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CHAPTER
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SWOT analysis of agro-waste based adsorbents for persistent dye pollutants removal from wastewaters

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ABSTRACT

Dyes, especially from textile industries, are significant pollutants in water and wastewater, which have become pervasive in the environs to which they are discharged. The effluents containing different types of dyes have become ubiquitous in the environment. While several treatment techniques have been developed to address the removal of recalcitrant dyes from water and wastewater, the adsorption technique is highly preferred due to its many advantages. However, selecting the appropriate alternative adsorbents with high adsorption capacity to costly activated carbon has continued to receive great attention. This book chapter reviewed the applicability of adsorptive techniques of agro-waste based adsorbents for the removal of dye pollutants from water and wastewater. The mechanisms of persistent dye pollutant removals based on the adsorption processes were adequately described. Further, the strengths, weaknesses, opportunities and threats (SWOT) of using agro-waste materials as alternative adsorbents are also accounted.

KEYWORDS Agro-waste adsorbent, Dye pollutants, Adsorption mechanism, SWOT analysis

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Introduction

Due to the global water resources scarcity, the reuse of wastewater has recently been considered as a sustainable alternative to address the increasingly stiff competition of the limited resource, especially for agricultural activities, in many water-scarce regions (Libutti *et al.*, 2018; Mounira *et al.*, 2016). Hence, the need to ensure the adequacy of the quality of the treated wastewater for irrigation purposes and sustainable aquatic ecosystems (Kumar *et al.*, 2019; Adewumi and Ajibade, 2019; Baharvand and Mansouri Daneshvar, 2019). However, the increasing discharge of the generated wastewater into the environment without adequate treatment has been an utmost concern as it is related to human health and potential threats to aquatic lives (Lim and Aris, 2014). The rising population, changing consumption patterns and advances in industrialization are a few of many factors that are continually changing the diversities, patterns and quantities of wastewater generation. Moreover, the diversity of the wastewater sources have hindered the efficiency of some of the targeted treatment techniques. For instance, organic pollution generated from organic compounds originates from diverse sources, including domestic sewage, municipal wastewater, urban run-off and agricultural and industrial effluents (Adelodun *et al.*, 2019; Rashed, 2013). Most of the persistent organic pollutants are products of daily anthropogenic activities that have widespread in the environment (Katsoyiannis and Samara, 2004).

Although organic pollutants can be traced to various sources, wastewaters from industrial discharges are, however, regarded as highly toxic, carcinogenic and contain persistent organic pollutants (Doruk *et al.*, 2016). The industrial activities, especially textile processing is one of the high water-intensives which aided pollution of water bodies with high concentrations of dyes, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, heavy metals, surfactants and many other toxic organic compounds and also contributes to the depletion of available water resources (Vergili *et al.*, 2012; Tehrani-Bagha *et al.*, 2010; Salleh *et al.*, 2011). Among these organic pollutants, dyes are found to be the most common, recalcitrant, challenging to biodegrade and noxious pollutants (Peng *et al.*, 2016; Ali *et al.*, 2019).

The effluents containing different types of dyes have become ubiquitous in the environment as they can be found in the point source discharges of most of the industries, including textiles, paper and pulp, pharmaceutical, tannery, paint, food and et cetera. The dye pollutants pose undesirability in the aesthetic, obstructing sunlight into the water and degradation of the water environment where they are discharged (Nidheesh *et al.*, 2018). In fact, the excessive use of dyes has been linked to the various sources from which the persistent organic pollutants are produced (Shalla *et al.*, 2018).

Textile industries are the major sources of organic dyes. The dyeing operations, a significant component of textile activities, involve the use of poorly biodegradable dyes and other auxiliary organic materials, including soda ash, detergents and salts (Vergili *et al.*, 2012), which produce mutagenic and carcinogenic byproducts (Iqbal, 2016). The complexities in molecular structures of dye chemicals and the recalcitrant nature of textile effluents due to their diversity from manufacturing processes of different forms of textile products require highly efficient treatment techniques.

These treatment techniques and materials need to be affordable and be able to provide solutions to reuse the treated wastewater without any potential health-related issues to both humans and ecosystems. For these reasons, the treatment techniques, with high efficiency without secondary waste, are limited. Nevertheless, considering the toxicity of organic dye pollutants to our environment, both human and aquatic, it has, therefore, become increasingly important to intensify efforts towards the treatment of effluent containing dyes before their discharge into water bodies. Moreover, the reuse of adequately treated wastewater from textile industries can address the scarcity of water resources in the regions on concerns.

There has been rapid development in the treatment of wastewater containing dye pollutants in recent times. Consequently, several treatment techniques have been developed for their removal from water and wastewater. These include coagulation, biological treatment, chemical oxidation, electrochemical and membrane processes, aerobic microbial degradation and adsorption (Salleh *et al.*, 2011). While some of the methods are touted to be relatively effective, they are however expensive, high energy demand, incapable of removing different variety of dyes effectively and are found to produce byproducts which require further treatment (De Andrade *et al.*, 2018; Mezohegyi *et al.*, 2012; Pokhrel and Viraraghavan, 2004).

Moreover, some of these treatment techniques have limited applications in many parts of developing counties where indiscriminate point source discharges of persistent organic pollutants from industries, including dyes, persist (UNESCO, 2017). However, adsorption method is generally found to be effective for the removal of recalcitrant organic pollutants, including different forms of dyes, due to its simple operating design and conditions, no sort of unwelcoming secondary wastes and low cost of operations especially when non-conventional alternative adsorbents are used (Siddiqui *et al.*, 2019; Chang *et al.*, 2017).

The quality of the treated dye effluents largely depends on the type of adsorbents used and well-designed sorption processes, among many other factors (Salleh *et al.*, 2011). The major problem lies in selecting the appropriate adsorbents with an applicable adsorptive technique for the removal of dye pollutants from water and wastewater (Gupta and Suhas, 2009). This study, therefore, aimed to review the selected agro-waste based adsorbents used for the treatment or remediation of selected persistent organic dyes with their corresponding adsorptive techniques. In this study, we described and comprehensively compared some conventional adsorbents based on the strength of the adsorptive technique, used to remediate the wastewater pollution containing dye pollutants using the SWOT analysis.

Adsorption mechanisms for dyes removal from wastewater

Adsorption refers to the accumulation of pollutants, including dyes in the wastewater at the surface of the adsorbents. The physical and chemical interactions of adsorption processes occur at the interface of the two media i.e., adsorbent and wastewater. The pollutant molecules that are retained on the surface during the adsorption process are referred to as adsorbates while the materials upon which they are retained are called adsorbents. The bonding of adsorbates on the adsorbent surface is characterized by either Van der Waals, electrostatics and /or hydrogen bonds due to the presence of both carbonyl and hydroxyl groups on the adsorbents (Wakkel *et al.*, 2019).

Several factors aid the adsorption performance of any selected adsorbent in removing pollutants from wastewater. Aside the absorbent properties including high carbon or oxygen contents required of a suitable absorbent, other characteristics include large surface area with porous structure, high abrasion resistance and thermal stability and other operating conditions such as adsorbent dose, contact time, pH of the wastewater containing the dye pollutants and initial dye concentration (Ali *et al.,* 2012; Chandane and Singh, 2016; Aljeboree *et al.*, 2017).

Adsorption kinetics

The adsorption kinetics is a process used to investigate the adsorption mechanism. The adsorption rate using the kinetic study evaluates the best material choice of the adsorbent. The process explores the important kinetic parameters responsible for the sorption rate of the dye pollutants by the adsorbent. Further, the efficiency of the adsorption process can be assessed while also enable its applicability to industrial use and commercial applications. The kinetic models that are mostly used to describe adsorption mechanism for the dye pollutants removal are pseudo-first-order for simple adsorption kinetic analysis (Lagergren, 1898), pseudo-second-order based on adsorption equilibrium capacity (Ho and McKay, 1999), Elovich for chemisorption processes and also applicable to systems with heterogeneous adsorption surface (Low, 1960) and intra-particle diffusion for the identification of diffusion mechanism (Weber, 1963), using Eqs. (1) to (5).

$$q_t = q_e[1 - exp(-k_1 t)] \tag{1}$$

$$q_t = \frac{k_s q_e^2 t}{1 + k_s q_e t} \tag{2}$$

$$h_0 = k_s q_e^2 \tag{3}$$

$$q_t = \left(\frac{1}{\beta}\right) ln(\propto.\beta) + \left(\frac{1}{\beta}\right) ln(t) \qquad (4)$$

$$q_t = k_{id}\sqrt{t} + 1 \qquad (5)$$

where q_t (mg g^{-1}) is the amount of dye pollutants adsorbed at time t; q_e (mg g^{-1}) is the adsorption capacity of the dye pollutants at equilibrium; k_1 (min^{-1}), k_s (g gm^{-1}) and k_{id} (mg g^{-1} $min^{-1/2}$) are the adsorption rate constants for pseudo-first-order, pseudo-second-order and intra-particle diffusion models, respectively; t (min) is the contact time; h_0 (mg g^{-1} min^{-1}) is the initial sorption rate which can be obtained when approaches zero value.

Adsorption isotherms

The adsorption capacity can be enhanced using different forms of activation methods, which involve either physical activation such as carbonization of material or chemical activation using chemical activating agents (Adegoke and Bello, 2015). The effectiveness of the adsorption mechanisms in terms of relative adsorption capacity and equilibrium concentration of adsorbent through its interactions with adsorbate can be described using adsorption isotherms. The dye pollutant distribution between the two inter-surface media can be described using adsorption isotherm at a particular temperature when the equilibrium is reached (Aljeboree *et al.*, 2017). The commonly used adsorption isotherms are:

Freundlich isotherm is an empirical model that describes the multilayer adsorption based on the assumption of energy distribution on the adsorption surface (Freundlich and Heller, 1939). The adsorption rate varies with the strength of energy on the adsorption surface. The Freundlich isotherm model is expressed by the Eq. (6).

$$q_e = K_f \,.C_e^{1/n} \qquad (6)$$

where q_e (mg g^{-1}) is the unit adsorption capacity; C_e (mg/L) is the dye concentration at equilibrium; K_f and n [mg g^{-1} (L mg^{-1})^n] are Freundlich constants.

Langmuir isotherm model is based on the monolayer adsorption on the homogeneous surface with weak intermolecular forces (Langmuir, 1918). It is assumed that the adsorption rate decreases with increasing dye molecules on the adsorption surface (Aljeboree *et al.*, 2017). The Langmuir isotherm model is represented using Eq. (7).

$$q_e = \frac{q_{max}\,K_L\,C_e}{1 + K_L\,C_e} \qquad (7)$$

where q_{max} is maximum dye pollutants adsorbed; K_L (L mg^{-1}) is the Langmuir constant for adsorption energy and binding affinity of the adsorption surface.

Tempkin isotherm model describes the interaction effects of both adsorbent and adsorbate based on the assumption that the strength of energy on the adsorption surface decreases with coverage (Tempkin and Pyzhev, 1940). The Tempkin isotherm model is expressed using Eq. (8).

$$q_e = \frac{RT}{b} log(K_T C_e) \quad (8)$$

where b (kJ mol^{-1}) and K_T (L mg^{-1}) are the Temkin constants for adsorption energy and maximum binding energy, respectively. The detailed wide-ranging of isotherm models that have been extensively employed over the years is presented in Table 1.

Agricultural waste-based adsorbents for removal of dye pollutants

There have been several developed adsorbent materials for the removal of dyes from water and wastewater, with activated carbon regarded as the best of all and highly preferred (Martins and Nunes, 2015). However, the high cost of procurement, sludge production and regeneration problem have been the most significant constraints in the use of activated carbon as pollutant removal, including dyes. Moreover, Walker *et al.* (2003) reported the ineffectiveness of the activated carbon in the removal of both disperse and vat classes of dyes. The locally-sourced agricultural waste materials with high pollutant binding capacities have, however, been suggested and explored as alternative low-cost adsorbents (Salleh *et al.*, 2011; Adegoke and Bello, 2015).

Agricultural wastes are discarded in large quantities and these include rice husk, maize cob, peanut husk, soybean hull, eggshell, sesame hull, potato peels, citrus peels and many more. The agro-waste can be classified into plant-based and animal-based, depending on the origin of the waste materials. Living organisms such as algal and microbial biomass were also reported to have been used as pollutant adsorbents in water treatment (Siddiqui *et al.*, 2019). The agro-waste based adsorbents are used either in their raw forms or as composites for the removal of different classes of dyes. The presence of functional carboxyl, carbonyl and hydroxyl groups present at the surface of the agricultural wastes make them suitable adsorbent candidates for dye removal, most notably the cationic dyes (Salleh *et al.*, 2011; Wakkel *et al.*, 2019).

The removal of various types of dyes using some selected agro-waste based adsorbents with their adsorption capacities is presented in Table 2. The adsorption capacities were observed to vary significantly among the different adsorbents used in removing different dye pollutants, while adsorption mechanisms for which the maximum adsorption capacities occurred were mostly based on Pseudo-second order for adsorption kinetic and Freundlich and Langmuir for adsorption isotherms.

Table 1. List of linearized and non-linearized equations for adsorption isotherms models (Foo and Hameed, 2010)

Isotherm models	**Linear form**	**Non-linear form**	**Plot**	**Reference**
Langmuir	$\frac{C_e}{q_e} = \frac{1}{bQ_o} + \frac{C_e}{q_o}$	$q_e = \frac{Q_o b C_e}{1 + bC_e}$	$\frac{C_e}{q_e}$ VS C_e	Langmuir (1916)
	$\frac{1}{q_e} = \frac{1}{Q_o} + \frac{1}{bQ_o C_e}$		$\frac{1}{q_e}$ VS $\frac{1}{C_e}$	
	$q_e = Q_o - \frac{q_e}{bC_e}$		q_e VS $\frac{q_e}{bC_e}$	
	$\frac{q_e}{C_e} = bQ_o - bq_e$		$\frac{q_e}{C_e}$ VS q_e	
Freundlich	$log\ q_e = log K_F + \frac{1}{n} log C_e$	$q_e = K_F {C_e}^{1/n}$	$log\ q_e$ VS $log C_e$	Freundlich (1906)
Dubinin-Radushkevich	$\ln(q_e) = \ln(q_s) - k_{ad}\varepsilon^2$	$q_e = (q_s) exp(-k_{ad}\varepsilon^2)$	$\ln(q_e)$ VS ε^2	Dubinin and Radushkevich (1947)
Tempkin	$q_e = \frac{RT}{b_T} + \left(\frac{RT}{b_T}\right) \ln C_e$	$q_e = \frac{RT}{b_T} \ln A_T C_e$	q_e VS $\ln C_e$	Tempkin and Pyzhev (1940)
Flory-Huggins	$\log\left(\frac{\theta}{C_o}\right) = \log(K_{FH}) + n_{FH} \log(1 - \theta)$	$\frac{\theta}{C_o} = K_{FH}(1 - \theta)^{n_{FH}}$	$\log\left(\frac{\theta}{C_o}\right)$ VS $\log(1 - \theta)$	Horsfall and Spiff (2005)
Hill	$\log\left(\frac{q_e}{q s_H - q_e}\right) = n_H \log(C_e) - \log(K_D)$	$q_e = \frac{q s_H C_e^n H}{K_D + C_e^n H}$	$log\left(\frac{q_e}{q s_H - q_e}\right)$ VS $\log(C_e)$	Hill (1910)

Table 1. Continued...

Redlich-Peterson	$\ln\left(K_R \frac{C_e}{q_e} - 1\right) = g\ln(C_e) + \ln(a_g)$	$q_e = \frac{K_R C_e}{1 + a_R C_e^{g}}$	$\ln\left(K_R \frac{C_e}{q_e} - 1\right)$ VS $\ln(C_e)$	Redlich and Peterson (1959)
Sips	$\beta_S \ln(C_e) = -\ln\left(\frac{K_s}{q_e}\right) + \ln(a_S)$	$q_e = \frac{K_s c_e^{\beta} s}{1 + a_S C_e^{\beta} S}$	$\ln\left(\frac{K_s}{q_e}\right)$ VS $\ln(C_e)$	Sips (1948)
Toth	$\ln\left(\frac{q_e}{K_T}\right) = \ln(C_e) - \frac{1}{t}\ln(a_T + C_e)$	$q_e = \frac{K_T C_e}{(a_T + C_e)^{1/t}}$	$\ln\left(\frac{q_e}{K_T}\right)$ VS $\ln(C_e)$	Toth (1971)
Koble-Corrigan	$\frac{1}{q_e} = \frac{1}{AC_e^{n}} + \frac{B}{A}$	$q_e = \frac{AC_e^{n}}{1 + BC_e^{n}}$	-	Koble and Corrigan (1952)
Khan	-	$q_e = \frac{q_S b_K C_e}{(1 + b_K C_e)^{a_K}}$	-	Khan *et al.* (1997)
Radke-Prausnitz	-	$q_e = \frac{a_{RP} r_R C_e^{\beta} R}{a_{RP} + r_R C_e^{\beta} R^{-1}}$	-	Vijayaraghavan *et al.* (2006)
BET	$\frac{C_e}{q_e(C_S - C_e)} = \frac{1}{q_S C_{BET}} + \frac{(C_{BET} - 1)C_e}{q_S C_{BET} C_S}$	$q_e = \frac{q_S C_{BET} C_e}{(C_S - C_e)[1 + (C_{BET} - 1)\left({}^{C_e}/{}_{C_S}\right)]}$	$\frac{C_e}{q_e(C_S - C_e)}$ VS $\frac{C_e}{C_S}$	Bruanuer *et al.* (1938)
FHH	-	$\ln\left(\frac{C_e}{C_S}\right) = -\frac{\alpha}{RT}\left(\frac{q_S}{q_e d}\right)^{r}$	-	Hill (1952)
MET	-	$q_e = q_S\left(\frac{k}{\ln\left({}^{C_S}/{}_{C_e}\right)}\right)^{1/3}$	-	McMillan and Teller (1951)

Table 2. Adsorptive techniques and capacities of selected agro-waste material-based adsorbents

Adsorbent	**Dye pollutant**	**Adsorption kinetic**	**Adsorption isotherms model**	**Adsorption capacity (mg g^{-1})**	**Removal efficiency (%)**	**References**
Walnut shells	Methylene blue	Pseudo-second-order	Langmuir	178.90		Miyah *et al*. (2018)
Rice bran-based composite	Malachite green	Pseudo-second-order	Freundlich	22.32	-	Bhatti *et al*. (2017)
Egg shells	Methylated blue Congo red	Pseudo-second-order	Freundlich	94.90 49.50	-	Abdel-Khalek *et al*. (2017)
Citrus limetta Peels	Methylene Blue Malachite Green Congo red	Pseudo-second-order	Langmuir	6.36 8.73 6.60	-	Singh *et al*. (2017)
Zea Mays Cob	Methylene Blue Malachite Green Congo red	Pseudo-second-order	Langmuir	4.44 16.72 8.42	-	Singh *et al*. (2017)
Cationic surfactant -modified peanut husk	Light green	Pseudo-first-order	Freundlich	146.20	-	Zhao *et al*. (2017)
Breadnut (*Artocarpus camansi*) peel	Methylene blue	Pseudo-second-order	Langmuir	409.00		Lim *et al*. (2017)
Bengal gram (*Cicer arietinum*) seed husk	Congo red Methylene blue Rhodamine-B Acid blue 25	Pseudo-first order	Langmuir	78.12 333.33 133.34 5.56		Somasekhara Reddy and Nirmala (2017)
Fish scales waste	Azo	Pseudo-second-order	Langmuir	157.30		Ooi *et al*. (2017)
Carboxylic acid pretreated Sesame straw (*Sesamum indicum L.*)	Methylene blue	Pseudo-second-order	Langmuir	650.00		Feng *et al*. (2017)

Table 2. Continued...

Cedrela odorata seed chaff	Methylene blue Congo red Methyl violet Methyl orange	Pseudo-second-order	Langmuir	111.88 128.84 121.23 68.23	-	Babalola *et al*. (2016)
Soybean hull	Safranin	Pseudo-second-order	Temkin	47.00	89.5	Chandane and Singh (2016)
Dragon fruit peels	Alcian blue Methylene blue	Pseudo-second-order	Langmuir	71.85 62.58		Mallampati *et al*. (2015)
Calcined egg shell	Basic yellow 28	Pseudo-second-order	Freundlich	28.81	93.2	Slimani *et al*. (2014)
Peanut husk	Drimarine Black CL-B	Pseudo-second-order	Langmuir	38.00	-	Noreen *et al*. (2013)
Cocoa shell-based activated carbon	Methylene blue	Pseudo-second-order	Freundlich	212.72	-	Ahmad *et al*. (2012)
Peanut hull	Reactive black 5 (RB5)	Pseudo-second-order	Langmuir	55.55	-	Tanyildizi (2011)
Sesame hull	Methylene blue	Pseudo-second-order	Langmuir	359.88	92.79	Feng *et al*. (2011)
Rice husk treated with NaOH	Malachite green	Pseudo-second-order	Freundlich	17.98	98.9	Chowdhury *et al*. (2011)

SWOT analysis and perspectives

The summary of strengths, weaknesses, opportunities and threats of the agro-waste based adsorbents for the removal of dye pollutants from water and wastewater is presented in Table 3. The analysis indicated the use of agricultural waste as adsorbents for dye removals are highly beneficial not only in terms of water and wastewater treatment of dye pollutants but also as an opportunity for waste management. The agricultural waste materials are generated in large quantities and are of zero economic value, constituting environmental burdens. They are considered as the best alternative to other costly material based adsorbents.

Table 3. SWOT analysis of the agro-waste based adsorbents as dye pollutant removal.

Strength	**Weakness**
• Applicability to remove variety of dyes (Babalola *et al.*, 2016). • Relatively cheap to procure the materials (Chowdhury *et al.*, 2011). • Readily available (Bhatti *et al.*, 2017). • It is energy efficient process (Abdel-Khalek *et al.*, 2017). • Relatively good equilibrium time and rapid kinetics (Adegoke and Bello, 2015). • High carbon content (Singh *et al.*, 2017). • Good biodegradable and regeneration properties (Singh *et al.*, 2017).	• Chemical activation using NaOH, KOH, $ZnCl_2$, etc are required to improve porous structure of the adsorbents (Abdolali *et al.*, 2014). • Adsorption capacity of the same adsorbent vary with different dye pollutants removal (Abdel-Khalek *et al.*, 2017). • Not all the agro-wastes adsorbent based perform efficiently under natural conditions (Zhao *et al.*, 2017).
Opportunities	**Threats**
• Valorization of agricultural waste with low economic values. • Disposal problems associated with agricultural waste is reduced (Babalola *et al.*, 2016). • Cost of disposal of agricultural waste is eliminated. • Commercialization of agricultural waste as excellent adsorbent. • High profitability when explored at industrial scale.	• Spent adsorbents and removed dyes could cause environmental discomfort if not properly managed (Adegoke and Bello, 2015). • Adjustment of pH level for optimum adsorption process using some chemicals can create economic burdens on the use of agro-waste materials as adsorbent for dye pollutant removal (Lim and Aris, 2014). • Activation process using chemicals to improve the porous structure of some agro-waste materials require technical expertise.

Similarly, the adsorbents made from agro-wastes are efficient and the processes required to convert them to adsorbents are eco-friendly as they can be produced without going through any industrial process. Despite the numerous advantages of agricultural waste materials as adsorbents for dye pollutants removal, some plant-based agro-wastes, though with functional cellulose structures for trapping the pollutants, are found to release some toxic organic compounds into the water bodies being treated. The release of organic carbon can cause further deterioration of water quality through enhancement of the biological oxygen demand, chemical oxygen demand and total organic carbon contents.

Further, the adsorbents made from plant-based agro-wastes tend to attain saturation faster due to the coverage of interface by the dye molecules, thereby preventing further adsorption process. Although altering the pH of the dye solution using either acid or base can offer solutions to the stated problem, this process, however, requires technical expertise and costly instrumentation to achieve the desorption before regeneration occurs (Siddiqui *et al.,* 2017). Modifications of agro-waste through chemical pretreatments or their usage in composites form were reported to have enhanced adsorption capacities, unlike when the agro-waste materials are used as adsorbents in their raw forms (Feng *et al.,* 2017; Chowdhury *et al.,* 2011). However, this assertion is only applicable to some selected agro-waste materials targeting particular dye pollutant classes or types.

Conclusion

This study explored the use of agricultural waste materials as adsorbents for the removal of dye pollutants in wastewater and water treatment. The detailed review of the literature was carried out on the adsorption mechanisms of selected agricultural waste-based adsorbents considering different adsorption kinetics and isotherms with their corresponding adsorption capacities. The SWOT analysis was further carried out, highlighting some of the advantages and disadvantages of using agro-waste based adsorbents for the removal of persistent organic dye pollutants under their strengths and opportunities and weaknesses and threats, respectively. While there are abundant of agro-waste materials, including both plant and animal origins, which have been used as adsorbents, particularly to treat dye polluted wastewater, the adsorption capacities were found to vary widely with different dye pollutants. Meanwhile, the Pseudo-second-order type of adsorption kinetics and both Langmuir and Freundlich isotherm models resulted in maximum adsorption capacity of different dye pollutants among the majority of the agro-waste based adsorbents. The SWOT analysis revealed some disadvantages of using agro-waste materials as adsorbents for dye pollutant treatment, which are majorly on some improvements required to enhance the adsorption capacity. However, the advantages which are based on the strengths and opportunities outweigh the weaknesses and threats associated with the use of agro-waste based adsorbents, which make them highly preferred as sustainable materials for the treatment of dye polluted water and wastewater.

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