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Major elements distribution in the soil profile of petroleum contaminated soils

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Abstract

Information about the effect of petroleum waste contamination on soil physicochemical characteristics and major elements concentration in soil is in scarcity. The objective of this study was to understand that petroleum waste contamination can improve the major elements concentrations in soils. This can be evaluated with the changes in the pH, EC and organic carbon content in the soils. For that purpose soil samples (n=57) were collected at three depths within a soil profile of all sites of the study areas. Physicochemical parameters studied in all soils were pH, EC, OC, and major elements (Ca, Mg, Al, K, Na and P). Petroleum waste contamination had no effect on soil physicochemical characteristics except for soil organic carbon content. Soil organic carbon content increases with petroleum waste contamination. There was no correlation between the soil organic carbon and major elements content in any of the soil of both the study areas. It was noted in this study that all soils of Kohat Plateau were sufficient in calcium and sodium, whereas phosphorus and potassium were found to be deficient in such soils. Aluminum was found to be marginal in all soils. Petroleum waste contamination poses no effect on the lateral and horizontal distribution of all major elements in any of the soil profile of both the study areas. However calcium was found to be decreases with increase in depth in a soil profile and distance from the contamination source. This suggests that petroleum waste may increase the concentration of Ca in the soil. It was observed that pH showed a positive correlation with calcium and potassium, this suggests that calcium and potassium is pH dependent in all soils. Petroleum waste contamination poses no effect on major elements concentrations in all soils. Organic carbon content increases with the petroleum contamination except for a few exceptions.

Keywords: Petroleum waste, Contamination, Physicochemical characteristics, Soil profile.

1. Introduction

Petroleum waste is composed of significant portion of crude oil. Crude oil physical and chemical characteristics primarily depend on the geochemical features of the source rock (El-Nady et al., 2016; Inengite et al., 2017). Crude oil derived from acidic source rock may have acidic nature whereas alkaline source rock may produce alkaline crude oil (Al-Areeq et al., 2018). When such oil is extracted from underneath the surface, petroleum waste is generated. Thus the physical and chemical characteristics of the petroleum waste is likely to be same as of crude oil. When such petroleum waste is spilled over the soil surface may cause drastic changes in the soil physicochemical characteristics (Brakorenko and Korotchenko, 2016). Acidic petroleum waste may cause acidity in the soil whereas alkaline petroleum waste may increases the soil pH (Amadi et al., 1996; Udonne and Onwuma et al., 2014). Acidity and alkalinity of the soil may affect the availability of some essential nutrients necessary for plant growth and development (He et al., 2017). It is evident from the previous literature that nitrogen, potassium and sulphur than phosphorus are less vulnerable to change in soil pH (Shrivastava and Kumar, 2015). Under acidic condition phosphate ion bound Al and Fe thus become unavailable to plants (Chang et al., 2014). Whereas alkaline pH may cause flocculation of Ca and Mg with phosphorus thus reduces their availability to plants (Da-Silva and Fitzsimmons, 2016). Elevated levels of major elements such as Ca, K, Na, Mg and Fe in petroleum waste contaminated soils primarily depend on the extent of petroleum waste. Soil heavily contaminated with petroleum waste showed threshold levels of major elements. Kostecki (1999) reported that Na, K, Ca, Mg, S and Fe concentration was increased from 140 to 9200, 660 to 1800, 34800 to 49000, 4000 to 4500, 100 to 1600 and 3720 to 3824 ppm of soil heavily contaminated with crude oil. Petroleum waste spilled over the soil surface may cause anoxic conditions that can affect the mineralization of nitrogen and essentials nutrients for the microbes, necessary to degrade the hydrocarbons (Wang et al., 2013). Unluckily petroleum contaminated soil with high organic carbon may sequestered some of these major elements thus become unavailable to plants (Vidonish et al., 2016). Similarly petroleum contaminated soil because of lack of water may retard the solubility and mineralization of major elements in the soil solution (Namkoong et al., 2002). Thus soil fertility is at high risk. The present aim of this study was to establish a database that can provide an overview about the fate and effect on soil physicochemical characteristics of petroleum waste contaminated soils.

To achieve this aim the particular aspects examined were:

I. To establish the difference in the physicochemical characteristics between uncontaminated and petroleum waste contaminated soil samples.
II. To evaluate the total major elements (Al, Ca, K, Mg, Na and P) concentrations and their distribution in the uncontaminated and petroleum waste contaminated soils.
III. To correlate the extent of petroleum waste contamination with pH, electrical conductivity (EC), and organic carbon (OC).
IV. To observe the distribution of major elements in the soil profile impregnated with petroleum hydrocarbon.

2. Methodology

2.1. Study area

Kohat and Potwar Plateau were selected due to their background of oil exploration. Around three to four hectares of soil within the vicinity of oil fields was become contaminated with the spillage of petroleum waste from the waste pit over the last several years.

2.2. Soil sample collection and analysis

Prior to collect samples from the study areas the area was divided in 200 m^2 subplot. Soil samples were collected with auger randomly. Uncontaminated soil sample was collected far away from the exploration site. Soil samples were collected laterally and horizontally. Laterally soil samples were collected at three depths (0-15, 15-30 and 30+ cm). Whereas horizontally soil samples were collected from five points. First point for sample collection was at 30ft from the source of petroleum waste contamination. Whereas other sample collection points were at 50, 70, 100 and 150ft away from the source of petroleum waste contamination. In some sites the sampling distance was not maintained because of some limitations faced during sample collection.

Uncontaminated, petroleum waste contaminated soils and petroleum waste samples were collected from Potwar and Kohat Plateau. A pit was dig by excavating a pit up to a depth of 100cm (Soil Survey of Pakistan, 2004). Soil horizons were differentiated from each other within a soil profile according to US Taxonomical Classification (USDA, 1957). Surface litter was removed and around 1kg of soil was removed from each horizon of a soil profile and was placed in zibber bags. Triplicate subsample of 200g was removed from bulk soil sample of each horizon of a soil profile and was spread over the polyethylene sheet for dryness overnight. Thereafter soil was pulverized with pestle and mantle and was then allowed to sieve through 2mm mesh size. Sieved soil sample was placed in the plastic container and was incubated in the laboratory.

2.3. Nature of petroleum waste

Petroleum waste was composed of liquid and solid, water, sludge and crude oil. It is mainly contain saturates and aromatic hydrocarbons. The total concentration of petroleum hydrocarbons was estimated as 0.5g per kg of soil.

2.4. Physicochemical and geochemical characteristics of soil

Soil textural analysis was performed by using hydrometer method (American Society for Testing and Materials, 1985) and Day (1965). Other physicochemical characteristics mainly pH, EC, and organic carbon was estimated in all soil samples by using the techniques of Sparks (1996) and (Klute and Page, 1996), Page et al. (1982).

Major elements concentration in all the soil samples of both the study areas was determined with digestion from HF and perchloric acid (Jackson and Barak, 2005) Atomic Absorption Spectrometer and spectrophotometer (AAS) was used for the analysis of the samples.

2.5. Statistical analysis

"Statistical analysis were performed with Microsoft Excel and SPSS to form a multi elemental database. For the comparison of the analytical results descriptive statistics was carried out for standard deviation, mean, minimum, and maximum. For the determination of inter-elemental correlation, the Pearson correlation matrix was used. Table 1.1. represents the minimum, maximum, mean, and standard deviation, of all the physicochemical parameters along with their unit.

3. Results

3.1. Soil texture

Figures 3.1a and b shows that textural classification of uncontaminated soils were silt loam, loam and clay loam. The textural classification of uncontaminated soil at all sites was loamy in nature except for Kal and Sadqal. Texture varies from silty loam to clay loam in all petroleum waste contaminated soils except for a few exceptions. Soils of Messakaswal was sandy in nature. Texture remained same at all sites horizontally. Similarly no variation in the textural classification was observed laterally in any of the contaminated soil profile of Potwar Plateau. Most of the soils were sandy loam to silty clay loam in nature (Fig 3.1a).

Figure 3.1b represent the textural classification of uncontaminated and contaminated soils of Kohat Plateau. It was observed that the textural classification was loamy in any of the uncontaminated sites, however quite a variation in the textural classification was observed among the contaminated soils of Nashpa, Chanda and Mela sites of Kohat Plateau. Soils were loamy, sandy loam, and silty loam, whereas texture was loam in both soils of Nashpa oil field of Kohat. Texture classification remained same horizontally and vertically at Nashpa site.

Soils were loamy, sandy loam and loamy. Texture was loam in both soils of Nashpa oil field of Kohat. Texture classification remained same horizontally and vertically at Nashpa site. Whereas the texture was changed from sandy loam to loam vertically and to sandy clay loam horizontally at Chanda site. At Mela site texture remained same vertically whereas changed to silt loam horizontally.

3.2. Soil pH

Soil pH determined the soil acidity and alkalinity in the soil. It was noted in this study that soils of both sites were highly alkaline and more saline sodic. Petroleum contamination had no effect on soil pH and soil pH remained same in both uncontaminated and contaminated soils of both study areas. Similarly pH remained same vertically and horizontally in all soil profiles of the study areas (Figs. 3.2a and b).

3.3. Electrical conductivity

Electrical conductivity (EC μS/cm) is quite variable in the uncontaminated soils of Potwar Plateau. Extremely high EC 664 μS/cm was observed in the uncontaminated site. The value of EC reduces horizontally, whereas vertically remained same in all sites of uncontaminated soils. Petroleum addition had no effect on EC except for Kal (30 and 100ft) and Chaknaurang (50ft). Horizontally electrical conductivity remained same in all contaminated soils however it was low in Chaknaurang sites. Vertically and horizontally the same trend was observed in EC distribution in contaminated soils as described for uncontaminated soils of all sites of Potwar Plateau.

Electrical conductivity in the uncontaminated soils of Kohat Plateau shows the same trend of EC as of Potwar Plateau. Petroleum addition increases EC in the contaminated soils. EC was extremely high in the contaminated site of Chanda, whereas EC remained same horizontally and vertically in any of the contaminated soils of all sites of Kohat (Figures 3.3.a and b).

Uncontaminated soils were found to be deficient in Organic carbon content of both the study area. Organic carbon content increases with petroleum addition in some of the petroleum contaminated soils, While in other sites organic carbon content was low, but was high than uncontaminated soils. Vertically organic carbon content decreases with increase in depth in some of the sites of both the study areas, while in other sites, organic carbon content increases with increase in depth. This suggest that the petroleum waste may percolate underneath the surface soil and may sorbed in the soil particle thus increases soil carbon in subsurface soil. Horizontally organic carbon was more or less same in all soils of Potwar Plateau. Whereas organic carbon decreases with increase in distance horizontally in all soils of Kohat Plateau (Figures 3.4.a and b).

3.4. Major elements in the soils of Potwar and Kohat Plateau

Calcium content (1785.71- 2428.75 ppm) remained same vertically in uncontaminated soils of Potwar Plateau. Petroleum addition increases the calcium content at Kal (100ft) and CNG (30ft). Horizontally calcium content shows no clear trend in the contaminated soils of Potwar Plateau. Vertically calcium content remained same in the contaminated soils of Kal, Sadqal, Messakaswal sites except for Chaknaurang. Calcium content in uncontaminated soils of Nashpa was greater than Chanda and Mela of Kohat Plateau. Calcium content between uncontaminated and contaminated soils of Nashpa and Mela was same vertically. Horizontally calcium content increases in the contaminated soils of Nashpa and Mela. However calcium content followed irregular pattern of distribution both vertically and horizontally in the soils of Chanda (Figures 3.5.a and b).

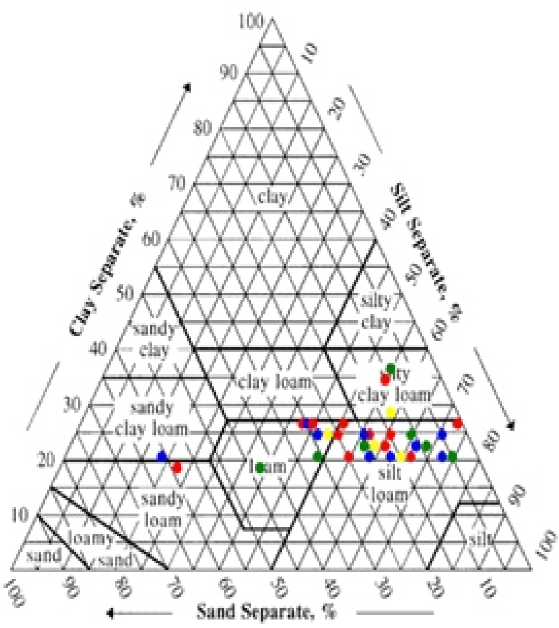

Fig. 3.1.a. USDA soil texture triangle of the Potwar Plateau.

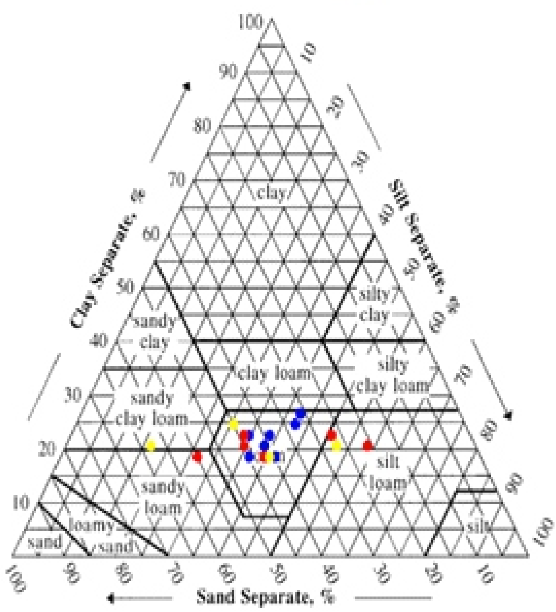

Fig. 3.1.b. USDA soil texture triangle of the Kohat Plateau

In the figure of soil texture triangle of USDA, the different colors represents samples from different horizons, Red color shows samples from horizon 'A', Blue shows horizon 'B' while green represents the samples from horizon 'C'.

Figures 3.2 to 3.4 show the difference in the physicochemical characteristics (pH, EC, and organic carbon) in the soil profiles of uncontaminated and petroleum waste contaminated soils with respect to distance in Potwar (a) and Kohat (b) Plateau.

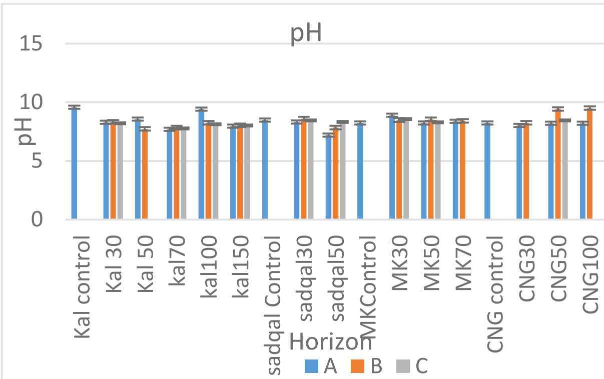

Fig. 3.2.a. Soil pH of the study area.

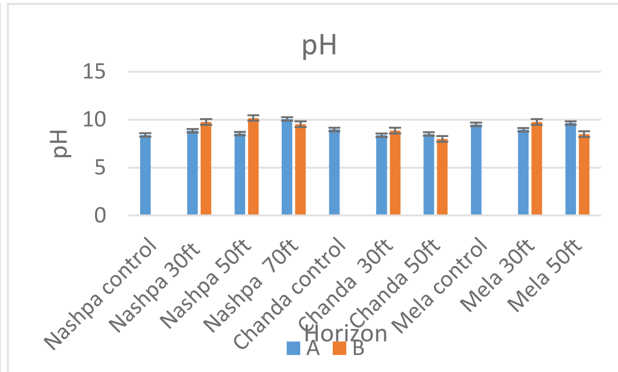

Fig. 3.2.b. Soil pH of the study area.

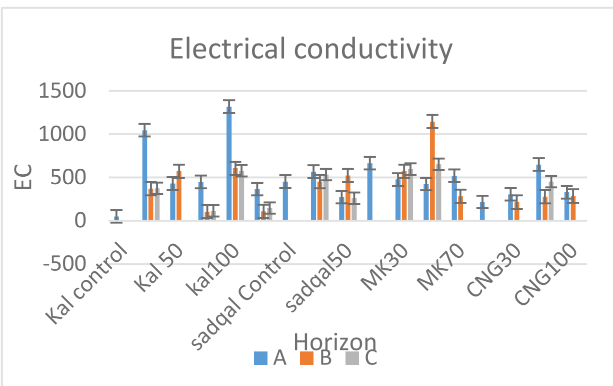

Fig. 3.3.a. Soil EC of the study area.

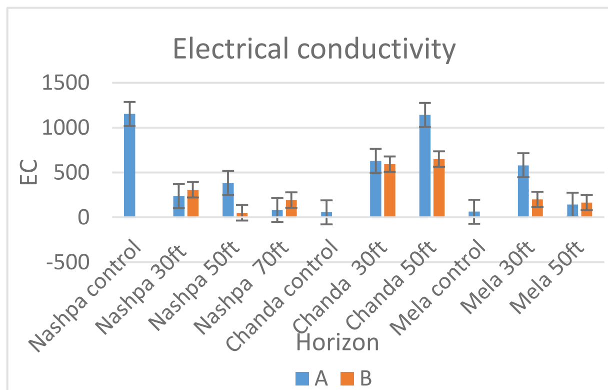

Fig. 3.3.b. Soil EC of the study area.

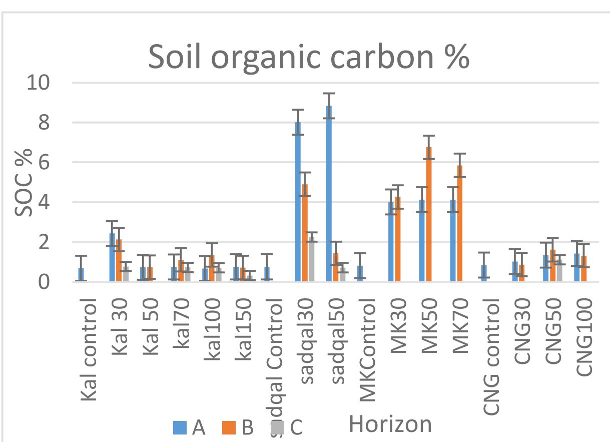

Fig. 3.4.a. Soil organic carbon of Potwar Plateau

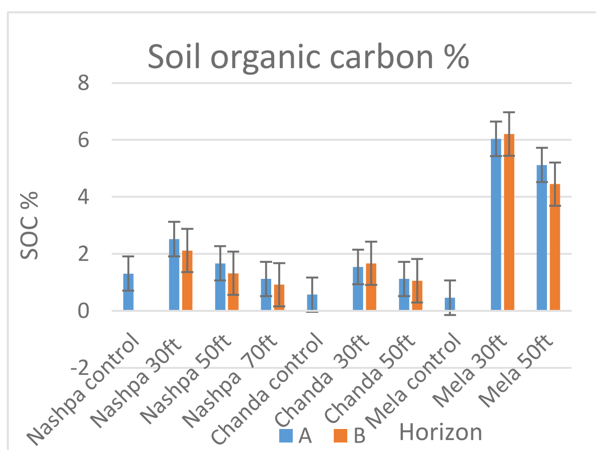

Fig. 3.4.b. Soil organic Carbon of Kohat Plateau.

Magnesium content in the soils of Potwar and Kohat plateau is presented in the figures (3.6.a and b). It was noted that the magnesium content remained same vertically in all uncontaminated soils of Potwar Plateau. Magnesium content was same between uncontaminated and contaminated soils of Potwar Plateau. However magnesium content was greater in the contaminated soils of Kal (100ft) and CNG (30ft) than uncontaminated soils. Whereas Magnesium content was low in the contaminated soils of Sadqal than uncontaminated soils and contaminated soils of Kal, Messakaswal and Chaknaurang. Vertically magnesium content was same in all contaminated soils except for Sadqal. Horizontally magnesium content increases in the contaminated soils of CNG than any other sites. Magnesium content in uncontaminated soils of Kohat ranged from 7505 to 14133.5 ppm. Uncontaminated soils of Nashpa and Mela were sufficient in Magnesium whereas such soils of Chanda field were deficient in magnesium. Magnesium content was same between uncontaminated and contaminated soils except for a few exception. Vertically magnesium content remained same in any of the soil profile except for Mela (30ft) and Chanda (30 and 50ft), however magnesium horizontal distribution was different at Nashpa (70ft), Chanda and Mela (30 and 50ft) in the contaminated soil profile.

Sodium content in the soils of Potwar and Kohat plateau is presented in the figures (3.7.a and b). It was noted that the sodium content remained same vertically in all uncontaminated soils of Potwar Plateau. Sodium content was greater in the contaminated soils of Kal (50ft), Sadqal (30ft), MK (30ft), than uncontaminated soils. Whereas sodium content was low in the contaminated soils of CNG (100ft) than uncontaminated soils. Vertically sodium content was same in all contaminated soils except for Sadqal (30ft) and Chanda (30ft). Sodium content remained same in the uncontaminated soil profiles of all sites except for Nashpa. Sodium content remained same between contaminated and uncontaminated soils of Kohat Plateau. However it was observed that sodium was greater in the contaminated soil of Chanda (30ft) than uncontaminated soils of same sites and all other sites. Horizontal distribution of sodium remained same except for a few exceptions. Vertical distribution of sodium remained same at all sites except for Chanda (30ft).

Potassium content in the soils of Potwar and Kohat Plateau is presented in the figures (3.8.a and b). It was observed that potassium content was greater in the uncontaminated soils of Kal site than Sadqal, Messakaswal and Chaknaurang sites. The only difference noted between uncontaminated and contaminated soils of Potwar Plateau was that potassium content was greater in the contaminated soils of Kal (50 and 100ft). The opposite trend of distribution of K was observed at 70 and 150ft distance from Kal site. Vertically the distribution of potassium remained same except for Sadqal and CNG. The horizontal distribution of potassium was remained same in all soils of all sites. However high content of potassium was present at Messakaswal site at 30 and 70ft and CNG site (30ft).

Potassium content remained same in the uncontaminated soils of all sites of Kohat Plateau. However distribution of potassium was more in the contaminated soils of Nashpa (50 and 70ft). Nonetheless opposite trend of potassium distribution was observed in the soils of Nashpa (30ft). Horizontal distribution of potassium increases at sites Nashpa and Chanda at 30 and 50ft. The opposite trend of distribution of potassium was observed at Mela (30 and 50ft) and Nashpa (70ft). Vertical distribution of potassium was same in the soils of all sites. However Nashpa shows that potassium was high in the subsurface horizon than surface horizon of Nashpa.

Aluminum content in the soils of Potwar and Kohat Plateau is presented in the figures (3.9.a and b). Aluminum content was evenly distributed in uncontaminated soils of Kal site than Sadqal, Messakaswal, and Chaknaurang sites. Horizontal distribution shows no difference in the concentration of Al in the soils. However Al was greater in the contaminated soils at Kal (150ft). Vertical distribution of Al was same in some sites, whereas increasing trend was observed at Kal (30ft), Sadqal (30ft) and Mk (70ft) and CNG. Aluminum content increased horizontally in the soils of all sites except Nashpa. Vertical distribution of Al was more in the surface soil than subsurface soil at all sites. However Aluminum content was high at Chanda (30ft) whereas subsurface soil have more Al than surface soil of Chanda (50ft).

Phosphorus content in the soils of Potwar and Kohat Plateau is presented in the figures (3.10.a and b). Phosphorus content was low in the uncontaminated soils than contaminated soils of all sites of Potwar Plateau. Phosphorus content was very high in the surface soil of sites Kal (50 and 70ft) and CNG (30 and 100ft). Whereas phosphorus was more in the subsurface contaminated soils of Kal (150ft) and CNG (50ft) than any other site. Vertical distribution of phosphorus was remained same in the contaminated soil of all sites except for CNG. Phosphorus content was greater at contaminated soils of Kal (50 and 70ft) and CNG (30ft) than any other site. Phosphorus content remained same in the uncontaminated and contaminated soils of all sites of Kohat Plateau. Horizontal distribution of phosphorus at Nashpa was greater at 30ft and decreases with increases in the distance at all sites. Vertical distribution of phosphorus remained same at all sites except for Mela at 50ft.

3.5. Descriptive statistics of the major elements

Table 3.1 shows the minimum, maximum, mean and standard deviation of pH, EC, organic carbon and major elements of both sides. The pH ranged from 7.19 to 10.17. The EC and organic carbon ranged from 48.10 µS/cm and 0.32%. Their maximum values reaches to 1319.00 and 8.83%. The minimum concentration of calcium and phosphorus starts from 0. Their maximum concentration reaches to 104962.00 and 469.10ppm at all sites of both study areas. Whereas the minimum concentration of Al, Na, K, and Mg ranged from 999.22, 863.63, 65.60, 4191.75 ppm in all soils of all sites of both study areas. However the maximum concentration of these elements reaches to 198265.30, 22366.87, 18034.70, and 19683.00 ppm in all soils of both study areas. The mean value of pH, EC, salinity, OC, Al, P, Na, K, Ca, and Mg was from 8.58, 431.20µS/cm, 0.232, 2.52, 82135.53, 107.06, 6785.23, 4518.06, 26788.80 and 9401.33ppm of all soils of all sites" of both the study areas.

3.6. Pearson's correlation matrix

Table 3.2. Show the Pearson's correlation matrix for the determination of inter-elemental analysis of the major elements in the soil of Potwar and Kohat Plateau. The inter-elemental relationship significant at $p < 0.01$ correlation levels are K and pH (0.555), Ca and pH (0.504), K and Na (0.707), Ca and Na (0.691), Mg and Na (0.528), Ca and K (0.975), Mg and K (0.603), Mg and Ca (0.626).

4. Discussion

Information about the fate and effect of petroleum waste contamination on soil physicochemical characteristics is in scarcity. The objective of this study was to evaluate the effect of petroleum waste contamination on soil physicochemical characteristics. The petroleum waste contamination had no pronounce effect on the, pH and EC except for a few exceptions. Organic carbon percentage was greater in petroleum waste contaminated soils of all sites, than uncontaminated sites. This suggests that petroleum waste contain enough carbon which directly increases the soil organic carbon. Elements like calcium, magnesium, potassium and phosphorus play an important role in the plants growth and soil fertility. The result of this study shows that in the soils of Kohat Plateau the concentration of calcium, potassium, and sodium was greater than Potwar Plateau. This difference may be because of the difference in the geochemical composition of Kohat and Potwar Plateau. Petroleum waste is trapped in the reservoir and the geochemical characteristic of such reservoir may contain a high content of these salts. This suggests that the difference in the geochemical characteristic between Kohat and Potwar Plateau may be the reason for high content of these salts in the petroleum waste contaminated soils. The results of this study is an agreement with the findings of Cook et al. (2002) they concluded that the petroleum waste contain high content of salts in the Kohat Plateau. The other reason may be that these salts are exposed over the earth surface in Potwar Plateau, whereas these salts are sequestered deep inside in the earth subsurface of Kohat Plateau (Kafayat Ullah et al., 2015). There was no remarkable difference in the concentration of

Figures 3.5 to 3.10a and b show the difference in the concentration (%) of major elements (Al, Ca, K, Mg, Na, P) in each horizon between uncontaminated and petroleum waste contaminated soil profiles with respect to distance in Potwar and Kohat Plateau.

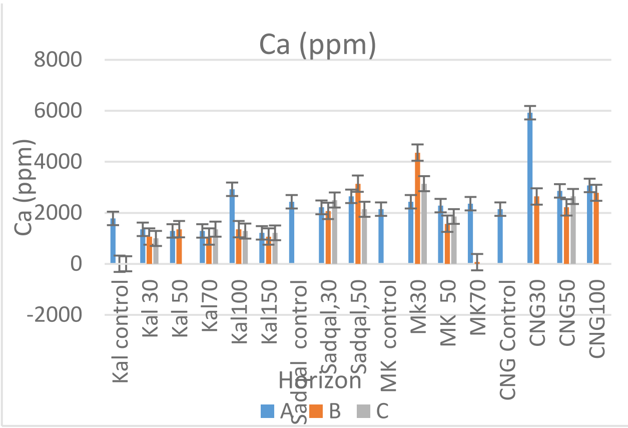

Fig. 3.5.a

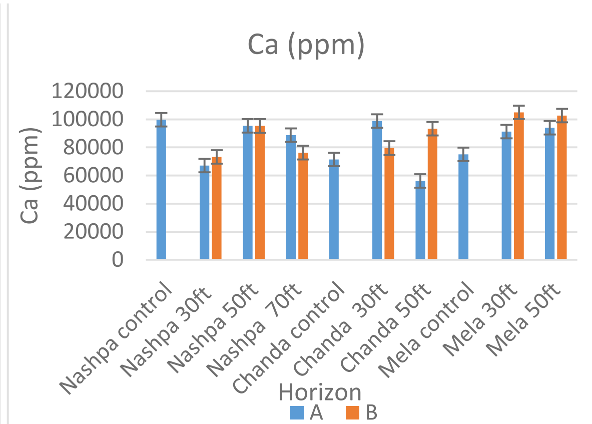

Fig. 3.5.b

The difference in the concentration of Ca in all horizons of contaminated and uncontaminated sites of Potwar Plateau (a) and Kohat Plateau (b) with respect to distance.

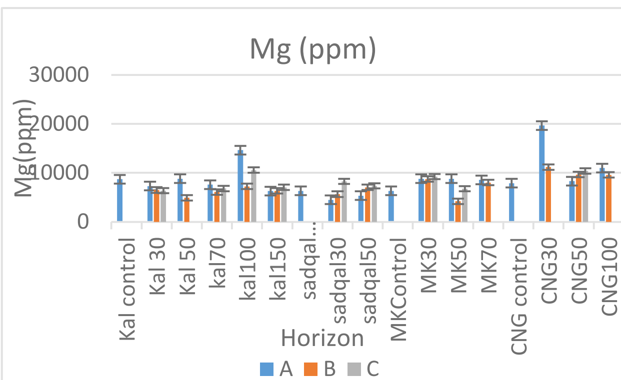

Fig. 3.6.a

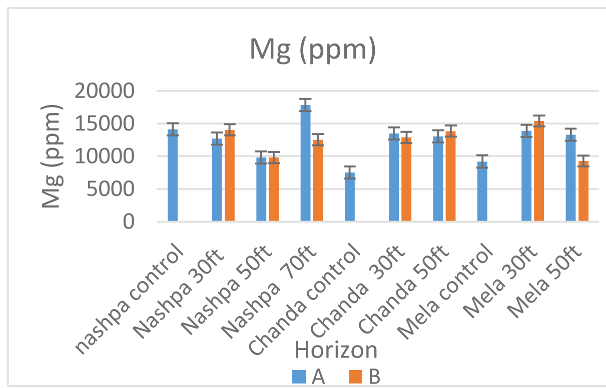

Fig. 3.6.b

The difference in the concentration of Mg in all horizons of contaminated and uncontaminated sites of Potwar Plateau (a) and Kohat Plateau (b) with respect to distance.

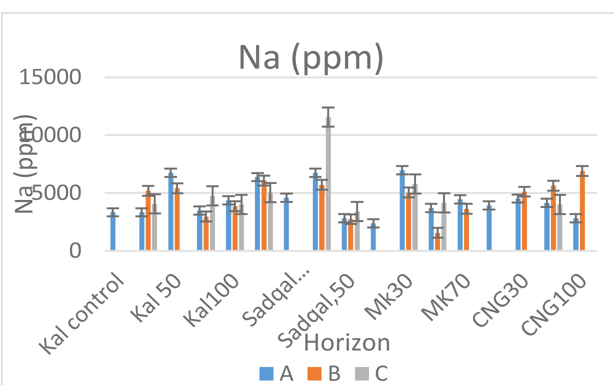

Fig. 3.7.a

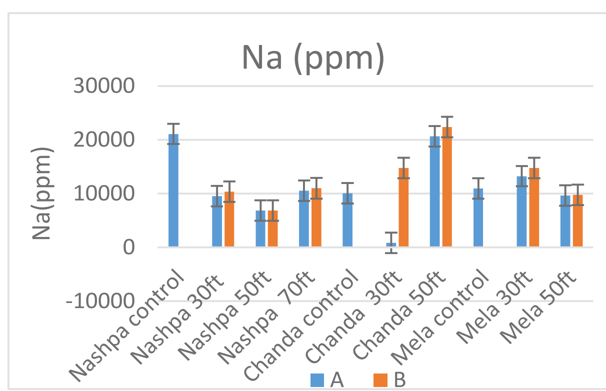

Fig. 3.7.b

The difference in the concentration of Na in all horizons of contaminated and uncontaminated sites of Potwar Plateau (a) and Kohat Plateau (b) with respect to distance.

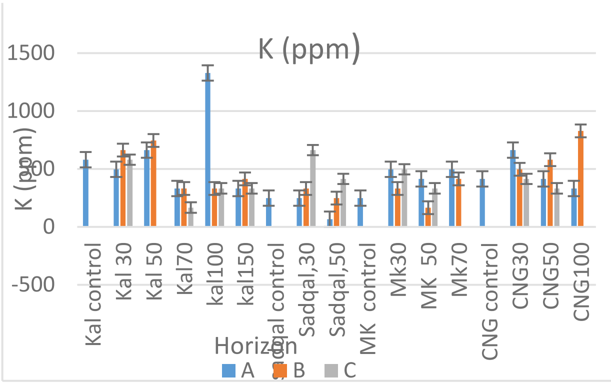

Fig. 3.8.a

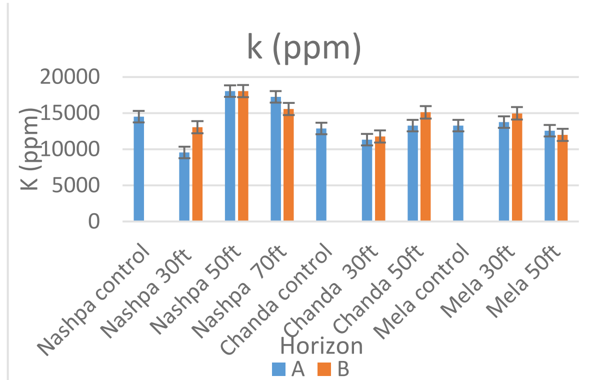

Fig. 3.8.b

The difference in the concentration of K in all horizons of contaminated and uncontaminated sites of Potwar Plateau (a) and Kohat Plateau (b) with respect to distance.

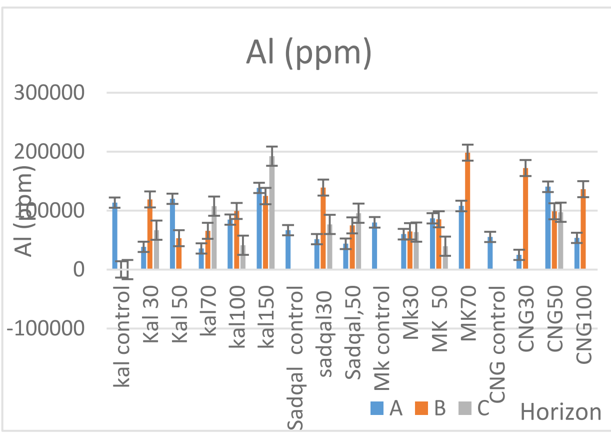

Fig. 3.9.a

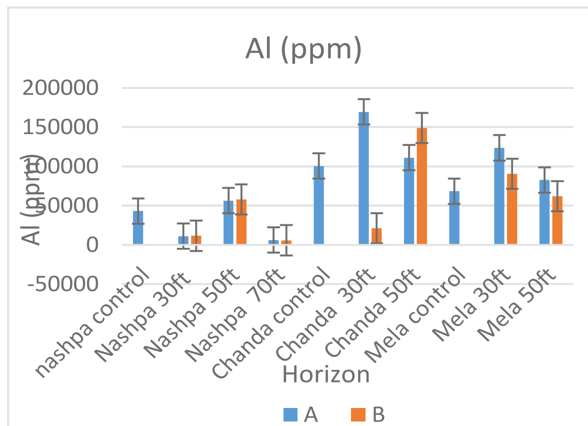

Fig. 3.9.b

The difference in the concentration of Al in all horizons of contaminated and uncontaminated sites of Potwar Plateau (a) and Kohat (b) with respect to distance.

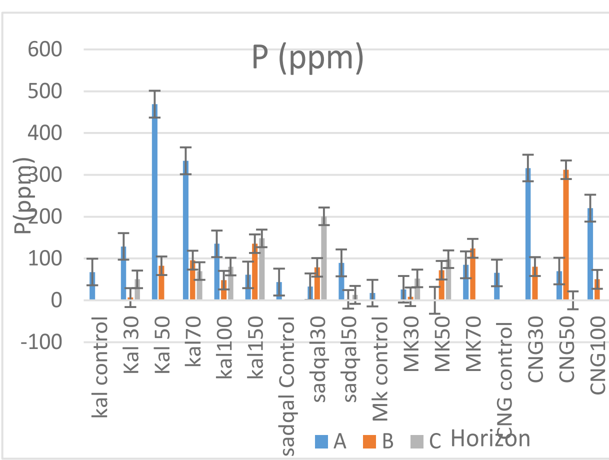

Fig. 3.10.a

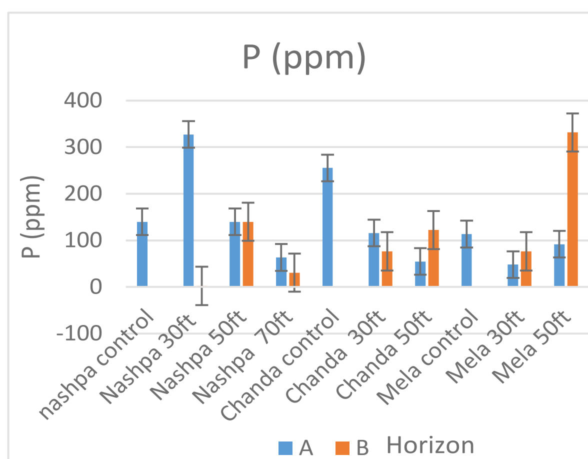

Fig. 3.10.b

The difference in the concentration of P in all horizons of contaminated and uncontaminated sites of Potwar Plateau (a) and Kohat Plateau (b) with respect to distance.

Table. 3.1. Descriptive statistics of the major elements

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
pH	57	7.19	10.17	8.58	.64860
EC	57	48.10	1319.00	431.20	294.55523
Al	57	999.22	198265.30	82135.53	46733.42495
P	57	.00	469.10	107.06	100.82927
Na	57	863.63	22366.87	6785.23	4739.07857
K	57	65.60	18034.70	4518.06	6332.48898
Ca	57	.00	104962.00	26788.80	38985.22423
Mg	57	4191.75	19683.00	9401.33	3390.07947
OC	57	.32	8.83	2.20	2.06

Table 3.1 shows the minimum, maximum, mean and standard deviation of pH, EC, organic carbon and major elements of both sides. The pH ranged from 7.19 to 10.17. The EC and OC ranged from 48.10 µS/cm and .32%. And their maximum values reaches to 1319.00µS/cm and 8.83 %. The minimum concentration of calcium and phosphorus starts from 0. Their maximum concentration reaches to 104962.00 and 469.10 ppm at all sites of both study areas. Whereas the minimum concentration of Al, Na, K, and Mg ranged from 999.22, 863.63, 65.60, 4191.75 ppm in all soils of all sites of both study areas. However the maximum concentration of these elements reaches to 198265.30, 22366.87, 18034.70, and 19683.00 ppm in all soils of both study areas. The mean value of pH, EC, Al, P, Na, K, Ca, and Mg was from 8.58, 431.20µS/cm, 82135.53, 107.06, 6785.23, 4518.06, 26788.80 and 9401.33ppm of all soils of all sites of both the study areas."

Table 3.2. Show the Pearson correlation matrix between all major elements of all sites of Kohat and Potwar Plateau. Whereas K and Ca shows a significant correlation with pH. It was also observed that K, Ca and Mg show a significant correlation with Na. Whereas Ca and Mg shows significant correlation with K. While Mg show significant correlation with Ca.

Correlation

	pH	EC	OC	Al	P	Na	K	Ca	Mg
pH	1								
EC	-.215	1							
OC	.139	-.023	1						
Al	-.198	-.015	-.179	1					
P	-.051	-.119	-.194	-.028	1				
Na	.282*	.154	-.102	-.058	.085	1			
K	**.555****	-.106	-.014	-.212	.075	**.707****	1		
Ca	**.504****	-.090	-.026	-.158	.101	**.691****	**.975****	1	
Mg	.452**	.052	-.170	-.166	.180	**.528****	**.603****	**.626****	1

**. Correlation is significant at the 0.01 level (2-tailed).

studied major elements such as Mg, Al, and P between the soils of Potwar and Kohat Plateau. This revealed the contention that these elements may not be mineralized.

However, the petroleum waste contamination in soil followed the irregular pattern of distribution of all elements of both study areas. Abrupt increase in Ca and Mg was noted in the contaminated soils of CNG and Kal (30 and 100ft) than uncontaminated soils. This may revealed the contention that petroleum waste may increases the concentration of these salts. This study is an agreement with the findings of Konkel (2016). Phosphorus and K was present at low concentration than any other elements in all sites of both study areas. This is suggested by the observation that these elements may present at low concentration in the soil naturally. Furthermore the addition of petroleum waste may not increase their concentration in any other soil. No Correlation was established between studied major elements (Al, Ca, K, Mg, Na, and P) and organic carbon of all sites. Positive correlation was observed between Ca and K with pH in all petroleum waste contaminated soils. Increase in the concentration of Ca in the contaminated soils was observed. This revealed the contention that the petroleum contamination can improve the Ca content in the soil. The result of this study is an agreement with the findings of Agbogidi et al. (2007). They concluded that petroleum contamination can improve the content of magnesium, potassium, phosphorus and sodium in the soil.

Conclusion

Petroleum waste contamination had no effect on soil physicochemical characteristics except for soil organic carbon content. Soil organic carbon content increases with petroleum waste contamination. There was no correlation between the soil organic carbon and major elements content in any of the soil of both the study areas. It was noted in this study that all soils of Kohat Plateau were sufficient in calcium and sodium, whereas phosphorus and potassium were found to be deficient in such soils. Aluminum was found to be marginal in all soils. Petroleum waste contamination poses no effect on the lateral and horizontal distribution of all major elements in any of the soil profile of both the study areas. However calcium was found to be decreases with increase in depth in a soil profile and distance from the contamination source. This suggests that petroleum waste may increase the concentration of Ca in the soil. It was observed that pH showed a positive correlation with calcium and potassium, this suggests that calcium and potassium is pH dependent in all soils. Petroleum waste contamination poses no effect on major elements concentrations in all soils. Organic carbon content increases with the petroleum contamination except for a few exceptions.

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