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# Batch adsorption removal of Nickel and Cadmium metal ion from wastewater using Waste material of Fabrics as Adsorbent

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**ABSTRACT**

The current research presents texture fly ash as an adsorbent for adsorption of Nickel and Cadmium metal ions from the aqueous solution. All tests to examine the impact of parameters, for example, pH and adsorbent measurements were done at 35 °C. The outcomes settled based on their ideal range for pH 6.8 and 0.1 g of adsorbent measurement. Mechanism of adsorption was clarified by Temkin isotherm that portrays the association of adsorbate and adsorbent. Adsorption binding isotherm constant and heat of adsorption expanded as temperatures expanded to 35 °C, 45 °C and 55 °C for Nickel metal ion, on another part for Cadmium metal ion binding constant consistent esteem expanded, however, the heat of adsorption diminished. A kinetic report was improved for the three temperatures 35 °C, 45°C and 55 °C. Kinetic behavior clarified by Pseudo-second request, Weber-Morris model, and Elovich second order equation.

**KEYWORDS**

Adsorption | Cadmium | Nickel | Fabric Fly Ash | Isotherm | Kinetic

**CITATION**

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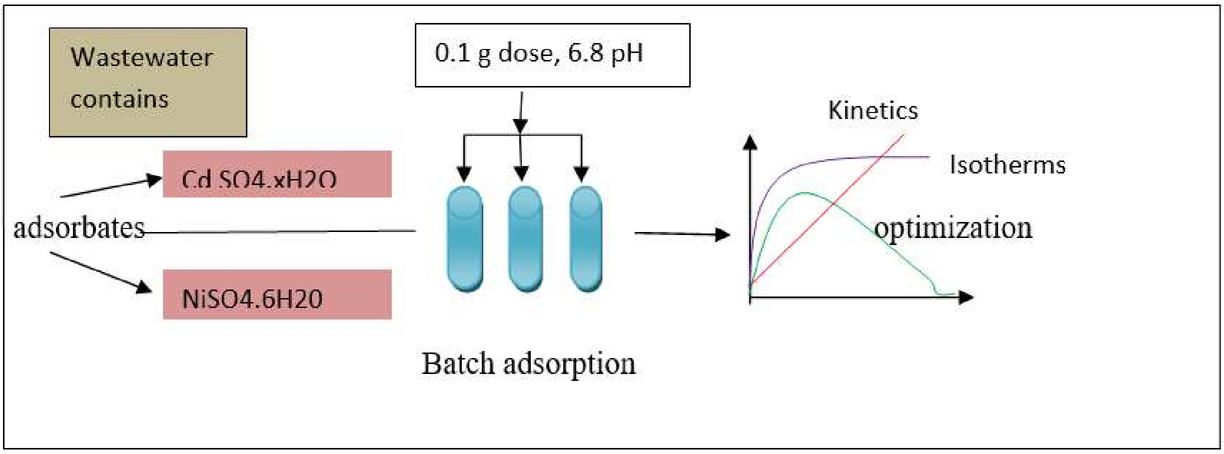
## Introduction




Present century polluted water is of major concern for all living organisms (Rezvani *et al.,* 2018). Polluted water released by various industrial sectors as well as domestic waste. But water released by industrial sectors contains many precious metals, so it has become necessary to remove these metals. These metals are heavy metals, precious metals as well as nutrient metals. If these heavy metals are taken by human beings in lesser quantity, then they play the role of nutrient metal for human body growth, but when these heavy metals limit exceed by permissible limit, then they play the role of toxic metals not only for the human body also for living organism. They may cause many serious diseases like cancer, kidney failure, high and low blood pressure, headache, nausea, vomiting, etc (Tchounwou *et al.,* 2012). So to stop this degradation of the environment, it is necessary to remove these heavy metals.

Heavy metals are metals which have high atomic weight, high density, and high specific gravity. There is some heavy metals available in periodic table, but some important and toxic heavy metals are cadmium, mercury, lead, arsenic, manganese, chromium, cobalt, nickel, copper, zinc, selenium, silver, antimony, and thallium. Some of the heavy metals are released by various industries like electroplating, mining, automobile, pharmacy, textile and dyes, chromate manufacturing, leather tanning, aluminum production, metal cleaning, and processing sectors (Ertugay *et al.,* 2008; Jain *et al.,* 2009; Prabu *et al.,* 2012). So the far number of methods available such as ion exchange, electro dialysis, membrane filtration, reverse osmosis, chemical precipitation and adsorption (Fu and Wang 2011). Conventional treatment methods offer high capital cost and undesirable percentage removal whereas biosorption has found on past researcher analysis very potent and efficacious method as it offers affordable and trouble free quality and provides high percentage removal (Kadirvelu *et al.,* 2001; Ricordel *et al.,* 2001; Tiwari *et al.,* 2015).

Nickel is a non-biodegradable toxic metal ion, and the presence of Ni (II) ions in drinking water may cause adverse health effects such as anemia, diarrhea, encephalopathy, hepatitis, lung and kidney damage, gastrointestinal distress, pulmonary fibrosis, renal edema, skin dermatitis, and central nervous system dysfunction (Zhang *et al.,* 2015; Khan *et al.,* 2012).

Cadmium is widely used and extremely toxic in relatively low dosages, is one of the principal heavy metals responsible for causing kidney damage, renal disorder, high blood pressure, bone fracture and destruction of red blood Cells (Kumar *et al.,* 2010).

As bunches of adsorbents, for example, activated carbon (Eleni *et al.,* 2015; Manjuladevi *et al.,* 2018), zeolites (kocaoba *et al.,* 2007; Taamneh *et al.,* 2017; Zendelska *et al.,* 2015), biomass (Mahmood *et al.,* 2017; Vakili *et al.,* 2014), fly ash (Sridevi *et al.,* 2013), plant materials (Emenike *et al.,* 2016; Samuel *et al.,* 2016), and so forth have prevailed in expulsion and provide high adsorption limit (Barakat, 2011; Keng *et al.,* 2014). The point of the Present examination to present texture of fly ash remains as an adsorbent for adsorption of Nickel and Cadmium metal ions. Waste cloth fabric ash provides better removal efficiency, so it has demonstrated as minimal effort and productive adsorbent. The adsorption of metal ions has never been reported by waste cloth fabric ash. Nettle ash has reported by one researcher (Mousavi and Seyedi 2011) and revealed adsorption efficiency 192.3 and 142.8 mg/g for cadmium and nickel metal ion. Novelty of the work is to exploit waste cloth fabric ash as adsorbent.

## Materials and methods

*Adsorbent utilised*

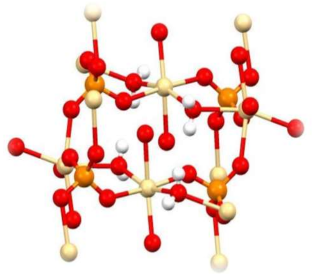
As some little bits of textures are dealt with as waste which is, for the most part, tossed at junk level. Along these lines, to limit the misuse of the material business, Waste fabric tests were gathered from around territories. Material texture at that point washed and dried in daylight till totally dry and after then totally consume within the sight of oxygen at the open territory. The physio-substance properties of the sample gives better description as detailed by (Page *et al.,* 1979). Moisture content of substance, pH, and specific gravity were found as 70%, 6.8 and 1.5 g $ml^{-1}$. Surface area found to be 50.876 $m^2/g$.

*Adsorbate used*

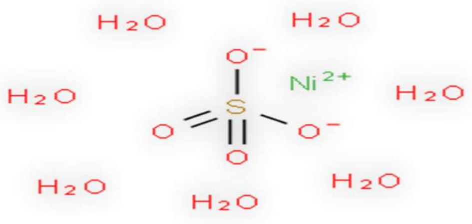
The synthetic compounds were utilized as Cadmium sulfate hydrate and Nickel (II) sulfate hexahydrate salts in batch adsorption study. For tests, these salts were utilized to get ready 25 ppm stock solution by dissolving in refined water. Impacts of parameters initial metal ion concentration, pH, and adsorbent measurements were contemplated independently. pH of the arrangement is balanced by 0.1 N HCl and 0.1 N $H_2SO_4$. Every one of the tests was directed by differing one of a factor while other staying settled at 35 °C. The wavelength (390 and 373nm) selected for both Cadmium and Nickel metal ions.

*Instruments used*

Absorbance was checked by UV-Vis spectrophotometer RIGOL Ultra 3660 for all adsorption studies available in the university. Perkin Elmer Frontier instrument was utilized to characterize for morphological image and XRD image which was available in Punjab University Chandigarh. Nitrogen adsorption-desorption isotherm and surface area were examined with the help of Quanta Chrome Nova 1000.



Cadmium sulfate




Nickel sulfate hexahydrate

Fig. 1 structure of adsorbate molecules

## Results and Discussion

*Characterization of adsorbent*

This testing of the adsorbent sample indicates the presence of the functional group. A presence of functional groups decides the adsorption behavior of adsorbent or tells about the mechanism of the adsorption reaction. An indication of a hydroxyl group, alcoholic group, -NH stretching and ethers shows the effective adsorption. Perkin Elmer Frontier model was used to characterize.

Comparison of FTIR band positions at different functional groups before adsorption and after adsorption obtained in the range 400 $cm^{-1}$ to 4000 $cm^{-1}$ with numerous groups as shown in Table 1. Broad peak was obtained at 3440 $cm^{-1}$ and 1626 $cm^{-1}$, N-H stretching 1462 $cm^{-1}$, C-O vibrations 1014 $cm^{-1}$. After adsorption peaks were shifted to other intensity due to the interaction of surface-ion. A similar trend reported somewhere (He *et al.,* 2016; Muinde *et al.,* 2017)

| WCFA adsorbent | Before adsorption | After adsorption |
|---|---|---|
| Coupled with H-bond | 3440 | 3418 |
| Ring stretches of C=C | 1626 | 1648 |
| Ring stretches N-H | 1462 | 1430 |
| Aromatic C-H deformation | 1014 | 1014 |

**Table 1:** FTIR information for the fabric fly ash before and after adsorption

Scanning Electron Morphology (SEM): this morphology test introduces the morphological image of the sample when a beam of electrons spread over the sample. It tells about the porous structure of the sample and the presence of cavities which is in favorable to adsorption (Visa *et al.,* 2014). Images of sample adsorbent shows rough surface at 10 µm and 20 µm. both average sizes image evident that adsorbent sample have sufficient pore size for adsorbates to adsorb.

BET nitrogen adsorption-desorption isotherm: the plot of adsorption-desorption nitrogen isotherm between relative pressure vs. volume adsorbed presents the amount of nitrogen gas adsorbed on to the surface of adsorbent as well as amount of that gas desorbs at constant temperature of 77K. This amount of gas adsorbs into the mesopore area due to high temperature operation and this mesoporosity is revealed by hysteresis behavior as shown in figure 4. A same trend presented by (Boycheva *et al.,* 2016).

XRD: XRD technique is very identical that determines the strength of unknown mineral and provide unit dimension of structure (Celik *et al.,* 2008). Diffractograph demonstrated a predominant phase of quartz and dolomite. This pattern of fraction clears the disappearance of dolomite and clay fraction comprises by phyllosilicates.

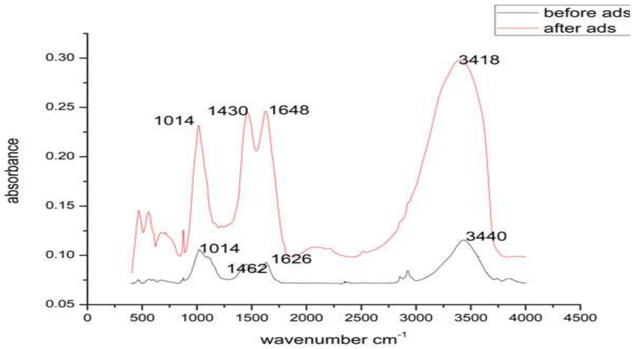



**Fig. 2:** Infra-red spectrum of Fabric Fly Ash before and after adsorption

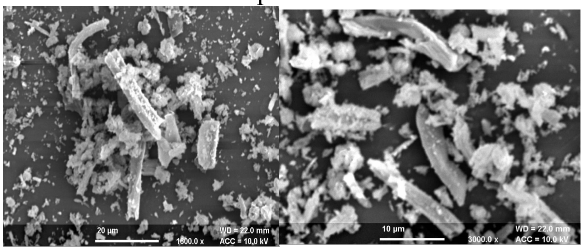


**Fig. 3** Morphological structure of Fabric Fly Ash

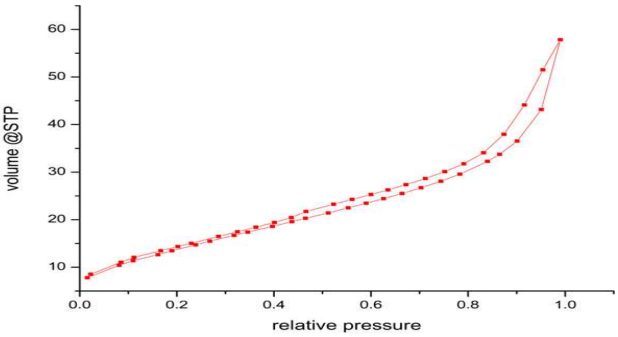



**Fig. 4:** BET Nitrogen adsorption-desorption isotherm of Fabric Fly Ash

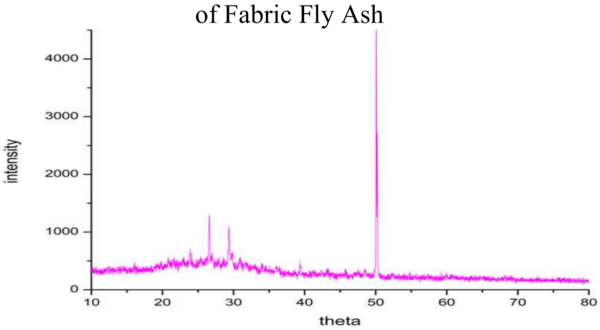



**Fig. 5:** XRD image of Fabric Fly Ash

*Effect of pH*

pH is a controlling factor in the adsorption process, and it also affects the toxicity of metal ions. The % removal of Cadmium by fabric fly ash increased as pH of the solution increased, and the maximum % removal (90%) is obtained at pH 6.8, on this value, it attains an equilibrium after this no further variation obtained, whereas % removal of Nickel ion decreased for high pH value as for low pH value % removal increased up to 65% because of the reason that at low pH protons released, therefore competition of metal ion with protons. This behavior completely depends upon the nature and properties of adsorbent (Anagho *et al.,* 2013; Prabakaran *et al.,* 2012).

*Effect of adsorbent dose*

Adsorbent dose effect studied on varying quantity from 0.1 to 0.3g in 15ml of 25ppm stock solution and rotary shaker was employed for shaking purpose for constant 2h. This optimization factor decides the optimum range of adsorbent used in the further experiment. The results showed that for Cadmium ion as well as for Nickel ion, optimum range is 0.1 g for the adsorbent. The effect of adsorbent dose onto the adsorbate ions revealed that on varying adsorbent dose % removal increased. For 0.2 g and 0.3 g adsorption capacity increased which means that as increased of the amount of adsorbent percentage removal and adsorption increased due to the availability of the more active sites. The similar observations are reported (Essomba *et al.,* 2014).

*Adsorption isotherms*

To know the mechanism of adsorption, isotherms can be used to predict the accumulation of substance. Langmuir, Temkin isotherms were used to predict adsorption potential. Langmuir isotherm gives knowledge of monolayer adsorption. It also assumes that adsorption takes place at the homogenous surface. Langmuir equation is (Kumar *et al.,* 2009)

$q_e = K\, q_0\, C_e / 1 + K\, C_e$ ..... (1)

$q_0$ is maximum monolayer capacity (mg $g^{-1}$), and K is Langmuir constant (L $mg^{-1}$). The plot of $1/q_e$ vs. $1/C_e$ gives slope and intercepts value for calculation of monolayer capacity. But this isotherm doesn't give straight line and also negative intercept value, same kind of work reported by (Kiurski *et al.,* 2012). Temkin isotherm is one that shows adsorbate-adsorbent interactions and also explains the logarithm coverage layer information. Equation presented by Temkin (Srivastava *et al.,* 2011)

$q_e = B \ln A_t + B \ln C_e$ ..... (2)

where $B = \frac{RT}{b_t}$ constant related to the heat of adsorption (J $mol^{-1}$) $A_t$ equilibrium binding constant (l $g^{-1}$) and $b_t$ Temkin isotherm constant. The plot between $q_e$ and $\ln C_e$ gives straight line presented in Fig. 6 and slope or intercept values helps to calculate all parameters to define this adsorption isotherm.

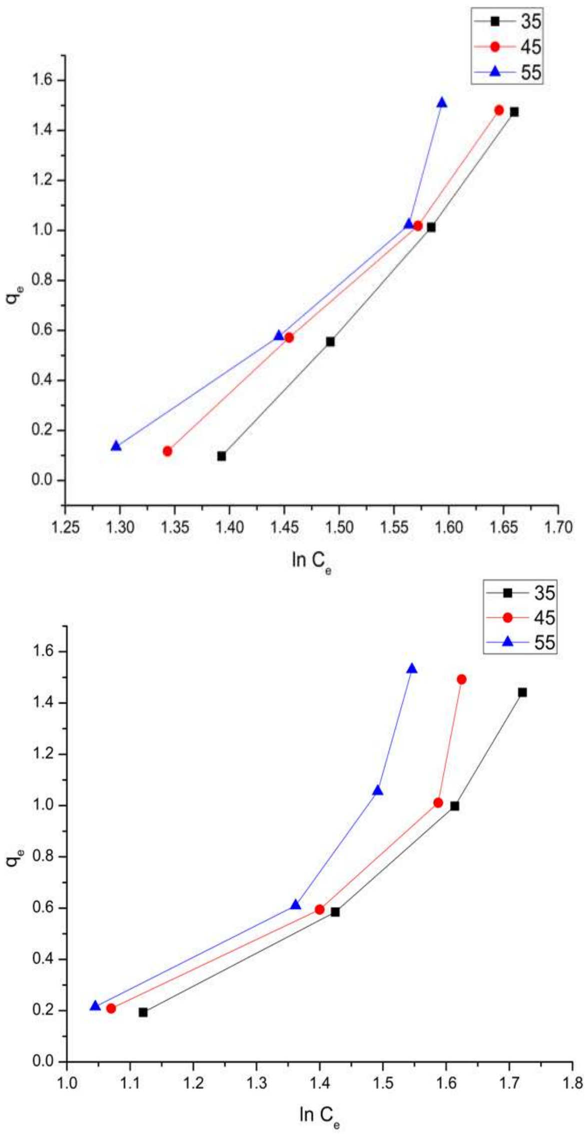



**Fig. 6:** Temkin isotherm at different Temperatures (a) Cadmium (b) Nickel

Temkin isotherm was studied concerning three temperatures 35 °C 45 °C and 55 °C. From the plot, it is proved that as the temperature increasing adsorption capacity per gram of adsorbent increasing from 35 °C to 55 °C. Parameters calculated such as Temkin binding constant increased from 0.722 to 0.903 for Cadmium ion as temperature increased. On the other hand, the heat of adsorption decreased from 5.115 to 4.189 as temperature increased. Similar kind of behavior is shown by Nickel metal ion (Rao *et al.,* 2014). All the calculated parameters are shown in Table 2.

*Chemical Kinetics*

Kinetics behaviour shows the efficiency of the adsorbent and speed of adsorption, adsorption constant and desorption constant values for fabric fly ash adsorbent. Kinetics also decides the order of reaction and how adsorption capacity takes place concerning time variations.

Langrage pseudo second order behavior is given by equation

$$t/q_t = 1/(K_2 q_e^2) + t/q_e \quad \ldots.. (3)$$

where $K_2$ second order rate constant (g mg$^{-1}$ min$^{-1}$). Adsorbent for Cadmium and Nickel metal ions adsorption comes under second-order behavior concerning linear correlation $R^2$. The plot between $t/q_t$ and t (Fig. 7) gives quiet well fit in the form of a linear line and slope and intercept values for calculating other factors. This study performs for three temperatures of 35 °C, 45°C and 55 °C, as temperature increased the amount adsorbed per gram of adsorbent decreased for both metal ions, similar trend reported by (Muthuselvi *et al.,* 2016; Venkatesan *et al.,* 2016; Panayotova *et al.,* 2001; Patil *et al.,* 2012).). Weber-Morris model is also known as the Intra-particle diffusion model which determines the rate of adsorption of any liquid system.

$$q_t = K_i * t^{0.5} \quad \ldots.. (4)$$

Where $K_i$ intra diffusion rate constant (mg g$^{-1}$ min$^{-1/2}$)

This equation shows time expansion of concentration (Tsibranska *et al.,* 2011).

Fig. 8 explains initial concentration behaviour of diffusion rate and as demonstrated by figure linear curve that does not pass through origin which means that diffusion takes place by the help of other models also. No boundary layer effect noticing here and it is not rate limiting or controlling step. Figure between $q_t$ vs. $t^{0.5}$ explain the linearity of the equation with respect to high value of correlation coefficient for both metal ions and all factors calculated as shown in Table 3.

Elovich kinetic equation is given by

$$q_t = 1/\beta\ [\ln (\alpha\beta)] + \ln t/\beta \quad \ldots.. (5)$$

where α and β are adsorption and desorption constant. This model also describes the second order kinetic behavior as demonstrated by fig. 9 and same trend reported by (Tan *et al.,* 2009) Desorption constant going to increase upon increased temperature for both the metal ions which is an indication of extent surface area coverage for the adsorbate molecules to adsorb.

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**Conclusion**

Adsorption on Fabric Fly Ash is found as a effective strategy. Fabric Fly Ash demonstrated as an effective and ease adsorbent. Adsorption subject to pH and adsorbent measurement, to optimize pH 6.8 and adsorbent dosage estimation of 0.1 g. Adsorption mechanism is very much clarified by Temkin isotherm and all parameters assessed from this isotherm gives linearity with temperature esteems. Dynamic models clarify the efficiency of the adsorbent. Kinetic behaviour takes after the pseudo-second-arrange show. All models Pseudo-second order, Intra particle dispersion, Elovich condition and Natrajan and Khalaf arrange give well fit concerning the direct relationship coefficient.

## References


Anagho SG, Tchuifon DR (2013), Nickel adsorption from aqueous solution onto kaolinite and metakaolinite: kinetic and equilibrium studies. Int. J. Chemis. 04.

Barakat MA (2011), New trends in removing heavy metals from industrial wastewater. Arabian J. Chemis. 4(4):361-377.

Boycheva SV and Zgureva DM (2016) Surface studies of fly ash zeolites via adsorption/desorption isotherms. Bulgarian Chemical Communications (A): 101-107.

Celik O, Damci E, and Piskin S (2008) Characterization of fly ash and its effects on compresssive strength properties of portland cement. Indian J Engg & Mater Sci 15: 433-440.

Eleni A. Deliyanni, George Z. Kyzas, Kostas S. Triantafyllidis, Kostas A. Matis (2015) Activated carbons for the removal of heavy metal ions: A systematic review of recent literature focused on lead and arsenic ions. De Gruyter Open 13(1): 699-708.

Emenike PC, Omole DO, Ngene BU, Tenebe IT (2016) Potentiality of agricultural adsorbent for the sequestering of metal ions from wastewater. Global J. Environ. Sci. Manage. 2(4):411-442.

Ertugay N, and Bayhan YK (2008), Biosorption of Cr (VI) from aqueous solutions by biomass of Agaricus bisporus. J Hazard. Mater. 154(1-3):432-439.

Essomba JS, and Tagne GM (2014), Adsorption of cadmium (II) ions from aqueous solution onto kaolinite and metakaolinite. Pure and Applied Chem. Sci. 2:11-30.

Fu F, and Wang Q (2011), Removal of heavy metal ions from wastewaters: a review. J. Environ. Manage. 92(3):407-418.

He K, Chen Y, Tang Z, Hu Y (2016), Removal of heavy metal ions from aqueous solution by zeolite synthesized from fly ash. Environ. Sci. & Poll. Res. 23(3):2778-2788.

Jain M, Garg VK, and Kadirvelu K (2009), Chromium(VI) removal from aqueous system using Helianthus annuus (sunflower) stem waste. J Hazard. Mater. 162(1):365-372.

Kadirvelu K, Thamaraiselvi K, and Namasivayam C (2001), Removal of heavy metals from industrial wastewaters by adsorption onto activated carbon prepared from agricultural solid waste. Bioresource. Techno. 76(1):63-65.

Keng PS, Lee SL, Ha ST, Hung YT, Ong ST (2014), Removal of hazardous heavy metals from aqueous environment by low-cost adsorption materials. Environ. Chemis. Letters, 12(1):15-25.

Khan MA, Ngabura M, Choong TSY (2012), H Masood, Biosorption and desorption of Nickel on oil cake: Batch and column studies. Bioresource Techno. 103(1):35-42.

Kiurski J, Adamovic S, Oros I, Krstic J and Kovacevic I (2012) Adsorption feasiblity in the Cr ions removal from waste printing developer. Global Nest J 14(1): 18-23.

Kocaoba S, Orhan Y, Akyuz T (2007) Kinetics and equilibrium studies of heavy metal ions removalby use of natural zeolite. Desalination 214(1-3): 1-10.

Kumar PS, and Kirthika K (2009), Equilibrium and kinetic study of adsorption of nickel from aqueous solution onto bael tree leaf powder. J. Eng. Sci. & Techno. 4(4):351-363.

Kumar PS, Ramakrishnan K, Kirupha SD (2010), Thermodynamic and kinetic studies of cadmium adsorption from aqueous solution onto rice husk. Braz. J. Chem. Eng. 27(2):347-355.

M Panayotova (2001), Kinetics and thermodynamics of copper ions removal from wastewater by use of zeolite. Waste Manage. 21(7):671-676.

Mahmood Z, Zahra S, Iqbal M, Raza MA and Nasir S (2017) Comparative study of natural and modified biomass of Sargassum sp. for removal of Cd2+ and Zn2+ from wastewater. Appl Water Sci 7:3469–3481.

Manjuladevi M, Anitha R, Manonmani S (2018) Kinetic study on adsorption of Cr(VI), Ni(II), Cd(II) and Pb(II) ions from aqueous solutions using activated carbon prepared from Cucumis melo peel. Appl Water Sci 8: 36.

Matta, Gagan; Kumar, Amit; Kumar, Amit; Naik, Pradeep K. and Kumar, Avinash (2018): Applicability of Heavy Metal Indexing on Ganga River System assessing heavy metals toxicity and ecological impact on river water quality. INAE Letters, An Official Journal of the Indian National Academy of Engineering. https://doi.org/10.1007/s41403-018-0041-4

Matta, Gagan; Kumar, Avinash; Tiwari, A.K; Naik, Pradeep K. and Berndtsson, R. (2018): HPI appraisal of concentrations of heavy metals in Dynamic and static flow of Ganga River System. Environment, Development and Sustainability, Springer Nature. (ISSN: 1387-585X; EISSN: 1573-2975) https://doi.org/10.1007/s10668-018-01182-3.

Mousavi HZ and Seyedi SR (2011) Nettle ash as a low cost adsorbent for the removal of nickel and cadmium from wastewater. Int. J. Environ. Sci. Tech. 8 (1):195-202.

Muinde VM, Onyari JM, Wamalwa B, Wabomba J and Nthumbi RM (2017) Adsorption of Malachite Green from Aqueous Solutions onto Rice Husks: Kinetic and Equilibrium Studies. J Environ Protection 8: 215-230.

Muthuselvi R, and Vashantha R (2016), Kinetic and Isotherm Studies on Adsorption of Nickel (II) Ions by Brassera Oleracea as a Bioadsorbent. Int. J. sci. & res. 4:2413-2420.

Page AL, Elseewi AA, and Straughan IR (1979), Physical and chemical properties of fly ash from coal-fired power plants with reference to environmental impacts. Springer New York: New York, NY. 71:83-120.

Patil S, Renukdas S, and Patel N (2012), Kinetic and thermodynamic study of removal of Ni (II) ions from aqueous solution using low cost adsorbents. Int.J. Environ. Sci. 3:322-341.

Prabakaran R, and Arivoli S (2012), Adsorption kinetics, equilibrium and thermodynamic studies of Nickel adsorption onto Thespesia Populnea bark as biosorbent from aqueous solutions. European J. Applied Eng. & Scientific Res.1(4):134-142.

Prabu K, Shankarlal S, and Natarajan E (2012), A biosorption of heavy metal ions from aqueous solutions using fish scale (Catla catla). World J Fish Mar Sci, 4(1):73-77.

Rao RKR, and Kashifuddin M (2014), Kinetics and isotherm studies of Cd (II) adsorption from aqueous solution utilizing seeds of bottlebrush plant (Callistemon chisholmii). Applied Water Sci. 4:371-383.

Rezvani1 P, Taghizadeh MM (2018) On using clay and nanoclay ceramic granules in reducing lead, arsenic,nitrate, and turbidity from water. Appl Water Sci 8:131.

Ricordel S, Taha S, Cisse I, Dorange G (2001), Heavy metals removal by adsorption onto peanut husks carbon: characterization, kinetic study, and modeling. Separation & purification Techno. 24(3):389-401.

Samuel J, Shanthi S, Vashantha R (2016) Utilization of Agro-waste Material as Potential Adsorbent for Removal of Cu(II) and Ni(II) Ions From Aqueous Phase. Indian Journal of Advances in Chemical Science 4(3): 346-354.

Sridevi V, Chandana Lakshmi MVV, vani yadla S (2013) adsorption isotherms study of lead from aqueous solution using fly ash. Int J Innovative Res in Sci, Eng and Techno 2(11): 7021-7030.

Srivastava V, Weng CH, Singh VK (2011), Adsorption of Nickel Ions from Aqueous Solutions by Nano Alumina: Kinetic, Mass Transfer, and Equilibrium Studies. J. Chem. & Eng. Data, 56(4):1414-1422.

Taamneh Y, and Sharadqah S (2017) The removal of heavy metals from aqueous solution using natural Jordanian zeolite. Appl Water Sci 7(4): 2012-2028.

Tan I, Ahmad A, and Hameed B (2009), Adsorption isotherms, kinetics, thermodynamics and desorption studies of 2, 4, 6-trichlorophenol on oil palm empty fruit bunch-based activated carbon. J. Hazard. Mater. 164(2-3):473-482.

Tchounwou PB, Yedjou CG, Patlolla AK (2012), Heavy Metals Toxicity, and the Environment. EXS, 101:133-164.

Tiwari DP, Singh SK and Sharma N (2015), Sorption of methylene blue on treated agricultural adsorbents:equilibrium and kinetic studies. Appl Water Sci 5:81-88.

Tsibranska I, and Hristova E (2011), Comparison of different kinetic models for adsorption of heavy metals onto activated carbon from apricot stones. Bulgarian Chem. Comm. 43(3):370.

Vakili M, Rafatullah M, Ibrahim MH, Abdullah AZ, Salamatinia B, Gholami Z (2014) Oil palm biomass as an adsorbent for heavy metals. Rev Environ Contam Toxicol. 232:61-88.

Venkatesan G, and Rajagopalan V (2016), Adsorption kinetic models for the removal of Cu(II) from aqueous solution by clay liners in landfills. Int. J. Environ. Sci. & Techno. 13(4):1123-1130.

Visa M, and Chelaru AM (2014), Hydrothermally modified fly ash for heavy metals and dyes removal in advanced wastewater treatment. Applied Surface Sci. 303(2014):14-22.

Zendelska A, Golomeova M, Blazev K, Krstev B, Golomeov B and Kretev A (2015) Adsorption of copper ions from aqueous solution on natural zeolite. Environ Protection Engg 41(4): 17-36.

Zhang X, and Wang X (2015), Adsorption and Desorption of Nickel(II) Ions from Aqueous Solution by a Lignocellulose/Montmorillonite Nanocomposite. PLoS ONE, 10(2): e0117077.