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Effect of temperature on the treatment of water polluted with crude oil using bioadsorbent in a packed bed reactor

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The bioadsorbent performance, in terms of fluid penetration and diffusion (residence time), is influenced by the operating temperature, a critical factor in the adsorption process. The study identified the optimal temperature for contaminant removal using the bioadsorbent as 45 °C, with a 1:1:1 mixture of particles sized at 50 µm, 150 µm, and 200 µm. Analysis of bioadsorbent samples dried under different conditions revealed variations in element concentrations. Sun-dried plantain fiber bioadsorbent exhibited higher levels of calcium (Ca), oxygen (O), carbon (C), and sulfur (S), whereas room-dried samples had elevated concentrations of magnesium (Mg), silicon (Si), iron (Fe), potassium (K), and sodium (Na). Banana fiber samples showed varying element concentrations, with sun-dried samples dominated by C, O, K, and Na, and room-dried samples containing higher levels of O, Fe, S, Si, Ca, and Mg. Palm kernel fiber samples also displayed variable element compositions. The study emphasized the significance of operating temperature in optimizing the bioadsorbent effectiveness for contaminant removal, reducing toxic substances in contaminated water. Microbial analysis of HUB concentration in each biounit revealed significant differences at various temperature levels. Notably, room-dried plantain fiber outperformed other bioadsorbent in the packed bed units. In conclusion, the study highlights the importance of temperature control in enhancing bioadsorbent performance and demonstrates the impact of drying conditions and fiber type on element concentrations. Room-dried plantain fiber exhibited the best results among the tested bioadsorbent.

Capsule Summary: The impact of temperature on the treatment of crude oil-polluted water using a bioadsorbent in a packed bed reactor was investigated. The study revealed that both the operating temperature and the type of bioadsorbent employed played crucial roles in removing contaminants.

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INTRODUCTION

Black coals and crude oil occur naturally in terms of hydrocarbon compound mixture, which is normal in terms of concentration and it has the characteristics of measurable harmfulness towards living systems in an ecosystem (Abbas et al., 2016). Also, it is observed that the concentration of crude oils as per their harmfulness differs

depending on their compositions in terms of chemical, physical and biological concentrations, as well as other factors such as environmental and biological states of the microorganisms at the time of contamination (Abd El-Latif et al., 2010). The mode of treatment before the discharge is very pivotal because of the contrasting factors it might cause in determining the degree of harmfulness and impacts on the environment. As noted by (Ademiluyi and Ujile, 2013), different species and different life stages of organisms have been revealed to have diverse vulnerabilities to pollution. The intensity of the pollution or contamination depends on the sophistication or reliability of the previous treatment before discharging into the environment (Adu-Gyamfi et al., 2013).

Various other scientists in their researches have revealed that microorganisms live everywhere and their existence are also useful in solving problems relating to the environments (Butler and Mason, 1997; Carberry and Wik, 2001; Ezekoye et al., 2020). In their research, they reveal that contaminants can be used as food and then bioreaction of the process could become by-products which could be friendly to the environment such as carbon dioxide (CO_2), water H_2O, heat released on the process, methane (CH_4), biomass concentration or increase in growth rate of the microorganisms involved in the degradation reaction of the process (Fadhil et al., 2021; Putra et al., 2009).

The activity of Crude Oil exploration influences the ecosystem due to continuous discharge of effluent and spill experienced especially in water log area of the Niger Delta. However, different measures have been adopted to enhance clean-up of polluted water medium, especially the application of bioremediation, which temperature is one of the controlling factors. The temperature variation induced the adsorbent and the microbial activities in a paced bed treatment unit or column, considering the fact that some organisms are more active when the operating temperatures are within the range of < 20 to < 45 ^oC (mesophilic temperature), < 20 to < 75 ^oC (thermophilic temperature) and < 20 to < 105 ^oC (super thermophilic temperature). In areas of industrial activity especially crude oil processing result in the generation of constituents that yielded tremendous impact of the degree of pollution and water contamination (Ujile and Okwakwam, 2018; Ukpaka, 2016). The toxic nature of the crude oil really influences the ecosystem of such environment when effluent is discharged or spill occurred and since the effect is massive to the environment, there is need to consider measures in which the contaminants can be treated as to reduce their effect on the environment. Different treatment methods have been used to enhance reduction of crude oil effect on the water medium, such as, physical, chemical and biological. Indeed, this research will address the biological methods of using bio-adsorbents of plantain stem fibre, palm fruit fibre and banana stem fibre to mitigate petroleum hydrocarbon in fresh water medium. Lack of adequate treatment of effluent water discharge into the environment as well as type of the adsorbent used influences the treatment of effluent. The poor performance of some adsorbents to reduce the toxic influence of the effluent discharged into environment was observed to have impact the elements and compound which are found useful in the ecosystem and environment as a whole. In order to ensure that the treatment carried out by the oil companies meets the standard requirement, there is need to introduce locally based adsorbents that possess high quality in contaminant mitigation (Taheran et al., 2018). In order to ensure that the treatment meets the required standard as well as ensure the reliability of the effluent discharge there need to examine the biokinetic parameters, and the kinetic of adsorption parameters upon the effect of temperature (Teas et al., 2001). The aim of the research work is to determine the effect of temperature on bio-adsorbent performance in a packed bed treatment unit connected in stages for treatment of contaminated water media.

MATERIAL AND METHODS

Conductivity for Wastewater (contaminated water)

The temperature and conductivity probes were plugged into the unit. The probes set to display the readings in ^oC and μS/cm, respectively by use of the Mode keypad. The probes were immersed into the liquid to be measured and the displayed liquid reading were taken directly in ^oC and μS/cm or mS/cm.

Determination of total hardness in water

A 50 ml of the sample was measured into a 250 ml conical flask. Then, 1 to 2 ml of the buffer solution was added and swirled into the flask. Later, 1 to 2 ml drops of the indicator solution were added and swirled into the mixture. A wine red colour was developed. Standard EDTA tyrant slowly was added, with continuous stirring, until the reddish tinge disappears and colour changes to sky blue. A blank solution was prepared with distilled water and the test was carried as stated above from steps A in the same condition (Eq. 1).

Fig. 1: Flow diagram of the treatment plant

Hardness mg $CaCO_3$/L = (A–B) × M × 100 × 1000S (1)

Where, A = Standard EDTA solution required for titration of the sample (ml), B = Standard EDTA solution required for titration of the blank (ml), M = Molarity of the EDTA solution, S = Sample volume used for the analysis (ml), 100 = molar mass of $CaCO_3$ and 1000 on version factor to liter.

Determination of chloride on test method ASTMD 512B and APHA 4500Cl.B: Silver nitrate titration method

A 50 ml of distilled water was measured into a conical flask. The pH was adjusted to the phenolphthalein end point (pH 8.3), using sulphuric acid or NaOH solution (10g/L). A 1.0 ml of potassium chromate indicator solution was added and mix. Standard $AgNO_3$ solution was added with drop wise from a 25 mL burette until the brick-red (or pink) colour persists throughout the sample. The procedure was repeated as described in steps a-d using exactly one half of the original sample

Chloride in Wastewater (contaminated water)

A 50 mL of sample was measured into a conical flask. The pH to the phenolphthalein end point (pH 8.3) was adjusted, using sulphuric acid or NaOH solution (10 g/L). A 1.0 mL of potassium chromate indicator solution was added and mix. Standard $AgNO_3$ solution was added with drop wise from a 25ml burette until the brick red (or pink) colour persists throughout the sample. The procedure was repeated as described in steps a-d using exactly one half of the original sample, dilute to 50 mL with water. Once the volume of titrant used in step (e) is one half of that used in titrating the aliquot in step (a), we proceeded to the data processing section, if not significant interference is present and compensation must be made, alternatively use another method. The chloride ion concentration (mg/L) was calculated in the original sample, mg/L as shown iun Eq. 2.

Chloride = $(V_1–V_2)$ x N x 35450 (2)

Where, V_1 = Standard solution $AgNO_3$ added in titrating the sample prepared (mL), V_2 = Standard solution $AgNO_3$ added in titrating the sample prepared (mL) and N = Normality of standard AgNO3 solution.

Determination of sulphate in fresh water

The following reagents were used for this purpose. Standard sulphate solution (dissolve 0,1479 g of anhydrous Na_2SO_4 in distilled water and dilute to 11 in a volumetric flask, 1mL = 0.100mg SO_4^2. Buffer solution A: 30 g magnesium chloride ($MgCl_26H_2O$) was dissolved in 5g sodium acetate ($CH_3COONaDH_2O$), 1.0 g potassium nitrate (KNO_3) and 20 mL acetic acid (CH_3COOH) (99%) in 500 mL distilled water and make up to 11. Buffer solution B (required when the sample sulphate concentration less 10 mg/l, and 30 g magnesium chloride ($CH_3COONa3H_2O$) was dissolved in 0.11 g sodium sulphare (NA_2SO_4) and 20 mL acetic acid (CH_3COOH) (99%) in 50 mL distilled water and make up to 11. Barium chlrodie ($BaCl_2$) crystals 20 to 30 mesh was used.

Preparation of calibration curve

A 0.00, 10.00, 20.00, 30.00 and 40.00 (mL) of the standard sulphate solution were measured into separate 100 mL volumetric flask. Half of the container was diluted with distilled water. A 20 mL of the buffer solution A was added and mix in stirring apparatus. While stirring a spoonful of $BaCl_2$ crystals was added and dilute with distilled water to the 100 mL mark. The obtained solution was stirred for 1 minute at constant speed. The stirred solution was operated at constant rate in all determinations. Immediately after stirring pour the solution was introduced into 100 mm cell and the turbidity measured at 5 minutes at 420 mm. These solutions contained sulphate ion concentration of 0.00, 10.00, 20.00, 30.00 and 40.00 (mg/L), respectively. On completion of the calibration run, the software automatically known values for the standards entered was obtained. The correlation coefficient for standard curve was at least 0.990. New calibration curve was prepared after every 3 months, or on the condition sample cell, lamp or alteration is made to the procedure.

Analysis sequence

The analysis was performed in following order, calibration blank, standards in increasing order, procedural blank, samples, quality control standard, blank (distilled water) and repeat steps v and vi after every 10 sample. The sample was filtered if turbid is high. A 100 mL sample was measured or a suitable volume into a 250 mL Erlenmeyer flask or beaker and the solution diluted to 100 mL with distilled water if required. A 20 mL of the buffer solution A was added and mix in stirring apparatus. While stirring a spoonful of $BaCl_2$ crystals was added and begin timing immediately. The obtained solution was stirred for 1 minute at constant speed. The stirring was operated at constant rate in all determinations. Immediately after stirring the solution was poured into 10 mm cell and the turbidity measured within 5 minutes at 420 mm. The SO_4^2 was measured as shown in Eq. 3 (Sample volume in mL).

SO_4^2 mg/I = mgSO_4^2 × 1000 mL (3)

Determination of exchangeable cation

Sample preparation procedure was adopted as per ASTM D5198, AAB Measurement for Mg, Ca_2 Na and K (APHA 20th edition 3111B/ASTM D3561. For Al and Ca APHA 20th edition 3111D. Reagent used were, water–prepared by distillation, concentrated HCl, concentrated HNO_3, standard solution of each exchangeable cation for calibration curve.

Table 1. Physicochemical analysis of different plant adsorbent used in this research

Sample	Temperature	pH	TOC (%)	TN (%)	P (%)	K%	T.B (cfu/mL)	T.F
Plantain Stem Fibre in powdered form	26.0	6.18	4.70	39.47	2.84	1.63	2.8x103	11.2x102
Palm Fruit Fibre in Powdered Form	25.8	5.20	3.26	25.33	4.27	2.07	1.4x103	6.3x102
Banana Stem Fibre in Powdered form	26.1	5.73	3.01	20.15	3.01	2.48	5.0x103	5.1x102

Table 2: Physicochemical properties of the fresh water and comparison with the WHO standard

Parameters	Concentration	WHO standard
Total Dissolved Solid (mg/L)	89.60	100
Electricity Conductivity (μs/an)	88.13	100
pH	5.72	6.5-8.3
Chloride (mg/L)	160	250
Sulphate (mg/L)	137	250
Alkalinity (mg/L)	5.03	-
Oil and Grease (mg/L)	6.28	-
Dissolved Oxygen (mg/L)	8.17	-
Iron (Fe) (mg/L)	0.38	0.3
Total Hardness (mg/L)	102.33	100
Nitrate (mg/L)	3.05	10
Turbidity (NTU)	3.91	5

Standard solution (100 mg/L) was prepared intermediately by diluting 10ml of stock solution to 11. Working standard solutions of exchangeable cations (Mg, Ca, Al, K and Na) were prepared. Stock Q.C. solution of each cation: 100mg/L standard purchased from Accu standard obtained in Nigeria market or any other accredited company was used. A 50 mg/mL of lanthanum solution (134 g $LaCl_3$, $7H_2O$ was dissolved in 1000 mL distilled water. Stock potassium solution: 190.7 g of potassium chloride was dissolved in 1000 mL distilled water. Stock sodium solution: 254. 2 g of sodium chloride was dissolved in 1000 mL distilled water, to ensure that metals are not introduced into sample during preliminary treatment. Soak glassware such as volumetric flask, beaker and funnels with 10% HCl overnight and rinse with distilled water.

Determination of oil and grease water

The oil and grease were analyzed using the adopted method of spectrophotometric instrumental analysis, which involves the sample collection from the storage tan with the aid of plastic container.

Determination of moisture content

Moisture content value of the samples were determined using drop of weight of the sample after the samples experienced dryness on the exposure to temperature effect. The mechanism of weighing the first samples and the result recorded and another measurement was carried out after the samples were subjected into drying for 15 to 37 °C. The different in weight of the adsorbents were measured at initial stage before drying as well as final stage after drying. The moisture content was evaluated using Eq. 4. The moisture content in terms of percentage was measured as shown in Eq. 5 (Where, W_c = Weight of container (g), W_w = weight of container plus wet sample (g), W_d = weight of container plus wet sample (g)).

$$\text{Moisture content} = \text{Initial } W_t - \text{dry } W_t / \text{dry } W_t \quad (4)$$

$$\text{Moisture content (\%)} = W_w - W_d / W_w - W_c * 100 \quad (5)$$

Determination of bulk density

The adsorbents were sieved with a 1.8mm, and 5.0mm sieves and a weight of 5g of the adsorbents were prepared. The process of bulk density was expressed using the recommended core sampler method. The adsorbent of particle size of 0.40mm was weight and placed in the core. However, the core was prepared with a nickel foil and stainless mesh made in a cylindrical shape. Indeed, the bulk density is expressed as the mass of adsorbent (sample) divided by total volume of the adsorbent (sample) as shown in Eq. 6.

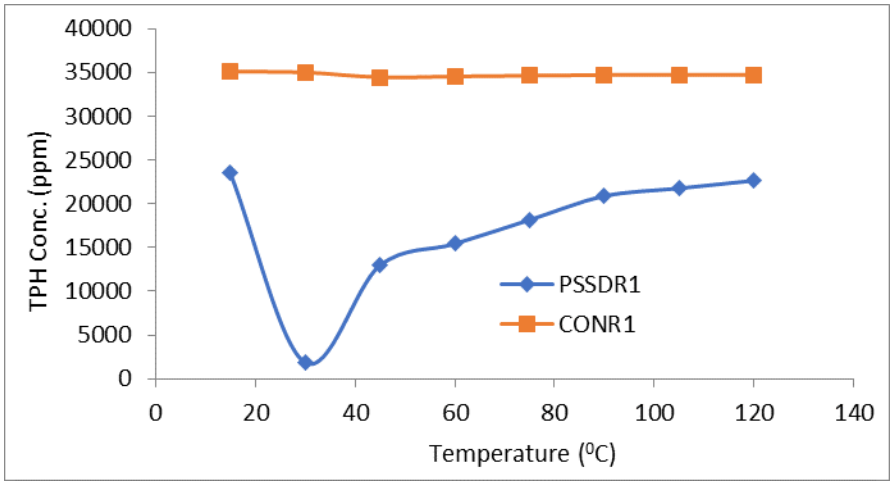

Fig. 2: TPH Concentration versus temperature for bio-adsorbent of PSSDR1 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

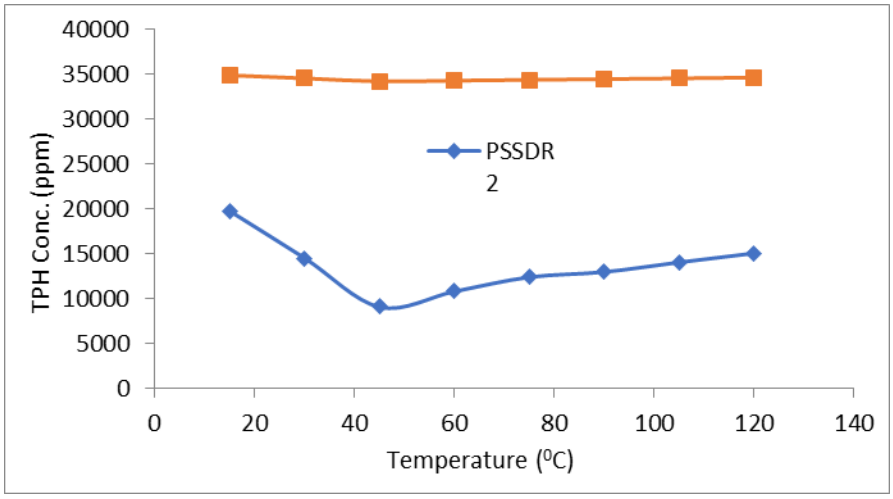

Fig. 3: TPH concentration versus temperature for bio-adsorbent of PSSDR2 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

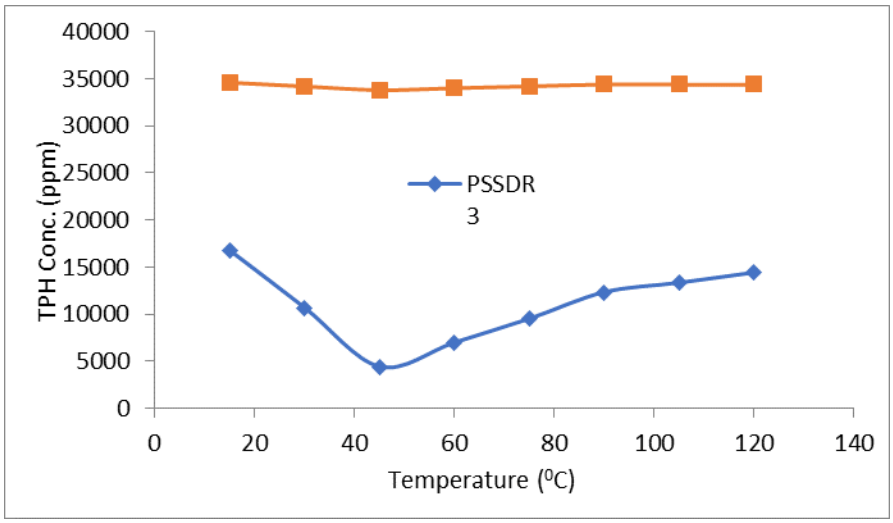

Fig. 4: TPH concentration versus temperature for bio-adsorbent of PSSDR3 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

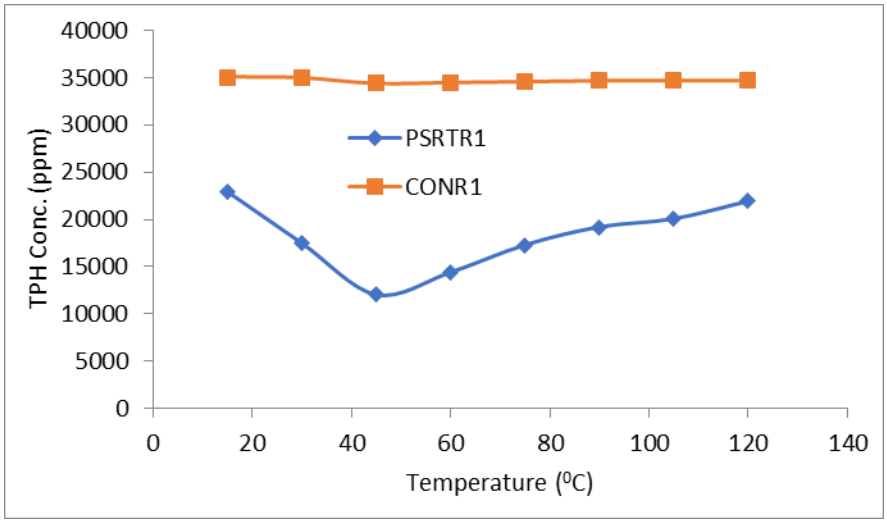

Fig. 5: TPH concentration versus temperature for bio-adsorbent of PSRTR1 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

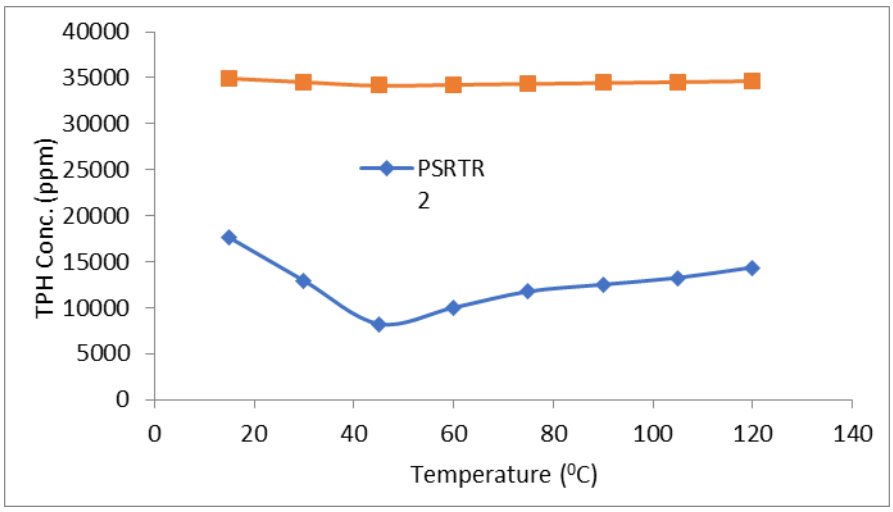

Fig. 6: TPH concentration versus temperature for bio-adsorbent of PSRTR2 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

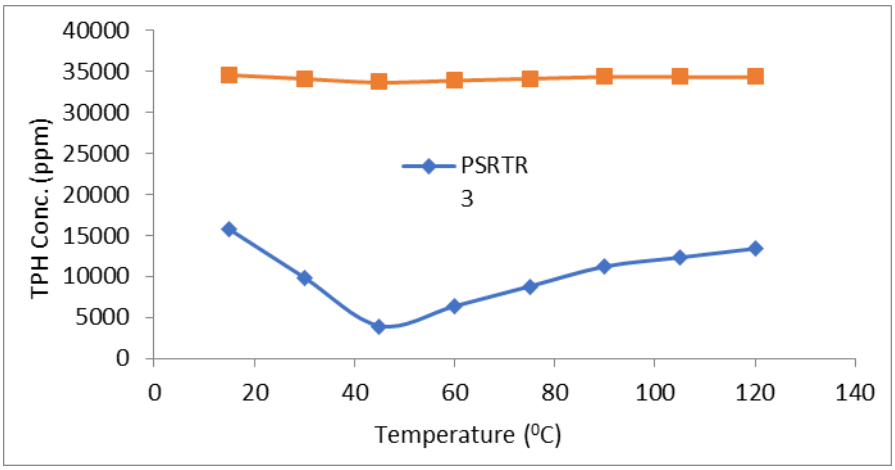

Fig. 7: TPH concentration versus temperature for bio-adsorbent of PSRTR3 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

$P^b = M_s/V_t$ (6)

Where, M_s denotes mass of the oven dried adsorbent (g) and V_t denotes adsorbent volume (cm^3) expressed to be equal to volume of a cylinder.

Scanning electron microscopy

The types of signals produced by a SEM include secondary electron (SE), back-scattered electrons (BSE), characteristic X-rays, light (cathodoluminescence) (CL), specimen current and transmitted electrons. Secondary electron detectors are standard equipment in all SEMs, but it is rare that a single machine would have detectors for all possible signals. The signals result from interactions of the electron beam with atoms at or near the surface of the sample. In the most common or standard detection mode, secondary electron imaging or SEI, the SEM can produce very high-resolution images of a sample surface, revealing details less than 1 nm in size. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. This is exemplified by the micrograph of pollen shown above. A wide range of magnification is possible, from about 10 times (about equivalent to that of a powerful hand-lens) to more than 500,000 times, about 250 times the magnification limit of the best light microscopes (Tirtom et al., 2012).

Back-scattered electrons (BSE) are beam electrons that are reflected from the sample by elastic scattering. BSE are often used in analytical SEM along with the spectra made from the characteristic X-rays, because the intensity of the BSE signal is strongly related to atomic number (Z) of the specimen. BSE images can provide information about the distribution of different elements in the sample. For the same reason, BSE imaging can colloidal gold immune-labels of 5 or 10 nm diameter, which would otherwise be difficult or impossible to detect in secondary electron images in biological specimens (Tong et al., 2010). Characteristics X-rays are emitted when the electron beam removes an inner shell electron from the sample, causing a higher-energy electron to fill the shell and release energy. These characteristics X-rays are used to identify the composition and measure the abundance of elements in the sample (Ukpaka and Ogoni, 2017).

Sample preparation

All sample must be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub. Several models of SEM can examine any part of a 6-inch (15 cm) semiconductor wafer, and some can tilt an object of that size to 45^0 (Unuabonah et al., 2008). Samples are coated with platinum coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. SEM instruments place the specimen in a relative high-pressure chamber where the working distance is short and the electron optical column is differentially pumped to keep vacuum adequately low at the electron gun. The high-pressure region around the sample in the ESEM neutralizes charge and provides an amplification of the secondary electron signal. Low-voltage SEM is typically conducted in an FEG-SEM because the field emission guns (FEG) is capable of producing high primary electron brightness and small spot size even at low accelerating potentials (US. DOD, 1994). Embedding in a resin with further polishing to a mirror-like finish can be used for both biological and materials specimens when imaging in backscattered electrons or when doing quantitative X-rays microanalysis. The flow diagram in Figure 1 demonstrates the fabricated plant for contaminants treatment. The fabricated plant is made up units' tank, pumps, pressure gauge (electronic or digital pressure gauge in psi, flex connectors, heaters, (temperature controller), packed bed units, bolts and nuts, circulation pumps, control panels (temperature control box and pressure, circulation pumps etc.) and filter materials. However, other important components include connection for contaminated water inlets and outlets, valves, PVC pipe as connectors, control wire line to the heaters, temperature probe, packed bed unit cover, recirculation line connections, control wire to the pumps and the PVC recycling connection line.

RESULTS AND DISCUSSION

Table 1 shows the physicochemical analysis of the different adsorbents used for this research and the following parameters were analyzed, temperature, pH, TOC, N, P, K, total bacteria and total fungi. The parameters analyzed and it concentration reveals that each bioadsorbent possess the characteristics of a good adsorbent which can be used for adsorption processes and the detail result of the physicochemical parameter is as shown in Table 1. Table 2 shows the result of the fresh water used for this thesis which was compared with the World Health Organization (WHO) Standard. The parameters considered in the parameters are total dissolved solid (mg/L), electricity conductivity (µs/an), pH, chloride (mg/ L), sulphate (mg/ L), alkalinity (mg/ L), oil and grease (mg/ L), dissolved oxygen (mg/L), iron (Fe) (mg/ L), total hardness (mg/L), nitrate (mg/L) and turbidity (ntu). The comparison of the fresh water with the WHO standard demonstrates that the physicochemical parameter of the fresh water is within the acceptable limit. Figure 2 shows decreases on TPH concentrate at temperature range of 15^oC to 30^oC before sudden increase in TPH concentrate in the packed bed unit 1 for plantain stem fibre of room dried (bioadsorbent) of particle size of 40µm and 200 µm mixed in the ratio of 1:1:1 by volume and mass. The control shows less change in contaminant degradation with temperature increase.

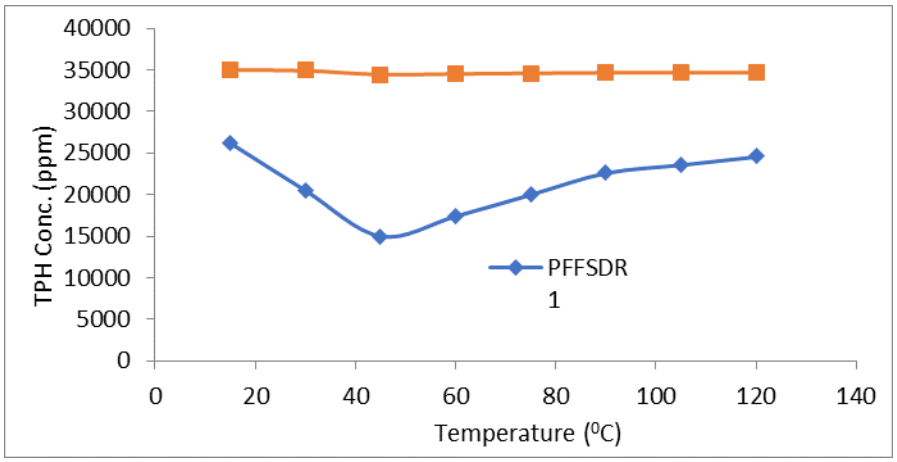

Fig. 8: TPH concentration versus temperature for bio-adsorbent of PFFSDR1 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

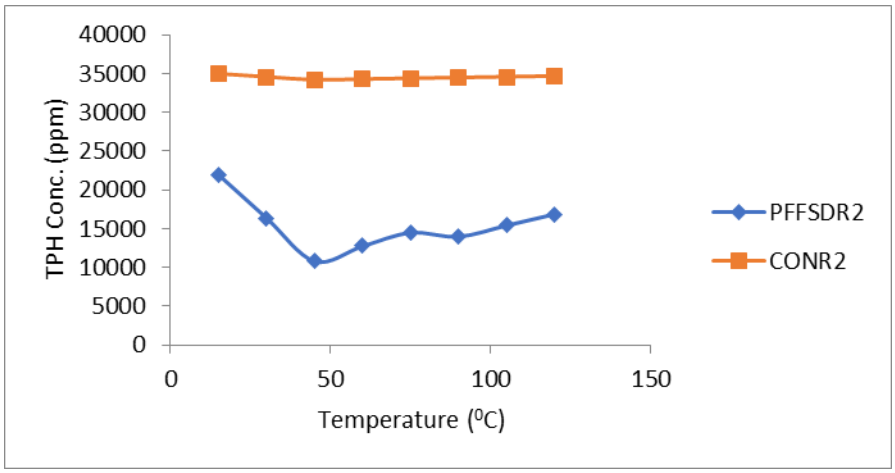

Fig. 9: TPH concentration versus temperature for bio-adsorbent of PFFSDR2 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

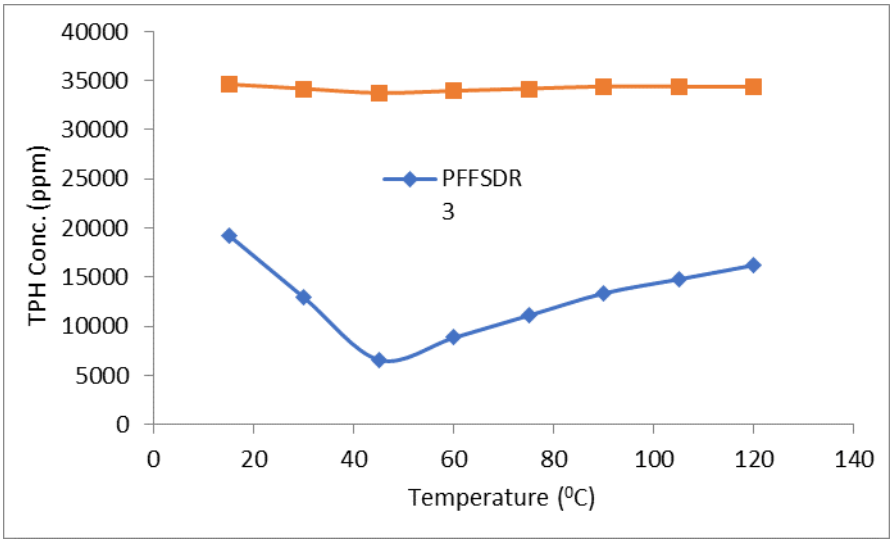

Fig. 10: TPH concentration versus temperature for bio-adsorbent of PFFSDR3 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

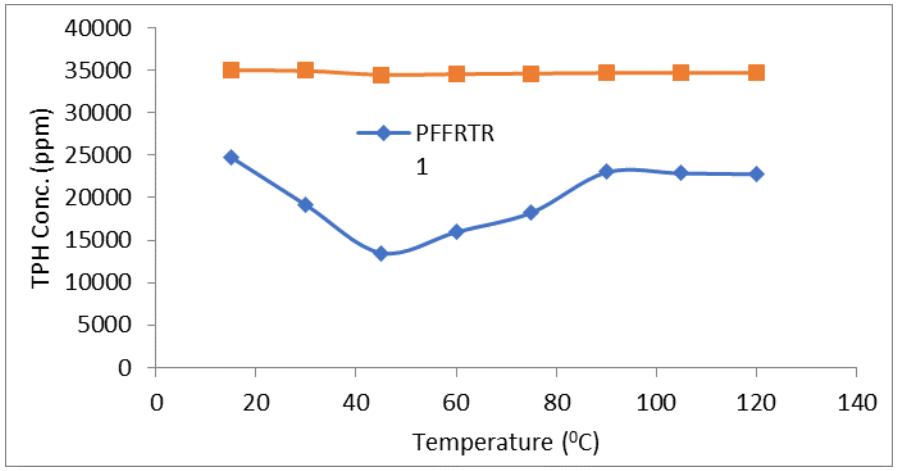

Fig. 11: TPH concentration versus temperature for bio-adsorbent of PFFRTR1 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

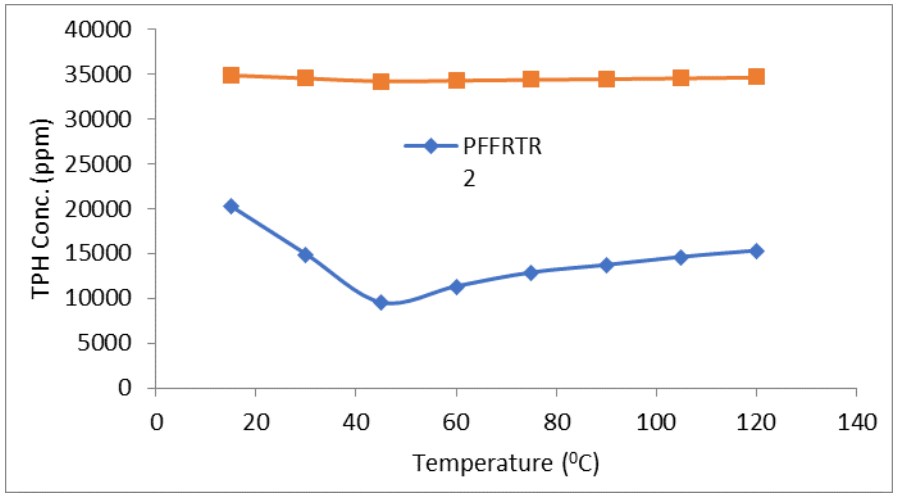

Fig. 12: TPH concentration versus temperature for bio-adsorbent of PFFTR2 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

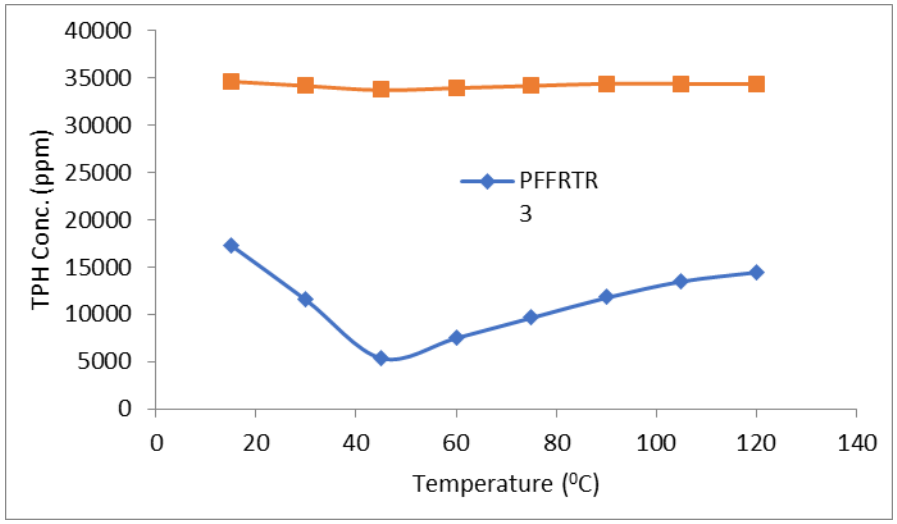

Fig. 13: TPH concentration versus temperature for bio-adsorbent of PFFRTR3 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

Figure 3 demonstrates TPH (contaminants) degradation with influence of temperature ranging from 15 °C to 120 °C. Result reveal decrease in contaminants (TPH) degradation from 15°C to 45°C before sudden increase was experienced and the control demonstrates less significant change in degradation. The degradation of the contaminants was experienced at low temperature range of less than 45 °C for plantain stem fibre of sun-dried material in packed bed unit 2. The packed unit 2 received it effluent or contaminant (TPH) from the output effluent from packed bed 1.

Figure 4 shows the contaminant degradation on the influence of temperature on packed bed unit 3 using plantain stem fibre of sun dried bioadsorbent. The result showcase decreases in contaminants degradation for 15°C to 45 °C and increase in contaminant was experienced with increase in temperature for bioadsorbent mixture of 50µm, 150 µm and 200 µm. And no significant change was experienced in the control because of less impact of temperature (subject in room temperature only). Figure 5 demonstrates the TPH (contaminants) decline upon the temperature increase from 15 °C to 45 °C and thereafter increase in contaminants concentration was experienced as the temperature increases from above 45°C to 120 °C. The result reveals the behaviors of packed bed unit 1 of plantain stem fibre of room dried material in unit 1 as bioadsorbent. The temperature effect of room condition was used to monitor the contaminants for the control unit and the obtained data show no significant variation in the process.

Figure 6 illustrates the TPH (contaminants) decline in concentration due to increase in temperature from 15°C to 45 °C and thereafter a sudden increase in TPH concentration was experienced with increase in temperature for packed bed unit 2 containing plantain stem fibre of room dried as bioadsorbent. And the temperature increases above 45°C the TPH (contaminants) concentration increases as well the concentration of the contaminant for the control sample shows less change in the process. Figure 7 illustrates contaminants (TPH) concentration decrease with temperature range of 15 °C to 45 °C and thereafter increase in contaminants (TPH) concentration was experienced with temperature range of above 45 °C to 120 °C for plantain stem fibre of room dried material packed in bed unit 3. The behaviors of the control show less change on contaminants concentration (TPH concentration).

Figure 8 shows the TPH (contaminants) concentration with change in temperature for packed bed unit 1 using palm fruit fibre-based material as bioadsorbent of mixture of 50 µm, 150 µm and 200 µm. However, decrease in contaminants (TPH) concentration was experienced with 14 °C to 45 °C and thereafter increase in contaminants (TPH) concentration experienced within temperature range of above 45 °C to 120 °C whereas the control sample demonstrates less change in contaminants degradation. Figure 9 show cases contaminants (TPH) concentration decline upon the action of increase in temperature with the range of 15°C to 45°C and thereafter increase in contaminants concentration (TPH) experienced with increase in temperature above 45 °C to 120 °C with the packed bed unit 2 containing bioadsorbent of 50µm, 150µm and 200µm as mixture in the ratio of 1:1:1 by volume and mass.

Figure 10 illustrates TPH (contaminants) degradation upon the effect of change in temperature in treatment unit of the packed bed unit 3 containing palm fruit fibre of sun dried. Obtained data reveals decline in contaminants (TPH) concentration within temperature of 15°C to 45°C and thereafter increase in contaminants concentration was experienced from temperature above 45°C to 120 °C the behavior of contaminants of the control reveals no significant change in contaminants concentration. Figure 11 show cases contaminants (TPH) degradation in packed bed unit 1 subjected to palm fruit fibre of room dried with comparison on the behaviours of the control sample. And the result reveals decline on contaminants (TPH) degradation with change in temperature from 15 °C to 45 °C and thereafter increase in TPH (contaminants) concentration was experienced at temperature above 45 °C to 120 °C.

Figure 12 shows the decline in contaminants (TPH) concentration in a packed bed unit 2 using bioadsorbent of palm fruit fibre of room dried. And the result show cases decline in contaminants concentration from 15 °C to 45 °C and thereafter increase on contaminants concentration with change in temperature for above 45 °C to 120 °C and the control sample demonstrate no significant change. Figure 13 illustrates effluent concentration (contaminants or TPH) after passing through the packed bed unit 3 containing bioadsorbent of palm fruit fibre of room dried. Decline on contaminants (TPH) concentration was notes within temperature range of 15 °C to 45 °C and thereafter rapid increase experienced from the temperature above 45 °C to 120 °C. The control sample reveals no significant variation in contaminants degradation and the mixture of the bioadsorbent used are 50 µm to 150 µm to 200 µm.

Figure 14 demonstrates decline in TPH concentration (contaminants) upon the temperature effect on packed bed unit 1 containing bioadsorbent of banana stem fibre sun dried sample. Decline on contaminants concentration was experienced at temperature of 15 °C to 45 °C and thereafter increase in contaminants concentration was experienced as demonstrate in Figure 14. The control sample illustrates no significant change in contaminants concentration for bioadsorbent mixture of 50µm, 150µm and 200 µm of mixed ratio of 1:1:1 in volume and mass. Figure 15 shows TPH decline within temperature of 15 °C to 45 °C and increase within above 45 °C to 120 °C on TPH (contaminants) concentration for packed bed unit 2 containing bioadsorbent of banana prepared on the condition of sun dried. The obtained data was related to the contaminants (TPH) degradation characteristics with the control sample and result demonstrates no significant change with packed bed unit 2 of BSSD2.

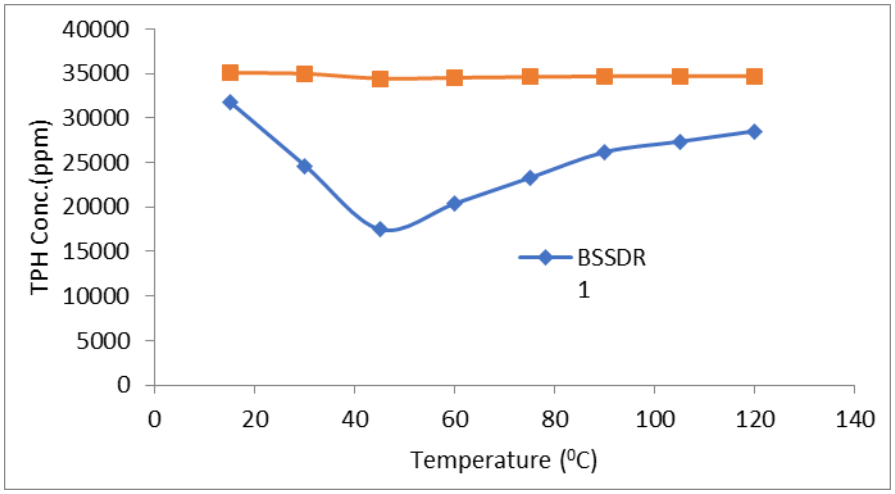

Fig. 14: TPH concentration versus temperature for bio-adsorbent of BSSDR1 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

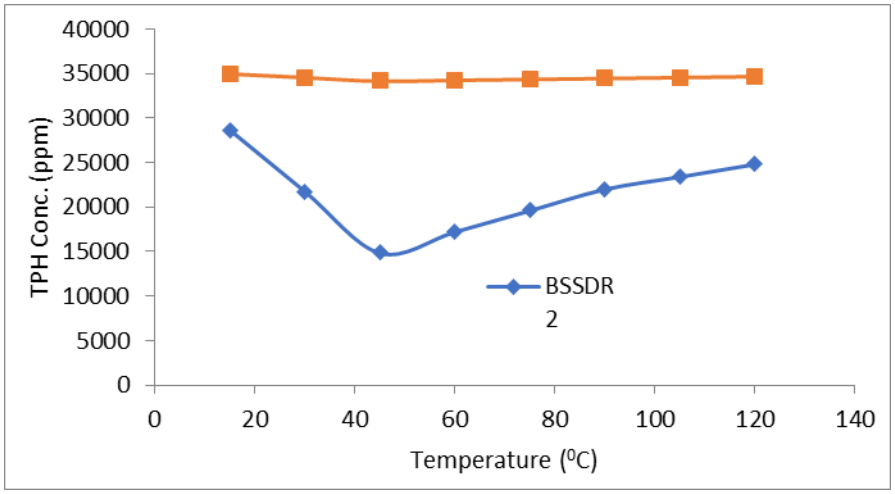

Fig. 15: TPH concentration versus temperature for bio-adsorbent of BSSDR2 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

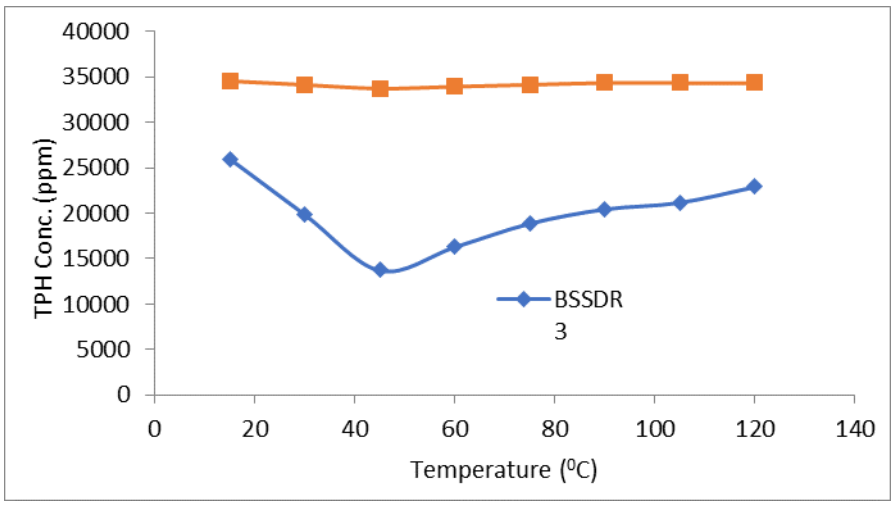

Fig. 16: TPH concentration versus temperature for bio-adsorbent of BSSDR3 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

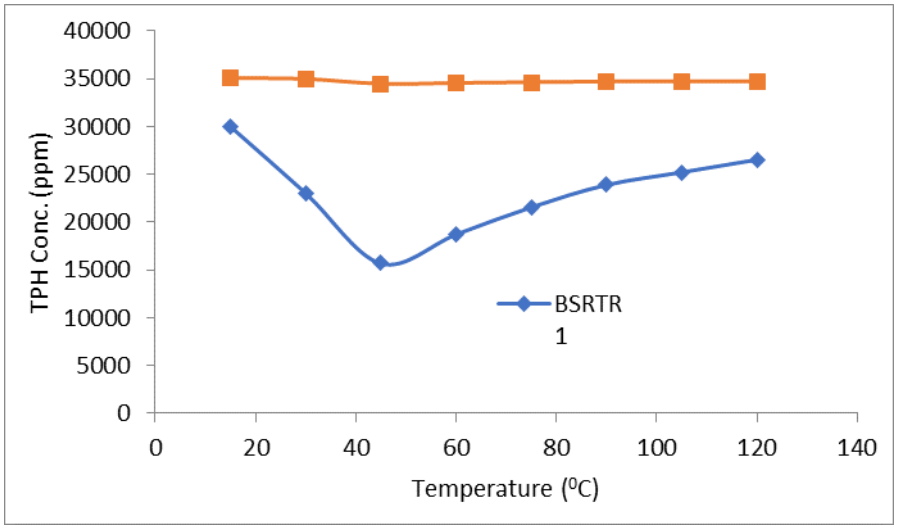

Fig. 17: TPH concentration versus temperature for bio-adsorbent of BSRTR1 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

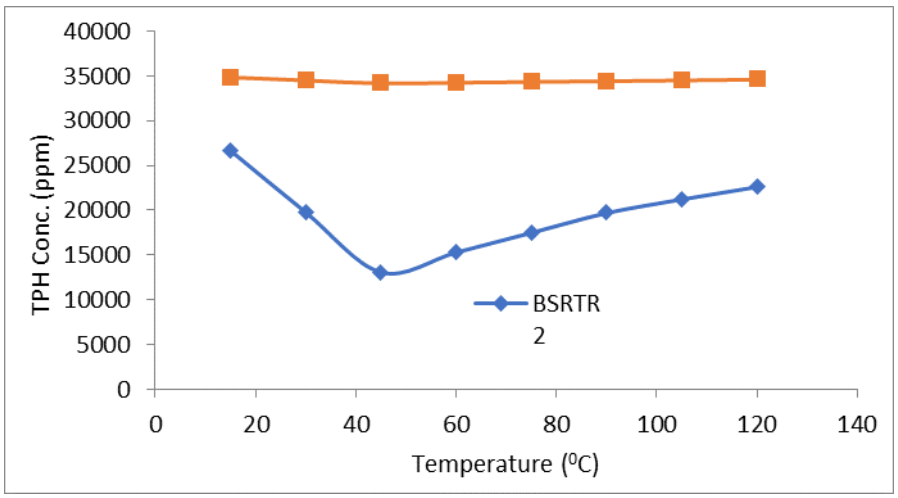

Fig. 18: TPH concentration versus temperature for bio-adsorbent of BSRTR2 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

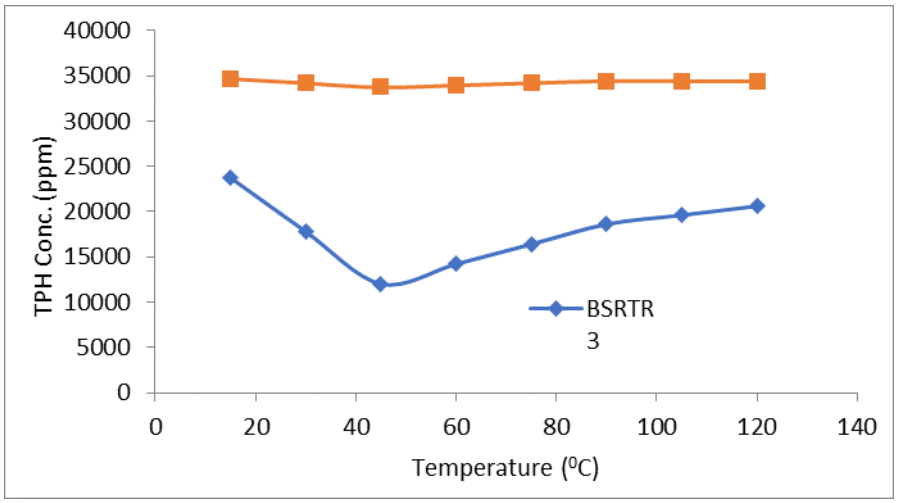

Fig. 19: TPH concentration versus temperature for bio-adsorbent of BSRTR3 of particle size mixed ratio of 1:1:1 of 50 µm, 150 µm and 200 µm with control sample

Figure 16 show cases contaminants decline within temperature range of 15 °C to 45 °C and rapid increase in contaminants (TPH) concentration from temperature above 45 °C to 120 °C. The bioadsorbent used in this case is banana stem fibre of sun dried and the mixture is of 50 µm, 150 µm and 200 µm in the ratio of 1:1:1 by volume and mass. It is revealed that no significant change was experienced in the control sample with packed bed unit 3 of BSSSD3. Figure 17 demonstrates percentage removal of contaminants from contaminated water medium using bioadsorbent packed in bed with locally prepared banana stem fibre of room dried (bioadsorbent) for the treatment purpose. Indeed, maximum reduction in contaminants removal was 55.33% at temperature of 45 °C followed by 46.68% at temperature of 60°C. However, the banana stem fibre demonstrates its usefulness as a good bioadsorbent for the treatment of contaminants water medium specifically when subjected to room dried. The packed bed 1 order of reduction or removal of contaminant by the bioadsorbent is as follows 55.33% > 46.68% > 38.60% > 34.50% > 31.99% > 28.83% > 24.51% > 14.75% > 31.99% 28.83% > 24.51% > 14.75% > with the respective temperature of 45, 60, 75, 30, 90, 105, 120 ad 15 (°C). Initial increase in contaminants reduction experienced before sudden decline with increase in temperature.

Figure 18 illustrates percentage removal of contaminants from contaminated water medium using bioadsorbent packed in bed with locally prepared banana stem fibre of room dried (bioadsorbent) for the treatment purpose. Indeed, maximum reduction in contaminants removal was 55.33% at temperature of 45°C followed by 46.68% at temperature of 60°C. However, the banana stem fibre demonstrates its usefulness as a good bioadsorbent for the treatment of contaminants water medium specifically when subjected to room dried. The packed bed 1 order of reduction or removal of contaminant by the bioadsorbent is as follows 55.33% > 46.68% > 38.60% > 34.50% > 31.99% > 28.83% > 24.51% > 14.75% > 31.99% 28.83% > 24.51% > 14.75% > with the respective temperature of 45, 60, 75, 30, 90, 105, 120 ad 15 (°C) before sudden decline with increase in temperature. Figure 19 show cases percentage removal of contaminants from contaminated water medium using bioadsorbent packed in bed with locally prepared banana stem fibre of room dried (bioadsorbent) for the treatment purpose. Indeed, maximum reduction in contaminants removal was 55.33% at temperature of 45 °C followed by 46.68% at temperature of 60°C. However, the banana stem fibre demonstrates its usefulness as a good bioadsorbent for the treatment of contaminants water medium specifically when subjected to room dried. The packed bed 1 order of reduction or removal of contaminant by the bioadsorbent is as follows 55.33% > 46.68% > 38.60% > 34.50% > 31.99% > 28.83% > 24.51% > 14.75% > 31.99% 28.83% > 24.51% > 14.75% > with the respective temperature of 45, 60, 75, 30, 90, 105, 120 and 15 (°C). Initial increase in contaminants reduction experienced before sudden decline with increase in temperature.

CONCLUSIONS

The initial concentration of the TPH (contaminants or effluent) was examine before treatment in each packed unit and after treatment in each change in concentration of the TPH at the output and input sampling. The was able to demonstrates the effectiveness of the bioadsorbent and their contribution in enhancing contaminants or effluent treatment. The initial concentration of the selected physicochemical properties of the contaminated water medium was monitored as well as the effect of temperature before treatment and after treatment. The physicochemical properties were influenced by the variation in temperature. The effect resulted to formation of strong acidic nature to weak acidic as well as weak acidic in nature to strong acidic. However, in the alkaline similar observation was encountered from weak alkaline to strong alkaline as well as strong alkaline to weak alkaline. These characteristics in the pH values were integrated to the variation in temperature as well as the nature of the bio-adsorbent.

DECLARATION OF COMPETING INTEREST

The authors declare no competing financial interest.

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