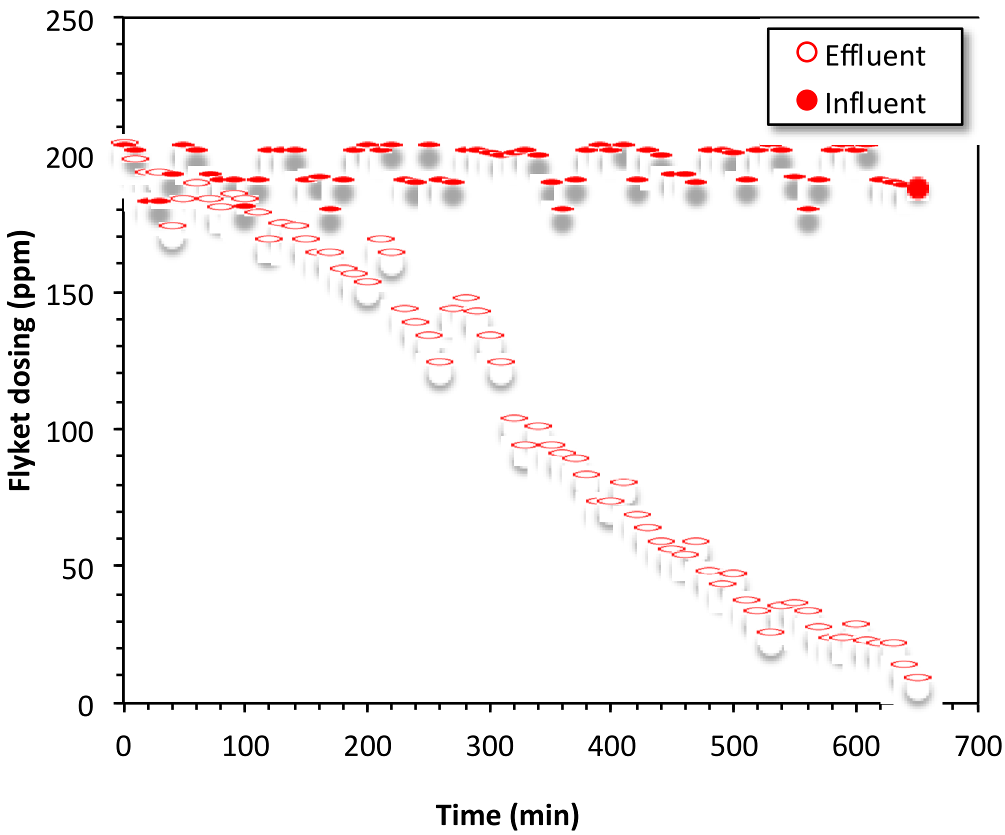

Figure 5. Time plot for the constructed alum sludge wetland trend in the system.

3.1.3. Flytek Influent Loading Effect on Treatments:

The influence of the Flytek loading is displayed in Figure 6. The data revealed that the influence of the initial pesticide loading ranged from 100 to 800 ppm at 26 °C with the removal efficiency being assessed. Notably, the obvious enhancement in the adsorption uptake is investigated by the Flytek removal with the decreasing pesticide concentration of influent to the column. According to the results of the XRD (Figure 2) the existence of highly adsorbent materials, such as alluminosillicate, which led to the high removal rate reached at 96% when the FT load is 100 ppm [31]. However, with the increase in the pollutant load the adsorption uptake declines to 93, 85 and 59% when the loaded Flytek corresponds to 200, 400 and 800 ppm, respectively, in comparison to 93% when 100 ppm of the FT is loaded. This trend in decline of the adsorption uptake, with the excess of FT loading, could be certified when the active sites of the AS material substrate is loaded with pesticide; therefore, it could not adsorb high loads of the Flytek. Hence, the rate of mass transfer for the solid-adsorbate interface is reduced, and therefore the increment of the adsorption capacity. The available published literature [32] also suggests a similar trend. However, Negi et al. [33] recorded the adsorption uptake of dye polluted water declined with a methylene blue dye increase.

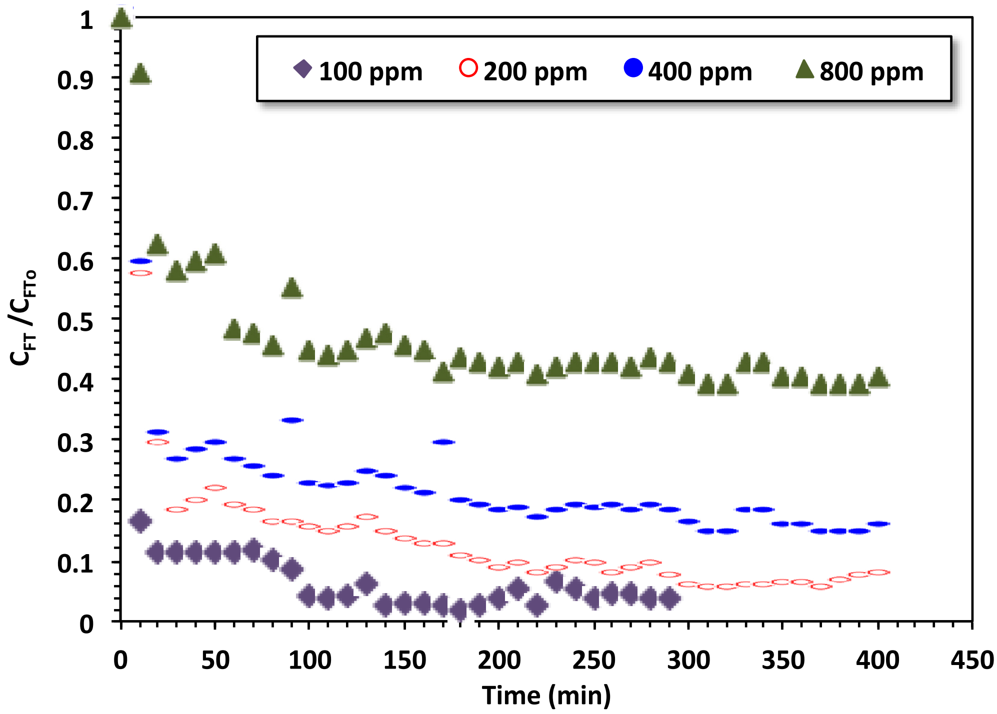

Figure 6. Flytek pesticide loading effect on the uptake concentration decline.

3.1.4. Overall Treatment by pH Variation

Commonly, pH plays a major role in adsorption technology since it significantly affects the adsorption behavior. Using this concept, the adsorption treatment methodology is applied for Flytek removal at various pH values (3–9), including the original effluent pH without adjustment (7.2); the results of this test are displayed in Figure 7. Various FT removals are attained and their removal is strengthened with a pH recorded at 7.2, which is signified as the original pH of the aqueous effluent without additional adjustment. Such phenomenon might be associated with a point of zero charge, pHpzc (i.e., the point that the alum sludge surface is generally near 8.0) [34]. However, behind or above such pHpzc the alum sludge surface is positively or negatively charged, which leads to a reduction in the adsorption efficacy. This is due to the repletion forces generated between the adsorbent “alum sludge” material surface and the pesticide molecules [22]. Hence, the Flytek molecules are certainly adsorbed at a pH of 7.2. Additionally, elevating the pH value to the alkaline range (pH 9.0) hinders the interaction between the pesticide molecules and the solid “alum sludge” adsorbent surface. Similar data was recorded by [35] an adsorption of a blue reactive dye by a bio-adsorbent.

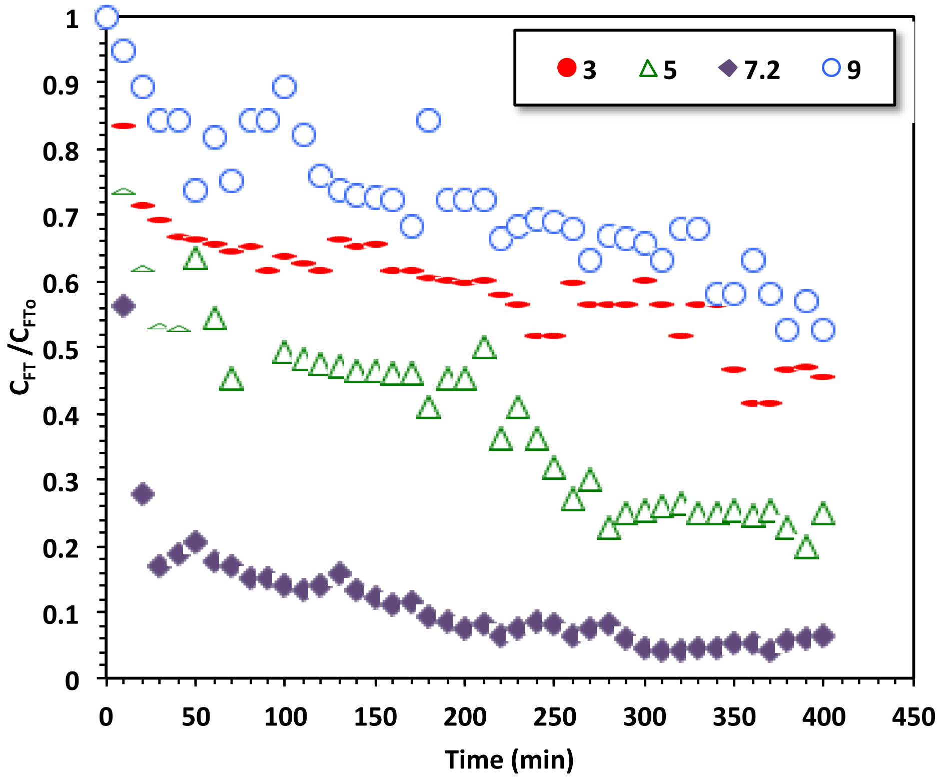

Figure 7. Effect of aqueous Flytek pesticide effluent pH on the uptake removal.

3.1.5. Temperature Effect on Flytek Removals

The temperature profile influence on the adsorptive capacity of the alum sludge was assessed for the Flytek pesticide. The data displayed in Figure 8 signifies a decline in Flytek removal, which is significantly observed when the temperature was elevated from a room temperature of 298 K to a gradual increase in temperature to 313 K of the aqueous solution, influencing the adsorption column. A decline in the removal rate from 96% to 85% with this temperature elevation is recorded. This is attributed to a decline in the adsorption capacity, and, hence, the pesticide elimination efficacy is reduced. Thus, the temperature change effects the Flytek adsorption capacity, indicating the significance of temperature on the alum-sludge-adsorption column scheme. This could be credited to the alteration of the chemical structure of the pesticide molecule with the temperature change to undesirable intermediates. The increment in adsorption capacity at low temperature systems could be due to the exothermic reaction nature of the adsorption system. This means that within the studied temperature ranges, the thickness of the absorption layer declines since the upsurges in the affinity of the Flytek pesticide molecules to escape from the adsorbent surface to the aqueous phase results in a decline in the adsorption as temperature increases [36]. Moreover, the attractive forces augmented by the alum sludge surface and the Flytek pesticide molecules are hindered, and, therefore, the adsorption declines [37]. This behavior in the reaction phenomenon was previously reported by various authors [37,38] on treating various dye types using numerous adsorbents, such as filler earth and fried clay.

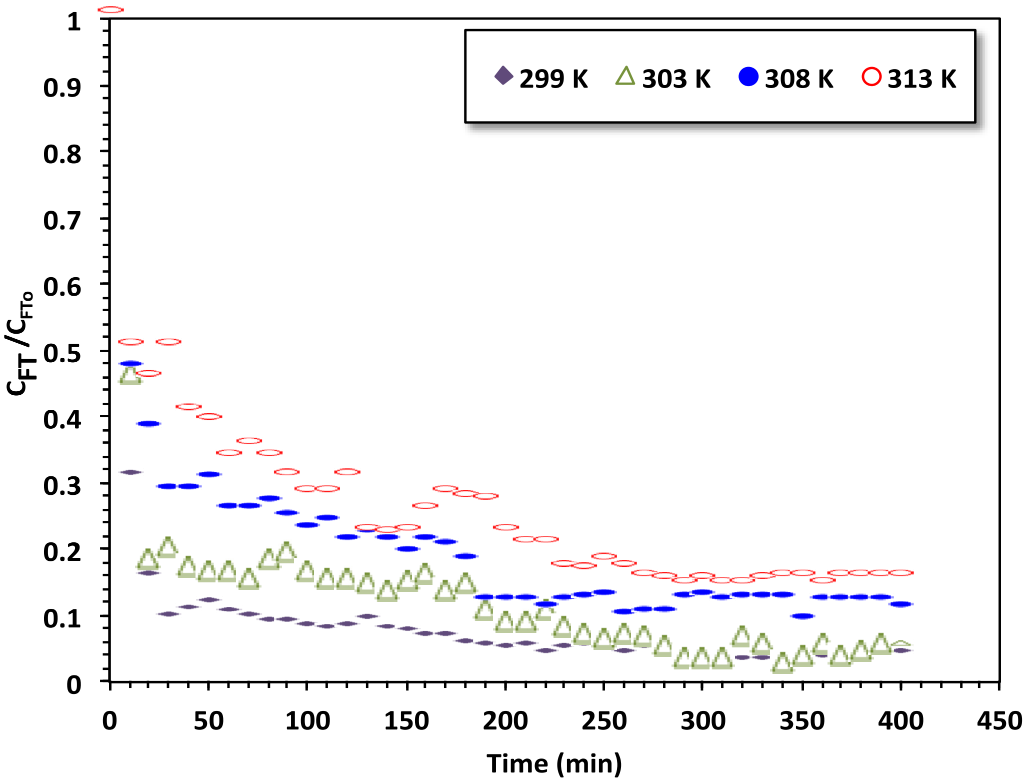

Figure 8. Effect of aqueous Flytek pesticide effluent temperature on the uptake removals.

3.2. Isotherms Modelling

Isotherm models for adsorption are investigated and applied to specify a relation between the Flytek pesticide adsorbate and the alum sludge adsorbent bed. The isotherms of the adsorption were applied according to the Langmuir and Freundlich models that are applied to analyze the isotherm results according to their liberalized form displayed in Table 2 [39]. The isotherms of the adsorption were conducted at 26 °C for 100 to 800 mg/L of the Flytek pesticide. Figure 9a,b and Table 2 display the isotherm parameters of Langmuir and Freundlich. According to the correlation coefficient results (r^2) tabulated in Table 2, the data were best fitted as the Freundlich isotherm model for the four systems, namely: #1 (100%) Sludge CW; #2 (80%) Sludge CW; #3 (60%) Sludge CW; and #4 (40%) Sludge CW since the correlation coefficient (r^2) ranged from 0.99–0.98. Hence, the Flytek (FT) adsorption system was categorized and found to be built on the heterogeneous multilayer adsorption surface. Additionally, the heterogeneity constant value (n) is an indication to categorize the adsorption as favorable when the (n) value is larger than "unity". As displayed in Table 3, the n data recorded for the Flytek adsorption on the alum sludge is favorable.

Table 2. Isotherm equilibrium model parameters of Langmuir and Freundlich isotherm for Flytek adsorption.

Isotherm	Parameters	#1	#2	#3	#4
Langmuir $\frac{C_e}{q_e} = \frac{1}{K_L} + \frac{a_L}{K_L} C_e$	a_L, L/mg	0.00377	0.0144	0.00244	0.00311
	K_L	0.82883	3.0778	0.42151	0.29652
	Q_o, mg/g	222.22	212.76	172.413	95.238
	r^2	0.84	0.87	0.99	0.97
Freundlich $\ln(q_e) = \ln K_F + \frac{1}{n} \ln C_e$	n	1.152	1.1735	1.18133	1.35464
	K_F	1.1278	1.9151	0.6694	1.4294
	r^2	0.99	0.98	0.99	0.99

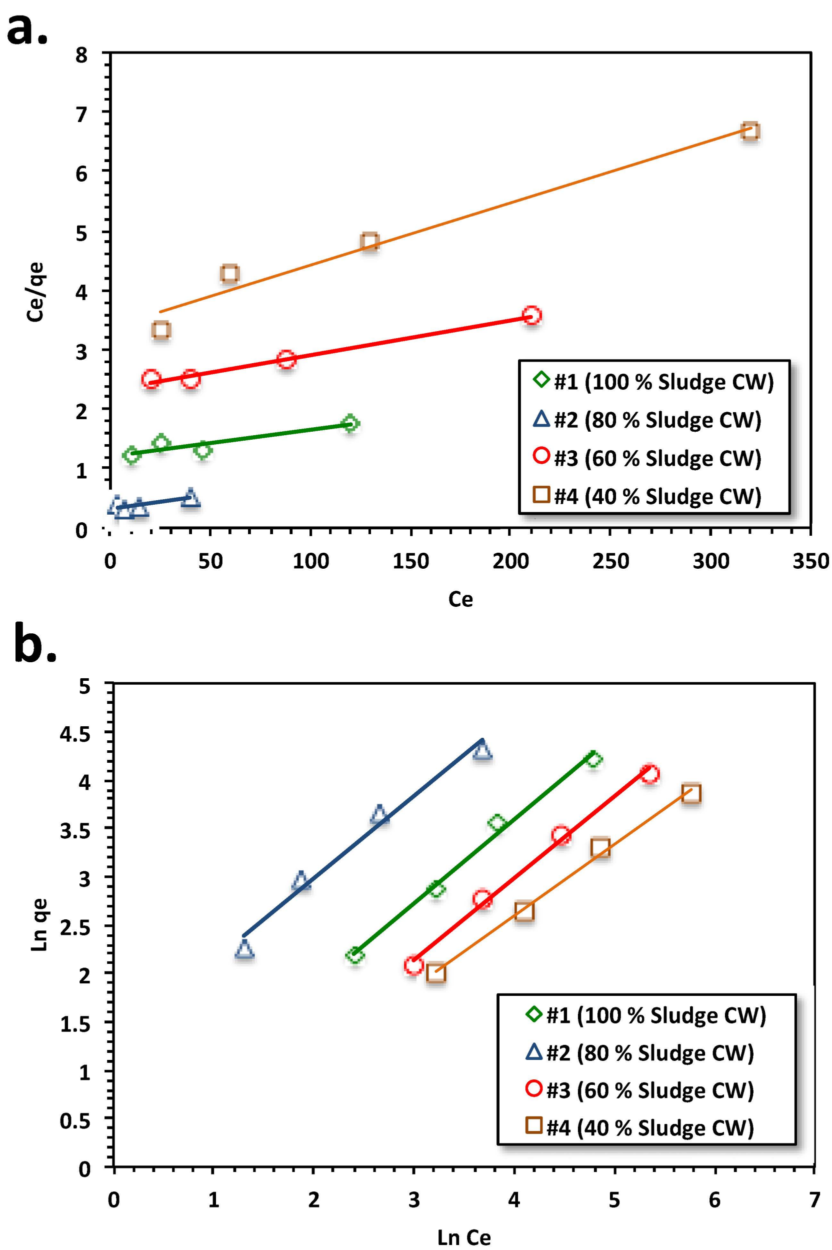

Figure 9. Comparison of (**a**) Langmuir and (**b**) Freundlich isotherm models of Flytek removal on alum sludge bed.

3.3. Column Kinetics' Study

Adsorption kinetic models illustrate and signify the magnitude and mechanism of the adsorption reaction [39]. Two kinetic models were used to explore the controlling mechanism of the Flytek pesticide removal from aqueous stream. Lagergren's 1st-order and pseudo 2nd-order were used to describe the relevant adsorption and the results are organized in Table 3. The linearized equation of the Lagergren's 1st-order model $((\log(q_e - q_t) = \frac{K_1}{2.303}t + \log(q_e))$, signifying that the initial adsorption kinetic model is associated with the absorption uptake. The model suggests that one absorptive site, in the solid-phase adsorbent is present, adsorbing one Flytek pesticide solute molecule. However, the linearized equation of the pseudo 2nd-order model is prearranged as: $\frac{t}{q_e} = \frac{1}{K_2 q_e^2} + \frac{1}{q_e}t$, where k_2 is the pseudo-2nd-orderrate constant.

From the data of the correlation coefficient values (see Table 3), validation of such kinetic models is verified according to the highest correlation coefficient (r^2), ranging from 0.94 to 0.99, which corresponds to the pseudo 2nd-order for all the systems in comparison to

0.92 to 0.97 for the Lagergren's 1st-order. Pseudo 2nd-order kinetic also correlates with the experimental data, which means the rate-limiting step of the reaction is chemisorption and the adsorption reaction is dependent on the adsorption uptake rather than the loading of the Flytek concentration. This investigation agrees with the previously reported literature [40] in eliminating an oil-contaminated solution.

Table 3. Comparing Lagergren's 1st-order and Pseudo 2nd-order models for Flytekabsorption system.

Kinetic Model	Parameters	#1	#2	#3	#4
Lagergren's 1st-order	q_e, mg/g	0.27	0.09	0.29	0.28
	k_1, min^{-1}	4.67	4.29	4.77	4.82
	r^2	0.67	0.97	0.63	0.62
Pseudo 2nd-order	q_e, mg/g	16,667	14,285	100,000	5000
	$k_2 \times 10^{-5}$, g·mg/min	7.2	24.5	0.25	6.675
	r^2	0.98	0.94	0.93	0.94

A comparison of the adsorption uptake of various substances as an adsorbate on alum sludge using different systems in the literature is compared to the current work and the data is tabulated in Table 4. Encouragingly, alum sludge could be applied for treating numerous pollutants, ranging from dyes, heavy metals and emerging pollutants with promising adsorption capacities. It is noteworthy to mention that it is not applied, to date, in treating agriculture effluent streams. Alum sludge is a suitable adsorbent candidate since it is a waste material, so the system is considered a win-win technology. It is noted from Table 4 that the adsorption capabilities are dependent on the type of pollutant and the operating conditions.

Table 4. Adsorption capabilities of numerous uptake removals from wastewater using AS adsorbent.

Pollutant	Testing Conditions	Adsorption Capabilities (mg/g)	Reference
Flytek	Initial pollutant = 200 ppm; pH = 7.2; Time = 600 min	76.03	Current investigation
Procion Blue dye	Initial pollutant = 11.8 ppm; pH 7; Time = 1 h	6.5	[41]
Phosphorus	Initial pollutant = 4.2 ppm; pH = 6.2; Time = 12 d	0.89	[42]
Phosphorus	Initial pollutant = 4.2 ppm; pH = 6.8; Time = 12 d	1.59	[42]
Arsenics	Initial pollutant = 1875 mg/kg; pH = 6–6.5; Time = 2 d	7.68 - 6.00	[43]
Arsenics	Initial pollutant = 37.7 µg As/L; pH 8.1; 20 h	0.003	[44]
Lead	Initial pollutant = 8.5 ppm; pH 5–8	0.21–0.22	[45]
Chromium	Initial pollutant = 8.5 ppm; pH 5–8	0.51	[45]
Chromium	Initial pollutant = 8.5 ppm; pH 5–8	0.30	[45]
cadmium	Initial pollutant = 0.1 g; pH 4.5; Time = 24 h	0.040	[46]
Cobalt	Initial pollutant = 25–800 ppm; pH 6.0; 48 h	17.31	[47]
Humic acid	Initial pollutant = 12.28 ppm; pH 5.56	0.47	[48]
Phosphorus	pH 7.0; Time = 24 h	0.90	[49]
Ammonium	Initial pollutant = 17 g/L; Time = 60 min	11.3	[50]

4. Conclusions

With increasing worldwide environmental challenges, a very distinctive response must be taken. Using this concept, the current investigation has validated the feasibility of a sustainable waste management system, which embraces a future world, for an integrated waste management system. A laboratory scale study demonstrated the promising application of an alum sludge (AS) by-product "waste" material from waterwork plants as a useful raw material, supporting the material labor in constructed engineered wetland systems for agriculture wastewater loaded with Flytek elimination and control. Trials on adsorption treatment columns as an introductory wetland system is applied, and the presence of an 80% alum sludge cake, supported with a gravel medium, showed the highest removal efficiency, reaching 96%. The optimal operating conditions, including pH (7.2) and temperature (299 K) were recorded with the results indicating that the dewatered AS cake can be a carrier for the Flytek pesticide for use in agriculture stream elimination. In particular, for long term operations, clogging of the CW scheme should be tested and the AS saturation with the pesticide should be explored prior to real life applications.

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Conflicts of Interest: The authors declare no conflict of interest.

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