



Optimization of Heavy Metals Adsorption Process in the Treatment of Sabon-Gari Abattoir Effluent in Jalingo Using Neem Leaf (*Azadirachta indica*)

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ABSTRACT

The discharge of untreated abattoir effluent into water bodies poses significant environmental and health risks due to its high heavy metal content. The treatment of abattoir effluent before discharging it into the environment is of critical concern because of the risk these heavy metals (Cu, Pb, Ni, Cd, Mn) have on human health. This study therefore focused on the optimization of adsorption process of heavy metals of Sabon-gari abattoir Effluents in Jalingo, Taraba state. Water sample was collected in a cleaned plastic bottle and tested to ascertain the concentration of the heavy metals (control) before checking the adsorption effect of activated Neem leave. Five metals were investigated using an atomic adsorption spectrometer (AAS) machine. Lead, cadmium and Nickel were the heavy metals of concern found to be harmful in the Sabon-gari abattoir. Dried Neem leaf was collected within Government Science school, Jalingo and pyrolyzed for 10minutes at 200-270°C. The carbonized Neem leaf was activated using lime juice at the temperature of 300°C. The research considered two factors, contact time and activated carbon dosage and also adopted Central Composite Design (CCD) in Response Surface Method (RSM) for the design of experiment (DOE). The initial concentrations of heavy metals in the effluent control samples are Lead (Pb), Cadmium (Cd) and Nickel (Ni) are higher than that of the WHO permissible limit by 1504% 340% and 900% respectively. Meanwhile, the optimum activated carbon dosages and contact for that Pb was adsorbed was 174.85 g at 69 min/32 seconds for both sieve 1µmm and 2µmm, likewise Cd optimum adsorption was 174.85 g at 60.00 min. for sieve 1µmm but 174.85 g at 69 min/32secs for sieve 2µmm and Ni optimum dosage also 174.85 g at 69 min/32 seconds for both sieve 1µmm and 2µmm. Future studies could improve the processes used to prepare the activated carbon made from neem leaves in order to increase its efficacy and investigate how well it performs in comparison to other bio-adsorbents in various environments.

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1.0 Introduction

1.1 Background study

Activated Carbon (AC) also known as activated charcoal is a versatile derivative of biomass predominantly amorphous (crystalline) solid that has extra ordinary large internal surface area and pore volume [1]. It is a carbonaceous material that possesses large surface area and high porosity [2]. The large specific surface area, large micro porosity with ample pore size distribution

possessed by activated carbon makes it feasible to let large amount of adsorption. Activated carbon has several applications such as removal of unwanted color, taste, odor, air purification and for treatments of other impurities from domestic and industrial waste water [3]. It is also used in the purification of several food products, chemicals and pharmaceuticals; and in several gas phase applications.

Heavy metals such as Zn, Fe, Cu, Cr, Hg, Pb, Ni, Co are toxic elements having specific gravity greater than 6g/cm³ [4].

The main natural sources of heavy metals include volcanic processes, weathering of rocks and soil erosion. While the anthropogenic sources include mineral processing, fuel combustion and industrial activities like mining, metal processing, chemical fertilizers and dye manufacturing etc. Heavy metals are non-biodegradable, recalcitrant and have high mobility in aqueous media, so they tend to accumulate in soils and living organisms leading to environmental repercussions. Heavy metals are taken up by plants which bio-magnify through food chains in animals and humans causing serious negative health effects due to their carcinogenicity [5]. Heavy metals have a high tendency to form complexes, are highly reactive and have increased biochemical activity which makes them very persistent in the environment. They are transported through aqueous medium and can concentrate in soil and water resources. This makes them extremely dangerous to all kinds of life forms and the environment. Hence, it is necessary to remove these toxic metals.

Abattoir effluent contains high levels of organic matter, such as manure, blood, fats, grease, hair, grit, and undigested feeds, as well as salts, phosphate, and nitrates. The organic matter in abattoir effluent is primarily due to blood and fats, which contribute significantly to the organic load and nitrogen content of the effluent. Abattoir effluent can have a significant impact on the quality of receiving water bodies, as it can degrade water quality by increasing biochemical oxygen demand (BOD), reducing dissolved oxygen (DO), and increasing suspended solids (SS) [6]. These changes can have negative effects on aquatic life, as they can lead to reduced oxygen levels and increased competition for oxygen among aquatic organisms. In addition to its impact on water quality, abattoir effluent can also pose a hazard to human health, as it may contain pathogens and other contaminants that can be harmful to humans [7].

Globally, heavy metals present in abattoir wastewater can cause wide range of medical issues such as disease, allergic dermatitis, immune response alterations, lung cancers in humans, circulatory system problems, diminished growth and organ damage if they accumulate in the body. These heavy metals can enter the environment through the discharge of untreated abattoir wastewater leading to the contamination of receiving water and aquatic life [8]. The presence of high concentration of heavy metals in the effluent not only leads directly to the contamination of receiving water but also has detrimental effects on the aquatic life of the water bodies. Therefore, it is crucial to develop effective treatment methods for removing heavy metals from abattoir effluents to protect human health and the environment [9].

In Nigeria, the regulation of abattoirs is primarily the responsibility of Local government councils as stated in the fourth schedule of the 1999 constitution [1]. However, there is evidence that the regulation of abattoirs is not always adequately

enforced, with some abattoirs operating illegally or without paper registration, poorly managed abattoirs can pose significant health risks to both workers and surrounding communities due to the potential for the spread of zoonotic disease and the emission of toxic biogas [10]. The challenges of abattoir waste management in Nigeria include poor design, obsolete facilities and deteriorating environments, which can lead to pollution of surface and underground waters, decreased air quality and potential transferable antimicrobial resistance patterns, there is a serious need for improved regulations and management of abattoirs in Nigeria to ensure public health and safety [11].

Contamination of river bodies from abattoir waste could constitute a significant environmental and health hazard the location of abattoirs is generally unregulated, aside, they are usually located near water bodies where access to water for processing is guaranteed. The animal blood is released untreated into the flowing stream while the consumable parts of slaughtered animals are washed directly into the flowing water. Improper management and supervision of abattoir activities have been identified as a major source of public health in Nigeria. Waste from slaughter houses typically contain fat, grease, hair, feathers, flesh, manure, grit and undigested food, blood, bones and processing water which is characterized by high organic level [2].

A visit to the Sabon-gari abattoir built over twenty years ago indicates that the environment is unhygienic and has a very bad odor with very poor hygienic condition, the abattoir has only one slaughter slab serving over hundred butchers who throng the place on daily basis to slaughter over 150 assorted animals including cows, goats and sheep. The abattoir lacks adequate water as butchers depend on well water which usually dries up during the dry season, forcing them to seek services of water tankers or water vendors to meet their needs; members of the nearby community do come around to complain about the smell sometimes. The Sabon Gari abattoir effluent has significant effects on the environment due to the presence of heavy metals and other pollutants in the wastewater. These effluents have led to the contamination of soil and water sources, affecting the physicochemical properties and heavy metal levels in the surrounding environment. The discharge of untreated abattoir effluents has resulted in soil and water pollution, posing risks to human health and aquatic life. This study was conducted in Sabon-gari abattoir, Jalingo will highlight the importance of understanding and mitigating the environmental impact of such effluents to prevent further contamination and protect ecosystems. These heavy metals, when present in abattoir wastewater, lead to significant environmental and public health hazards, emphasizing the critical need for proper treatment processes before discharge into water bodies. The aim of this research is to optimize heavy metals adsorption process in the treatment of abattoir effluents in Sabon-gari, Jalingo.

2.0 Materials and Methods

2.1 Materials

The materials used for this research were; Neem tree leave and lemon while equipment/tools used includes; Atomic Absorption Spectrometer (AAS), white plastic container, 250ml beaker, earth type baking oven, filter paper, mechanical sieve shaker, stop-watch and electronic compact scale.

2.2 Methods

2.2.1 Neem leaves sample collection and activated carbon preparation

Collection and Preparation of Neem Leaves: Neem leaves was collected from a Neem tree at Government science secondary school, Jalingo and washed with distilled water several times to remove any impurities. The leaves were then dried in an oven at 65°C overnight prior to pyrolysis or chemical activation [5]. The neem leaf was pyrolyzed in an alumina oven between 200-250°C at about 10minutes to yield carbon powder [9]. Plate 1 is present a Lime orange and its Juice while Figure 2 is raw and carbonized Neem leaves. The carbonized neem leaf powder was mixed with the activating agent (lime juice plus water in the ratio of 1:3) and allowed to stand in a covered stainless-steel container for 24hours. It was then removed and heated for 1hour 30minutes in

the oven at 200°C temperature to activate the carbon. The activated carbon was taken to the Department of Agricultural and Bioresources Engineering laboratory, Taraba State University to sieve it into two different mesh sizes 1micro-millimeter and 2micro-millimeter respectively.

2.2.2 Abattoir effluent sample collection

Abattoir wastewater (AWW) was obtained at about 8:30AM from a local and oldest slaughterhouse in Sabon-gari community of Jalingo Local government area, Taraba state, Nigeria grab method in a sterilized plastic bottle. The Abattoir wastewater was allowed to stand for some minutes so that all solid particles settle below the container capable of clogging the surface of the adsorbent and was preserved in a dark-amber colored container (water sample bottle) maintaining the *in-situ* temperature which was measured to be 23°C. Plate 3 presents the present status of the Jalingo old abattoir and the effluent canal.



Plate 1: Lime Oranges and Lime orange Juice



Plate 2: Raw and Carbonized Neem leaves



Plate 3: Abattoir status and sample collection point in the canal at Sabon-gari

2.3 Design of experiment

Design of experiment (DOE) is a systematic, efficient method that enables scientist and engineers to study the relationship between multiple input variables (aka factors) and key output variables (aka responses). The preparation of Activated Carbon was optimized through Response Surface Methodology. Center Composite Design was chosen to generate the experimental matrix in order to determine the number of experimental runs (Table 1) to be performed while simultaneously studying the effects of several factors [12]. Using the Mini-Tab Application version 2021, the design of experiment was based report from previous related researches work the minimum and maximum doses of 30-150grams of the activated carbon was used and the maximum and minimum time interval of 15-60 minutes was also used. The volume of abattoir effluent was constant for all experiments.

Table 1: Design of Experiment

Time (Min)	Dosage (g)
15.00	30.00
60.00	30.00
15.00	150.00
60.00	150.00
5.68	90.00
69.32	90.00

37.50	5.15
37.50	174.85
37.50	90.00
37.50	90.00
37.50	90.00
37.50	90.00
37.50	90.00

Abattoir effluent Analysis Laboratory

The procedure for adsorption using activated carbon to treat abattoir effluent involves the following steps; the activated carbon was added to the abattoir effluent and allowed to come into contact with the contaminants. This was done through batch adsorption processes [8] based on the dosage and time prescribed on DOE. After the adsorption process, the activated carbon was separated from the treated effluent, typically through filtration. Plate 4 illustrates the activities of weighing and stirring activated carbon and activated carbon plus effluent respectively.

After the treatment was done for each run the samples were each filtered and kept in separate containers in preparation for Atomic Absorption Spectrometer analysis through Germany made Whatman no. 541 filter paper. The sample were then left under room temperature until validation analysis began (Plate 5).



Plate 4: Weighing of activated carbon and stirring process of activated carbon plus abattoir effluent in a beaker



Plate 5: Filtration after treatment and adsorption analysis

Validating the effects of activated carbon

Validity test was carried out on the treated samples using Atomic Absorption Spectrophotometer (AAS) machine (Model AA-6800, Shimadzu Corporation, Japan), through the following steps in order to ascertain the effects of activated carbon on the abattoir effluent

2.3.1 Laboratory Sample Preparation

The raw sample was mixed with nitric and Sulphuric acid in the ration of 2:1 and then filtered before digestion was done. A prepared series of standard solutions with known concentrations of the element of interest was already present in the laboratory, these standards was used to create a calibration curve, which was used to determine the concentration of the unknown abattoir effluent (both treated and untreated samples). The prepared samples were introduced into the AAS instrument using the graphite furnace AAS method where the liquid

sample was introduced directly into the cuvette. The absorbance of the sample was measured at the wavelength corresponding to the element of interest. The absorbance of the sample was then compared to the calibration curve to determine the concentration of the element in the sample. Quality control checks was performed, such as measuring a blank (a sample without the element of interest) and a spiked sample (a sample with a known concentration of the element of interest) to ensure the accuracy and precision of the measurements. The concentration of the element in the sample was calculated and the results reported, along with all relevant information such as the method used, the detection limit, and the precision of the measurements were all carried out.

3.0 Results and Discussion

3.1 Results

3.1.1 Initial concentration (control)

Table 2 presents the laboratory results of control sample of the effluent using AAS machine. The laboratory analysis indicated that three heavy metals were of concern in the effluent gotten from the area as seen on the control. Comparing the of value Pb to that of WHO, it is above the permissible limit by 1504%. This is therefore extremely high. Cd also indicated to be higher than the WHO permissible limit by 340% and Nickel

Table 2: Heavy metals that of concern and their respective variation with WHO permissible level

Heavy Metal	Conc. of Control (ppm)	WHO permissible limit [10]	Diff btw conc. & WHO level	Percentage
Pb	0.802	0.05	0.752	1504
Cd	0.022	0.005	0.017	340
Ni	0.2	0.02	0.18	900

(Ni) is above the WHO permissible limit by 900%. There is therefore an urgent need to treat the effluent from abattoir in order curb the potential menace it incur on human health. Meanwhile, Table 3 present the result of treatments based on the design of experiment. The DOE from mini Tab 21 version which gave rise to 13 runs determined the dosage and contact time (factors). After treating samples based on the dosages and contact time, the responses were as recorded on the Table 3.

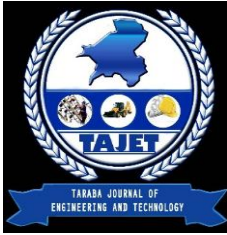
Table 3: Result of laboratory Analysis on the responses to factors

Factors		Responses					
Dosage (g)	Time (minute)	Pb (ppm) of 1 μ mm	Pb (ppm) of 2 μ mm	Cd (ppm) of 1 μ mm	Cd (ppm) of 2 μ mm	Ni (ppm) of 1 μ mm	Ni (ppm) of 2 μ mm
30	15	0.741	0.721	0.02	0.018	0.15	0.13
60	60	0.65	0.602	0.016	0.0141	0.11	0.09
150	15	0.247	0.213	0.017	0.015	0.17	0.15
150	60	0.173	0.123	0.008	0.007	0.03	0.028
90	5.68	0.64	0.617	0.0191	0.016	0.179	0.177
90	69.32	0.224	0.2	0.012	0.008	0.036	0.03
5.15	37.5	0.69	0.632	0.0183	0.017	0.17	0.016
174.85	37.5	0.124	0.116	0.0073	0.006	0.035	0.032
90	37.5	0.247	0.158	0.0152	0.0146	0.071	0.067
90	37.5	0.238	0.139	0.015	0.0138	0.068	0.058
90	37.5	0.24	0.14	0.0151	0.0144	0.065	0.055
90	37.5	0.19	0.151	0.015	0.0146	0.063	0.054
90	37.5	0.201	0.139	0.0148	0.014	0.07	0.066

3.1.2 Effects of Factors on the Responses

Figure 1, 2 and 3 presents the 3-D surface plots responses of lead, cadmium and Nickel to the factors (dosage (g) and time (Minute)). All the results indicated that adsorption level increases with increase in dosages and time for both 1 μ mm and 2 μ mm sieves. However, at some points of the

dosage and time, adsorption level decreased in the experiment for lead (Figure 1) for both sieves at approximately carbon dose of 100g and time 60 minutes. Effect of the sieve size was not really noticeable on the lead (Pb). However, the adsorption of Cd was different for when it come to sieve sizes. 1 μ mm sieve size activated carbon adsorb Cd faster compared to the 2 μ mm

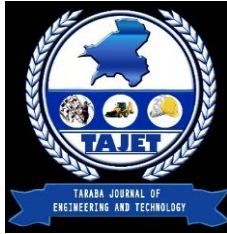


Sieves as the time and dosages increase as shown on Figure 2. Meanwhile, in the case of Nickel (Ni), the effective was also perceptible as the contact time and dosages of activated carbon increased. But 1 μ mm activated carbon pattern was faster compared to that of 2 μ mm sieves as shown on Figure 3.

3.1.3 Optimum Effects of Activated carbon dosage and contact time

The optimum point is that point in the experiment that the activated carbon and the contact time gave the best adsorption result despite all errors due parallax known or unknown. Figure 4, 5, and 6 presents signal-to-noise ratio (SN) for activated carbon dose and contact time. The signal-to-noise ratio was determined based on smaller is better. Figure 4 indicates that the best adsorption was obtained at 174.85 g of the activated carbon and at contact time 69 minutes 32 seconds for 1 μ mm and 2 μ mm sieve sizes. Meanwhile Cd indicated that the activated carbon dosage and contact time that could over good adsorption was at 174.85 g and 60.00 minutes for 1 μ mm and 2 μ mm sieve sizes.

The research indicated that the effluent emanating from the Sabon-Gari abattoir exhibited considerable concentrations of heavy metals, notably lead (Pb), cadmium (Cd), and nickel (Ni). In particular, lead concentrations were recorded at 1504% above the permissible threshold established by the World Health Organization, cadmium at 340% above, and nickel at 900% above. Additional research has corroborated the efficacy of bio-based activated carbons, including those synthesized from Neem leaves, in the adsorption of heavy metals. For example, Olayiwola *et al.* [13] demonstrated that activated carbon derived from Neem leaves effectively adsorbed heavy metals such as Pb and Ni, achieving removal efficiencies exceeding 85% under optimal conditions, which is comparable to the 90-95% efficiency documented in the current study. Nevertheless, the results are subject to variability contingent upon the preparation methodology employed for the activated carbon. For instance, Suleiman [4, 14] highlighted that the procedures involved in carbonization and activation (e.g., the temperature and types of activation agents utilized) significantly affect the porosity and surface area of the activated carbon, thereby impacting its capacity for adsorption.



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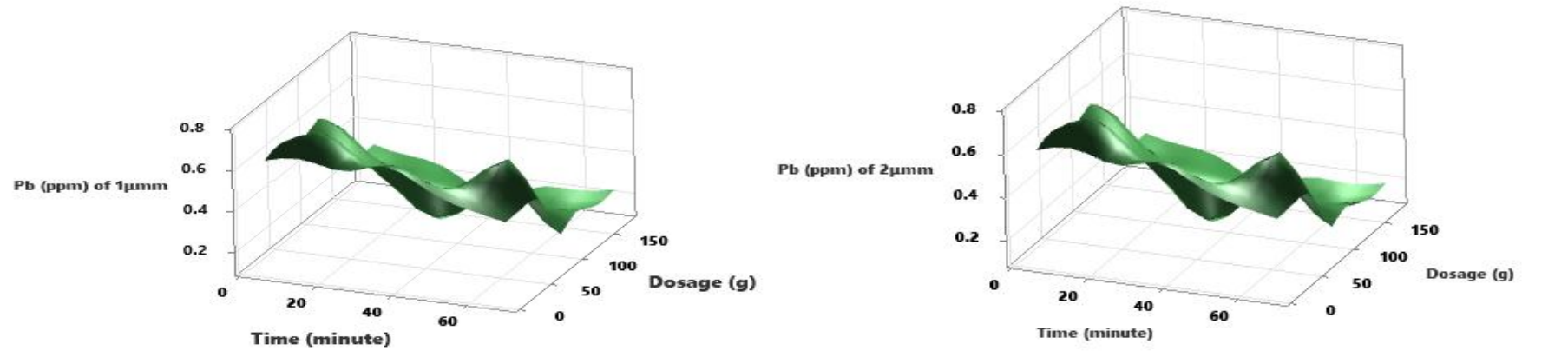


Figure 1: Surface Plot of Pb (ppm) of 1µm and 2µm Sieves vs Dosage (g) vs Time (minute)

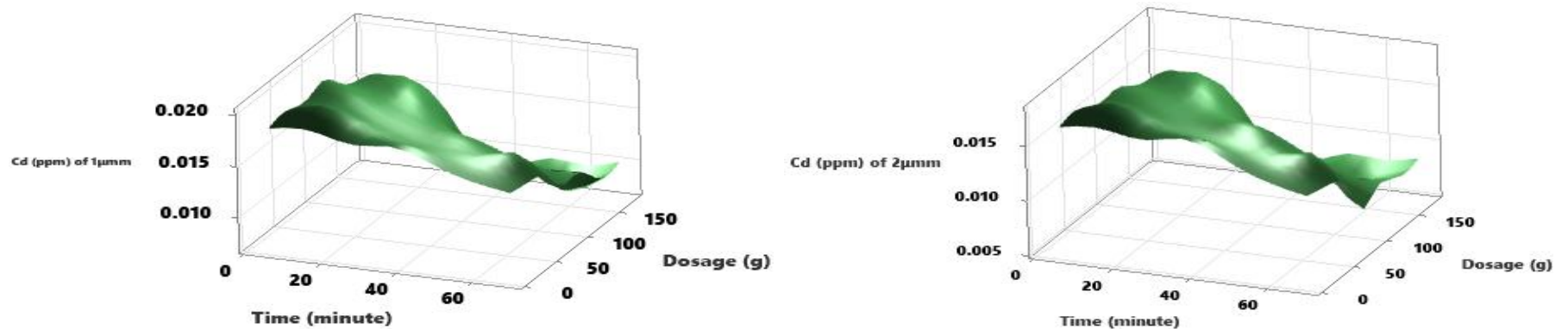


Figure 2: Surface Plot of Cd (ppm) of 1µm and 2µm Sieves vs Dosage (g) vs Time (minute)



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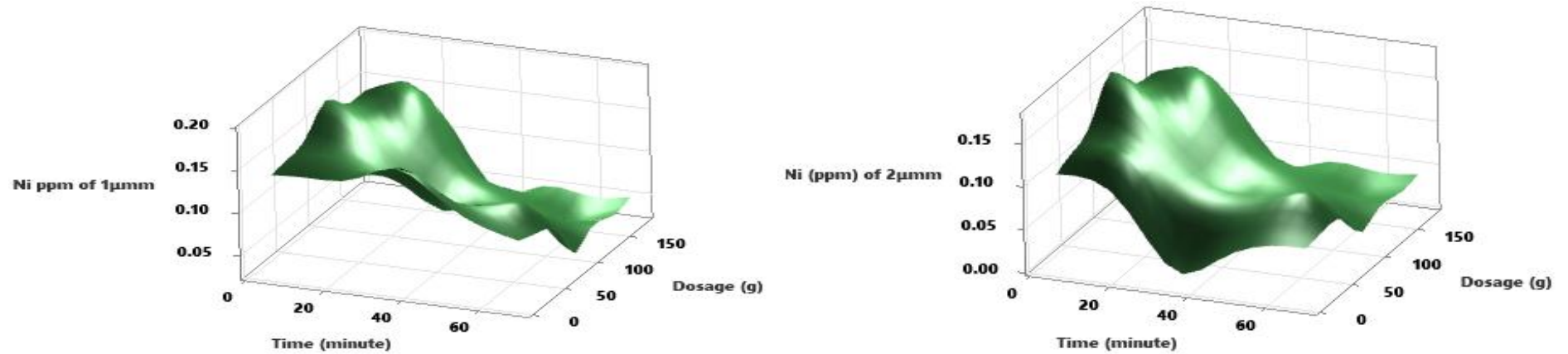


Figure 3: Plot of Ni (ppm) for 1µm and 2µm Sieves vs Dosage (g) vs Time (minute)

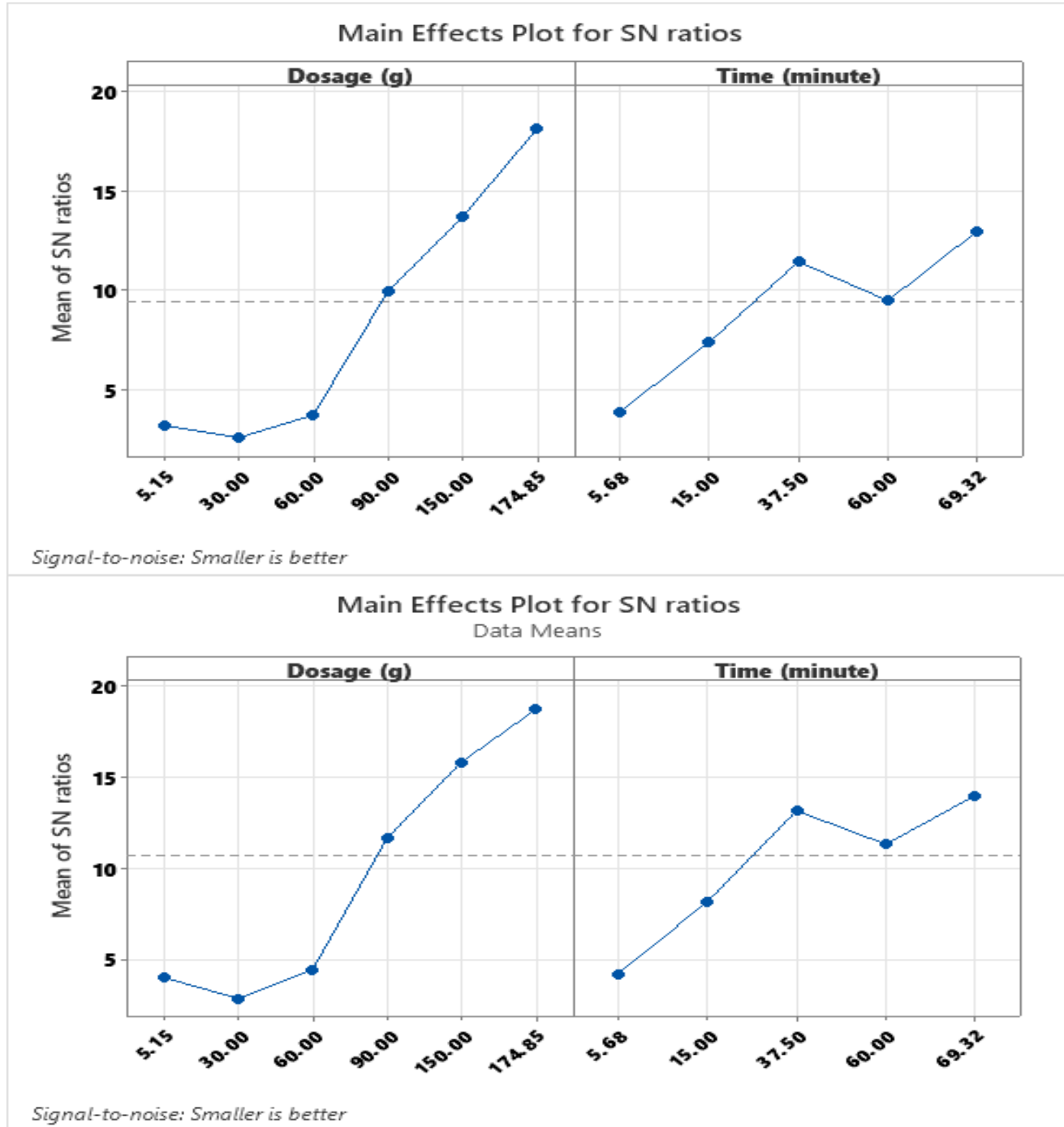


Figure 4: Taguchi Analysis- Pb (ppm) for 1 μ m and 2 μ m Sieves sizes Vs Dosage (g), Time (Minute)

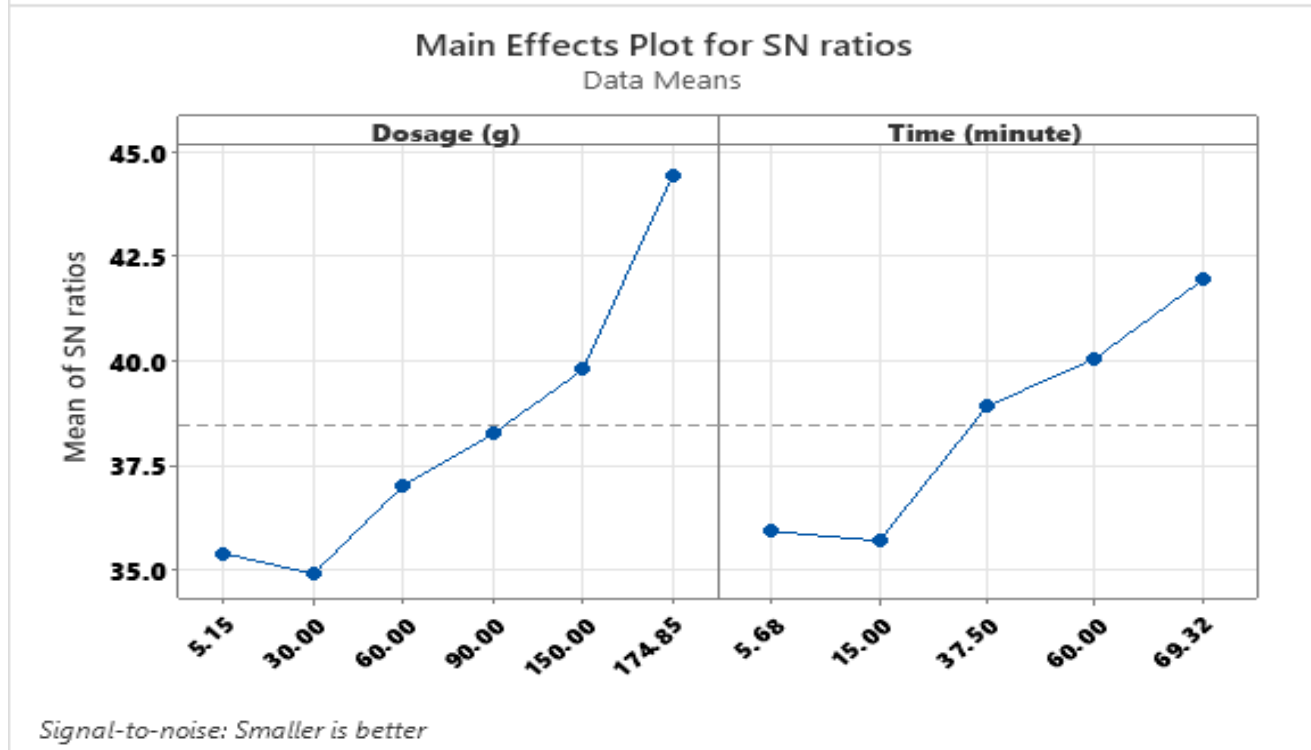
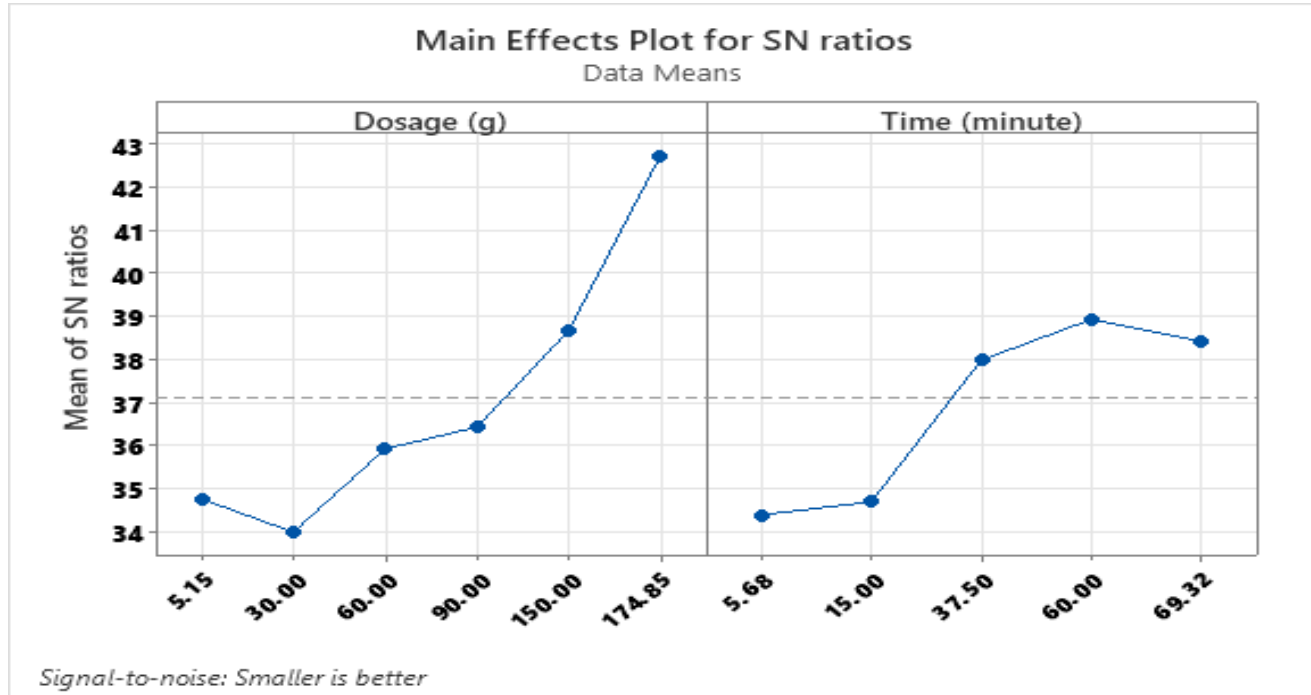


Figure 5: Taguchi Analysis- Cd (ppm) for 1 and 2 sieve sizes Vs Dosage (g), Time (Minute)

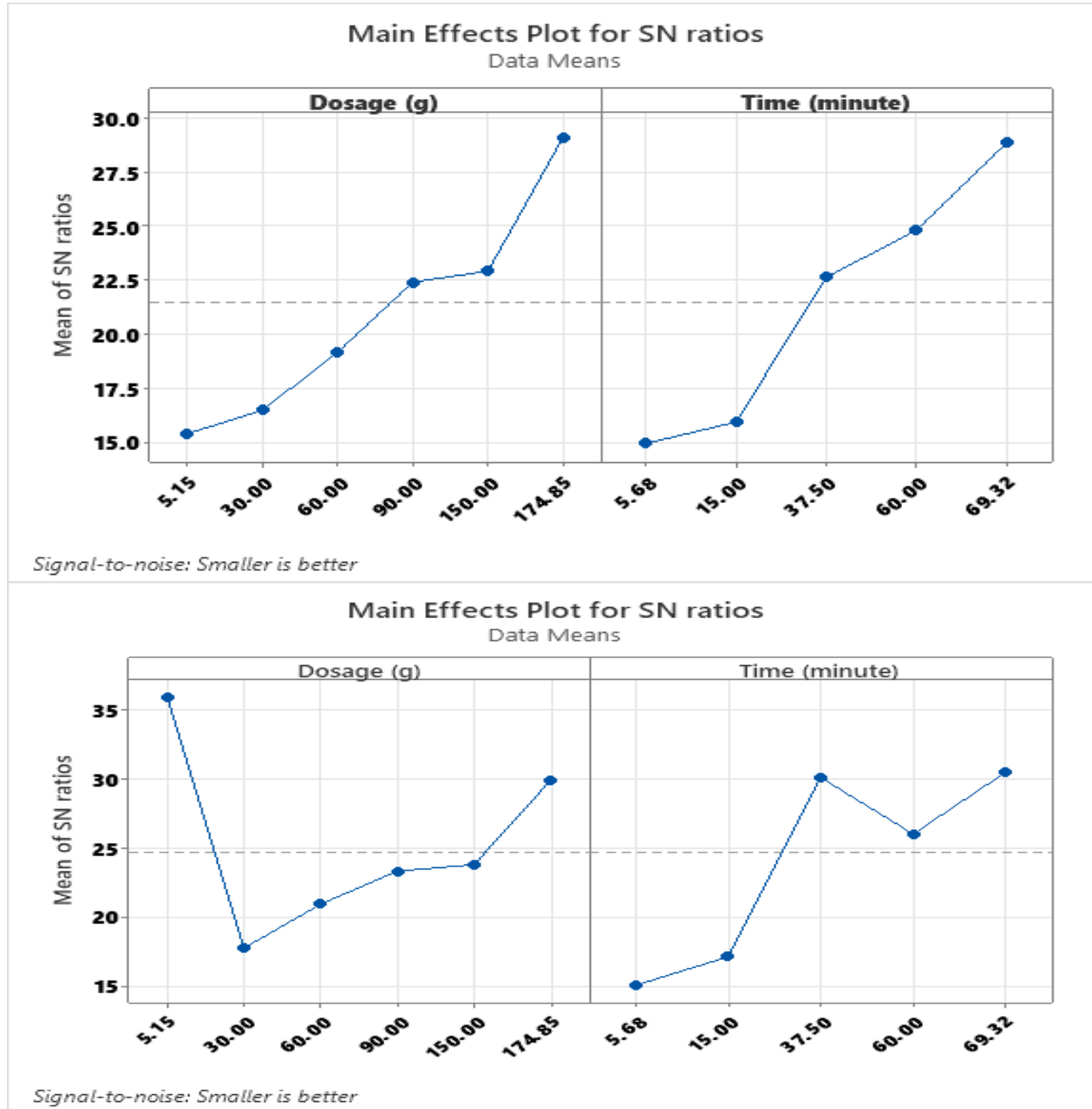


Figure 6: Taguchi Analysis- Ni (ppm) 1µmm and 2µmm Sieves sizes Vs Dosage (g), Time (Minute)



3.2 Discussion

3.2.1 Effect of Contact Time and Dosage

The research utilized Response Surface Methodology (RSM) combined with Central Composite Design (CCD) in order to optimize the adsorption process. The findings revealed that an increase in the dosage of activated carbon and a longer contact time generally led to improved adsorption efficiency for all metals. Nonetheless, at certain levels, the efficiency reached a plateau or even experienced a slight decline, suggesting potential saturation of the adsorbent. Sieve Size Impact: The research further investigated the influence of various sieve sizes of the activated carbon. It was noted that the smaller sieve size (1 μ m) exhibited greater effectiveness in adsorbing Cd and Ni compared to the larger sieve size. The application of RSM to optimize adsorption parameters aligns with findings from other studies, including those by Thangagiri *et al.* [12], which employed RSM to identify the optimal contact time, pH, and adsorbent dosage for the removal of heavy metals using bio-adsorbents. Their findings corroborate the importance of optimizing these parameters to achieve high removal efficiencies.

The little decrease in adsorption efficiency shown in this paper at larger dosages (Figure 1), however, is in contrast to several other research that describe a continual increase in adsorption efficiency with increasing dosage (till reaching an equilibrium point). This may be the result of variations in the type of adsorbate, starting concentrations, or the particular properties of the activated carbon that was employed. Neem leaf-based activated carbon has been proven to be relatively more effective at adsorbing certain heavy metals like Pb and Cd when compared to other bio-based adsorbents like coconut shell [2]. However, activated carbons gotten from other sources, like as coconut shells, may indicate greater performance in adsorbing further contaminants due to their larger surface area and absorbency [11].

4.0 Conclusion and Recommendation

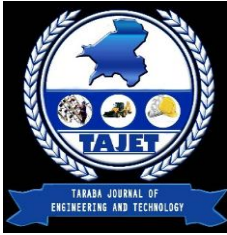
This research investigated concentration level of heavy metals in effluent from Sabon-gari abattoir. Cadmium, Nickel and Lead were found in Sabon-gari abattoir effluent, it can pose significant health risks. Cadmium, Nickel are highly toxic and can cause severe health issues including anemia, brain damage, kidney dysfunction/damage, respiratory problems, cancer and bone deformations. Lead poisoning is a major public health concern due to its detrimental effects on various bodily functions. Therefore, the presence of Cadmium, Nickel and lead

in potable water (above WHO limit) can have serious implications for human health. The effectiveness of activated carbon obtained from Neem leaves in eliminating heavy metals from wastewater is confirmed by the study's results, which are in line with the larger body of research on bio-based adsorbents. The results highlight how crucial it is to optimize parameters, especially dosage and contact duration, in order to maximize adsorption efficiency. Activated carbon prepared from what is termed agricultural waste like the Neem Leaves that is all over the place showed strong affinity to heavy metal adsorption.

Future studies could improve the processes used to prepare the activated carbon made from neem leaves in order to increase its efficacy and investigate how well it performs in comparison to other bio-adsorbents in various environment. Also concerned authority over Sabon-gari abattoir should curtail the abattoir processes of effluent disposal to the environment.

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