Oil Fields Flare Pollution

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Abstract: Environmental protection from air pollution is a priority for major cities across the world. This study will discuss the risk of gas emissions from oil fields, using collected data around an oil field in Kurdistan region. A site survey was conducted of agricultural lands around the oil field and close to the flare. 12 samples were tested and analyzed for polycyclic aromatic hydrocarbons (PAHs). Sixteen priority PAHs listed by the US Environmental Protection Agency were investigated. The average total content of PAHs in all samples was 0.654 mg·kg^{-1}. The minimum concentration detected at location 9 was 0.310 mg·kg^{-1}, while the maximum concentration detected at location 3 was 0.869 mg·kg^{-1}. It was found that the PAH concentrations decreased with increasing distance from Taq Taq oil field, suggesting that the area close to the field was more affected by gas pollution. The agriculture products in the surrounding area may need a test before use. Suggestions are provided for the oil company and the local authority to reduce the risk of gas emissions on Koya city and surrounded villages particularly the land adjacent to the Taq Taq oil field.

Keywords: Flare, Emission, PAHs, Geographic Information System (GIS), Contamination

1. Introduction

Emissions from oil fields and their effects on the Kurdistan environment have caused increasing concern since 2004, particularly in the city of Koya (since 2005) from the Taq Taq oil field. Excessive discharge of hydrocarbons to flare results in a plume of thick black smoke (Figure 1), which is causing significant negative impacts to the local environment. Pollutants are also released from other activities associated with the production of crude oil, such as transport, electricity generation and heating operations. Taq Taq oil field is located in the Kurdistan Region of Iraq, 60 km north of the giant Kirkuk oil field, 85 km south-east of Erbil and 120 km north-west of Sulaymaniyah (Sinopec, 2021). The approximate distance from the Taq Taq oil field to the city of Koya is 5 km. Activities at the oil field may have significant adverse effects on the surrounding lands. No previous studies have addressed potential pollution from the flare gas in this region. Environmental pollution by oil takes many different forms; the most damaging source is the combustion of oil products, e.g., flaring. In this study the agricultural lands around the Taq Taq oil site were surveyed and soil samples were collected to determine the effects of the flare gas emissions.

Soil is the primary environmental reservoir for persistent organic pollutants (POPs). Soil can either act as a sink for POPs or become a source of POPs back into the atmosphere (Mackay, 2011). Among the

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POPs, polycyclic aromatic hydrocarbons (PAHs) are very important. PAHs are complex chemicals which include carbon and hydrogen with a fused ring structure, containing at least two benzene rings (Sexton et al., 2011).

The incomplete combustion of organic material, such as petroleum fuels, can produce PAHs. In addition, burning carboniferous materials discharges huge amounts of gas (i.e., the black smoke shown in Figure 1) containing PAHs. Highways, airports, society, industries and oil fields all contribute to the discharge of PAHs into the atmosphere, which then reach the soil. More than 100 PAHs have been characterized in nature and 16 of them were classified as priority pollutants according to the US Environmental Protection Agency (USEPA) (Bishoni et al., 2005). Some PAHs and their derivatives are highly toxic. The mutagenic or carcinogenic properties of PAHs are the main risk to human health (Prycek et al., 2007) and they have been shown to cause several health problems (Hati et al., 2009) such as skin cancer.

Contamination of air, soil and water by petrochemical industries and their products has been studied widely across the world (Atuma & Ojeh, 2013), (Slaski & Li, 2000) and (Inengite et al., 2012). Alani, et al. (2020) found water contaminated with Pb in a distance 50m from gas flaring. In Iraq, oil production was initiated in the 1920s, whereas in the Kurdistan Region, oil production began after the Gulf War in 1991. Very few studies have been published documenting the environmental effects of the discharge gases from petroleum production industries and oil fields in this region. This study aimed to determine hydrocarbon concentrations in agricultural soils around the Taq Taq field, Kurdistan region of Iraq and to generate a map of PAH pollution using a geographical information system (GIS). The concentrations of PAHs found in the soil samples indicated that gas emissions from oil production activities have polluted the area around the Taq Taq field.

Figure 1: Taq Taq oil field flare

2. Materials and Methods

2.1 Site Description

The Taq Taq field was selected for investigation. The field is located at the city of Koya in an area surrounded by villages and agricultural lands. The area of the study site is about 2,827.4 ha and is located between 35°58'42" to 36°01'13"N and 44°30'16” to 44°33'07" E. The elevation of the study area ranged between 449 and 639 m above sea level. The land is used for agricultural purposes, mainly wheat and barley production. Taq Taq is one of the oldest oil fields in the Kurdistan Region, located near the city of Koya, 85 km SE of the capital city of Erbil and 60 km N of the giant Kirkuk oil field (Figure 2). Addax Petroleum developed taq Taq in 2005. The waste gases are burned via two flares (Figure 1), but one of the flares does not function optimally and thus releases more PAHs to the environment than the other flare.

2.2 Sample Collection

The locations for sample collection around the oil field flare are presented in figure 3. Because of certain restrictions, only 12 samples were collected from 12 locations. These locations were selected with reference to the pollution source (flare) and the wind direction. Soil samples were collected to a depth of 10 cm from the soil surface. Grid points were created across the survey area of 500 m × 500 m using a random systematic method. At each grid point (location), a square area about 20 m × 20 m was located and five samples were taken, one from the center and each corner. The samples were mixed after removing grass and debris and this process was repeated for each location.

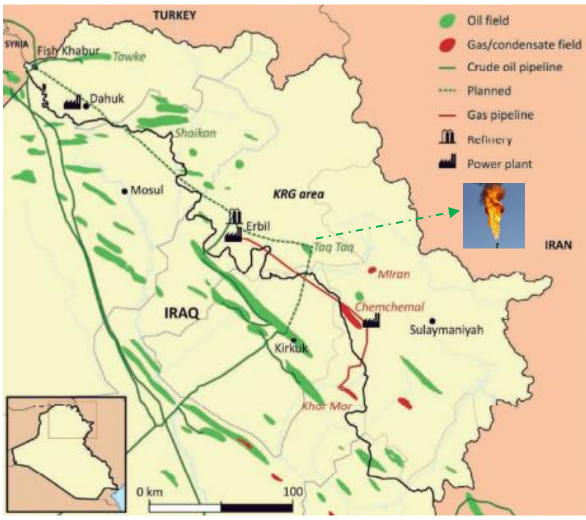

Figure 2: Map of the area (KRG-Map, 2021)

The soil samples collected from the depth 10cm below the surface, total weight of each sample at each location was approximately 500g. During the survey, the samples were sealed in special containers made of aluminum foil and the cover was sealed to avoid contact with air. Immediately after the survey, all samples were transferred to the laboratory. At all times the sample containers were kept in buckets with ice, and then in refrigerators once in the laboratory to avoid volatilization of hydrocarbons. The PAH concentrations found in the soil samples at each location (station) in the vicinity of the Taq Taq oil field 5,000m buffer are presented in Figure 4.

2.3 Laboratory Testing Method and PAH Extraction

Four gram from each soil sample was extracted for 30 min with 20 mL of dichloromethane (DCM) in an ultrasonic bath extractor. The extracts were filtered and then concentrated to 1 mL prior to silica–alumina column fractionation. PAH compounds were eluted using a 20 mL mixture of DCM: hexane (1:1). The PAH-containing fraction was evaporated using nitrogen to a volume of 1 mL and then submitted for gas chromatography–mass spectrometry (GCMS) analysis (Fadzil et al., 2008). The

USEPA has listed 16 priority PAHs. This study analyzed the concentrations of those 16 priority PAHs in soil samples and the codes in brackets were used to denote these PAHs throughout this work; anthracene (ANT), naphthalene (NAP), fluoranthene (FLT), acenaphthene (ACP), fluorene (FLU), phenanthrene (PHEN), pyrene (PYR), benz(a)anthracene (BaA), acenaphthylene (ANY), chrysene (CHR), benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), benzo[b]fluoranthene (BbF), indeno[1,2,3-cd]pyrene (IPY), benzo[g,h,i]perylene (BgP) and dibenz[a,h]anthracene (DBA). All PAHs were quantitatively analyzed by GCMS (GC17AAF) using a 30 m × 0.25 mm ID, film thickness 0.25 µm fused silica capillary column (SUPELCO PTE) with helium as the carrier gas under 15 psi pressure and flow rate of 1.2 mL min−1. Sample volume of 1 µL was injected manually. Peaks were verified based on key fragment ions, retention times compared with those of external PAH standards, and/or mass spectra. Only those peaks located within the proper range (2%) of retention time were integrated for qualification and quantification. Quantitation was performed using external standards of a mixture of PAHs also used by (Fadzil et al., 2008).

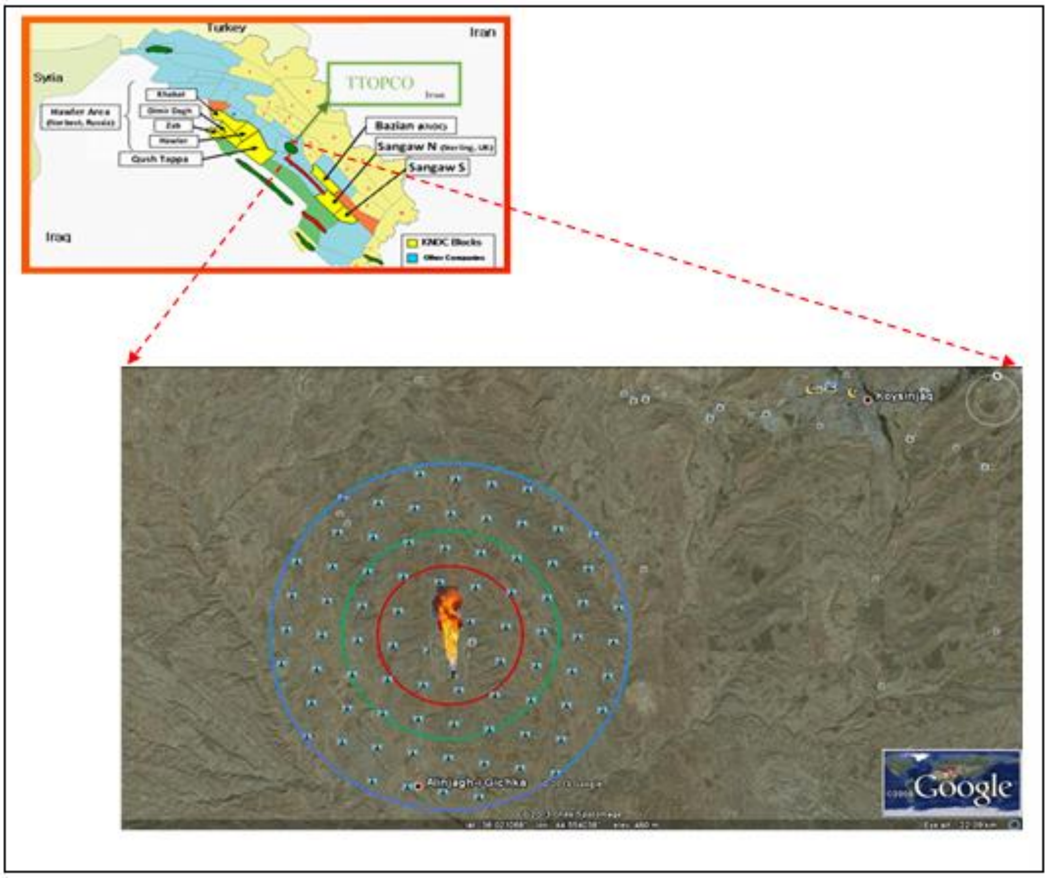

Figure 3: Survey area and sample locations (upper ma p abstracted from (KRG-Map, 2021); lower map generated from (USGS, 2020)

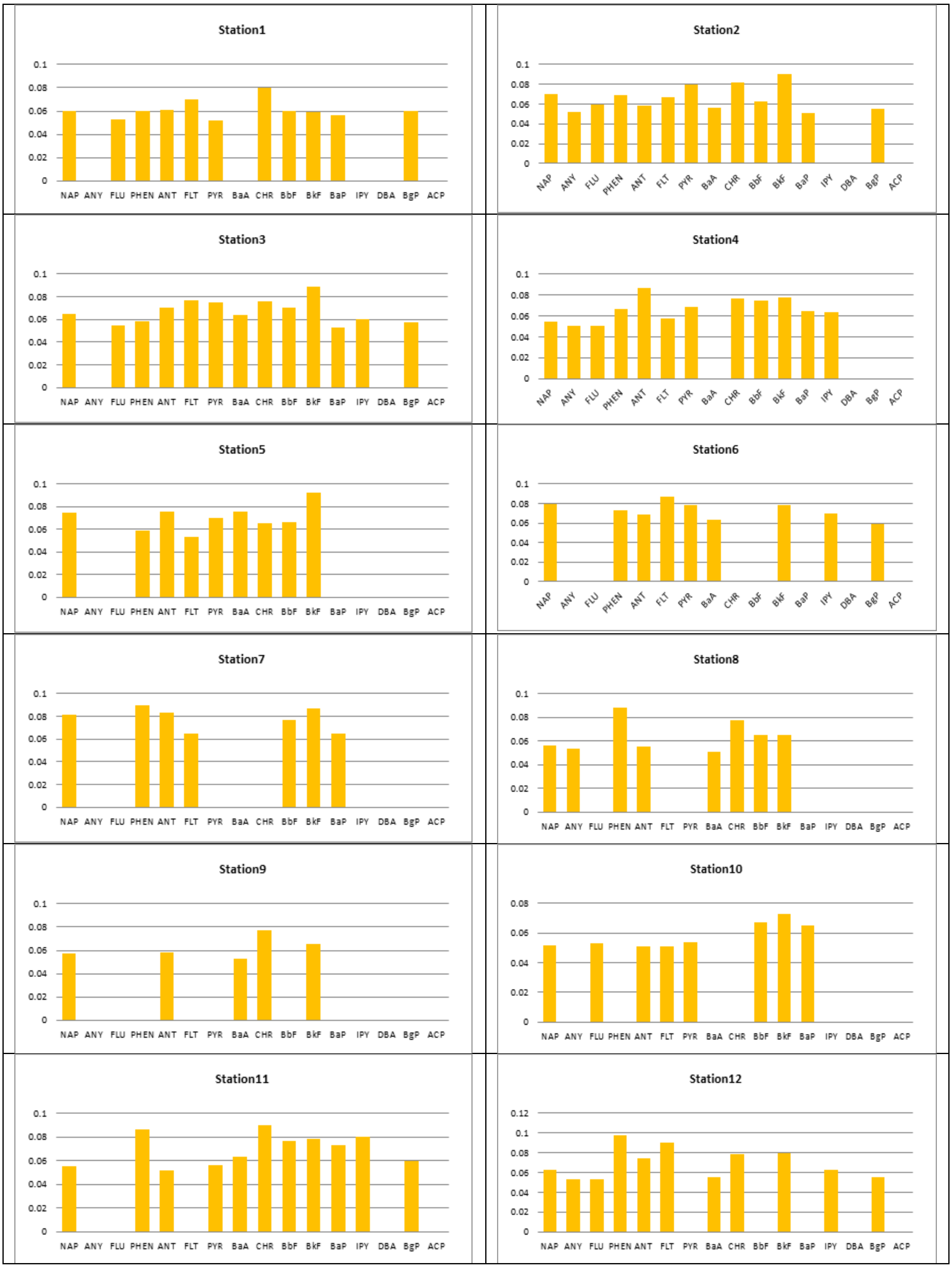

Figure 4: PAH concentrations (mg kg^{-1}) in topsoil in the vicinity of the Taq Taq oil field (5,000 m buffer zone)

2.4 Mapping

A map was created for the survey area using an ArcGIS (Figure 3) and the sample locations for PAHs were targeted. The position of each sample location was recorded using a Global Positioning System (GPS) receiver (GPS Garmin 62s, USA). From the GPS receiver, the World Geodetic System 1984 (WGS84) coordination system was transmitted to the Universal Transverse Mercator (UTM) coordination system to fit the real map. GIS Software (Arc. 10.1, ESRI, USA) was used for the analysis and distribution of the map. The concentrations of PAHs were presented as a distribution map on the GIS map (USGS, 2020).

3. Flare Environmental Impacts

Flare is affecting on the surrounding cities, villages, agricultural lands, the rivers and the people in the area especially the oilfield workers. Concentrations of PAHs in air, water and soils have constantly increased over the last 100 years, particularly in industrialized areas (Fadzil et al., 2008).

3.1 Surrounding Cities

The overall distribution of PAH was found to be closely related to the pollution sources, the size of city and the type of industry. Three cities are affected by the gas emission from Taq Taq field, (Figure 5) shows the location of the cities of Koya, Taq Taq and Erbil and their distance from the field. Urban area is reported to have higher soil concentration of PAHs than forest or agricultural soils, mainly because of direct exposure to vehicular emissions (Fadzil et al., 2008). Therefore, the pollution of the above cities is higher and discharge PAHs will contaminate the air from the flare and the road vehicles.

3.2 Surrounding Villages

Many villages surround taq Taq field; their locations are demonstrated in (Figure 6). Soils from urban industrial area usually consist of high concentration of PAHs, sometimes be 10 to 100 times higher than those in less populated and undeveloped areas (Fadzil et al., 2008). Therefore, the villagers in the area around the field are directly affected by the PAHs discharged from the flare. The risk of Asthma, skin cancer and the other diseases caused by PAHs will be increased among the villagers.

3.3 Agricultural Lands

Plants are important sinks for atmospheric PAHs, playing a role in the annual cycling of PAHs. Vegetation has been successfully used as a quantitative indicator of exposure to both gaseous and solid phase PAHs in ambient air. There are two possible pathways through which airborne PAHs can enter plants; uptake by root systems, once pollutants are deposited to the soil, and uptake by above-ground organs, mainly leaves, directly from air (Slaski & Li, 2000). PAHs could be translocated from roots to shoots; this issue remains somewhat controversial.

Volatile PAHs enter plants primarily through gaseous diffusion via open stomata, although absorption by the waxy leaf surface accounts for a portion of total PAHs in tissues (Slaski & Li, 2000). Figurre 7 shows the land use map of the area around the Taq Taq field including the agriculture lands. The products from these lands are all subjected to be contaminated by discharge PAHs for the oil field flare. It should be mentioned that the land use map was created using Landsat 8 satellite data, and maximum likelihood classification method was utilized to create the map.

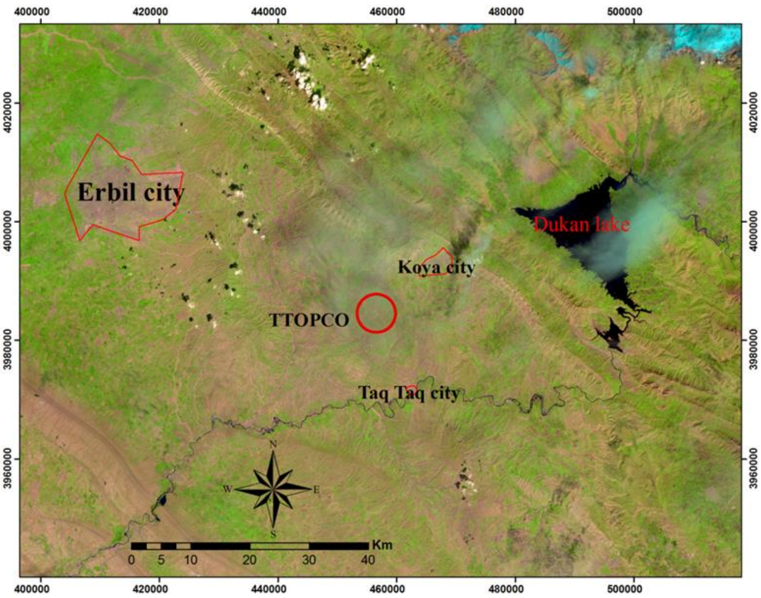

Figure 5: Taq Taq field surrounded cities

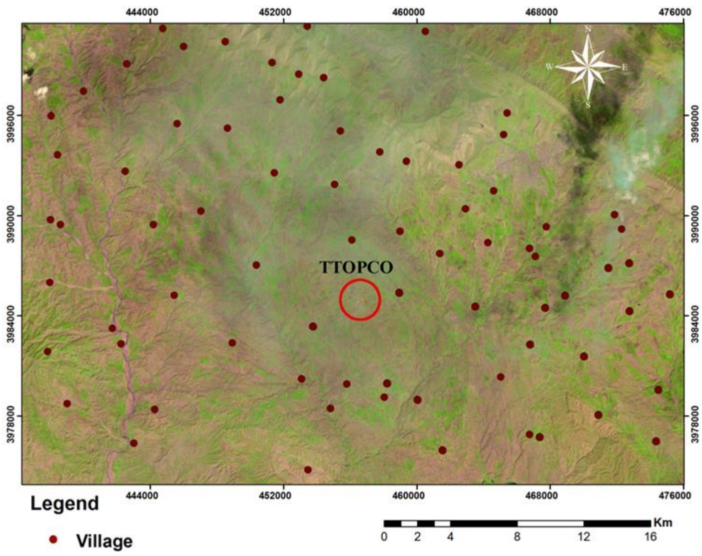

Figure 6: Taq Taq field surrounded villages

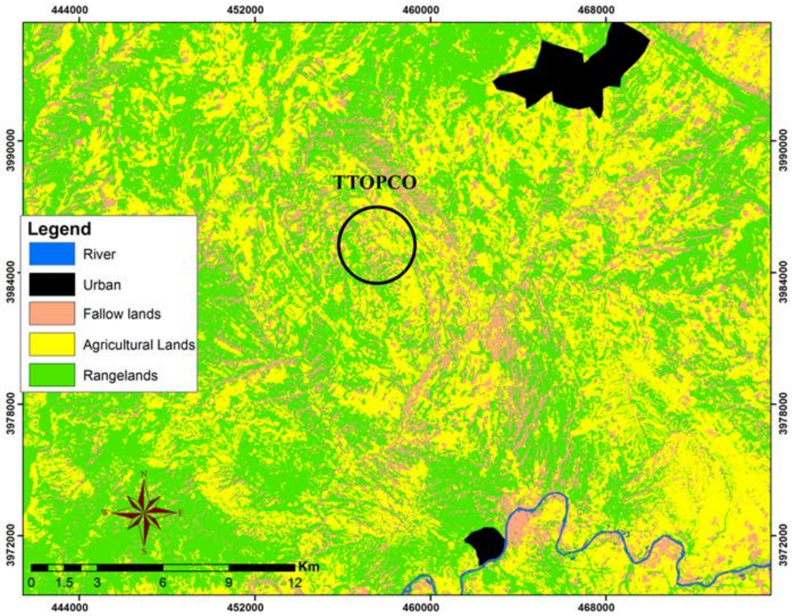

Figure 7: Taq Taq field surrounded land use

3.4 Rivers

Flaring is environmentally harmful due to the release of toxic components into the atmosphere and the emission of the greenhouse gas CO2. Moreover, resulting in water pollution from flaring may threaten the local fishing industry [o11016]. In (Figure 8), the black solid line indicates the main river (Zab) and the blue lines are small rivers and branches that eventually enter the main river. It's worth noting that the Zab river's path was manually derived from the Landsat 8 satellite image using the manual digitization process. However, a digital elevation model map and hydrological algorithm in the ArcGIS program were utilized to extract tributaries. This river is the source of drinking water for the people in the area, mainly Taq Taq residents as the river cross this town. Contamination of the river or its branches by PAHs will increase the risks of diseases.

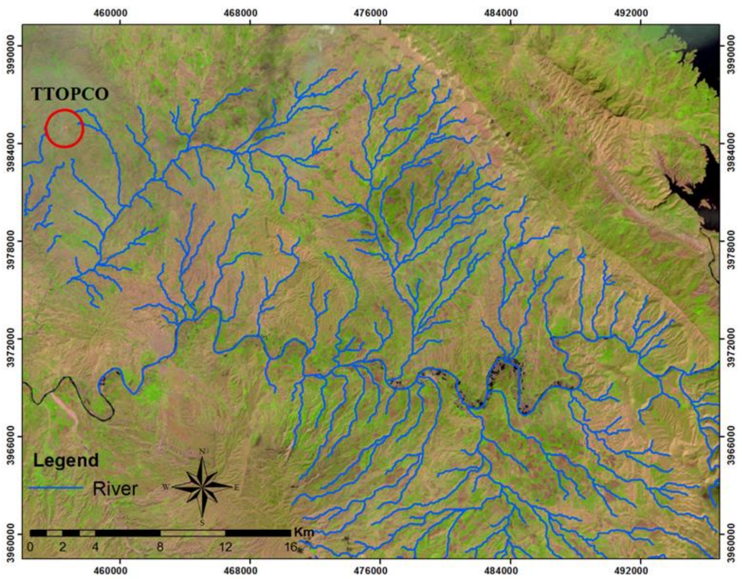

Figure 8: Taq Taq field surrounded rivers

5. Results and Discussion

Oil fields discharge gases to the environment via flaring of waste gases (Figure 1). Flares are used extensively to dispose of unrecoverable gases emerging with oil from oil wells; these gases are composed largely of low molecular weight hydrocarbons. Among the 16 PAHs listed by the USEPA are compounds accumulated mainly in the humus layer of soil. The pathways of PAH dissipation in contaminated soil include volatilization, irreversible sorption, leaching, accumulation by plants, and biodegradation (Reilley, 1996). PAHs with three or more rings tend to be strongly adsorbed to the soil (Nam et al., 2003). Strong sorption, leaching coupled with very low water solubility and very low vapor pressures make leaching and volatilization insignificant pathways of PAH dissipation (Park et al., 1990). PAH concentrations in soil correlate significantly with the corresponding levels in air (Fadzil et al., 2008), therefore, PAH determination in soil may provide important information on the overall state of environmental pollution. Characteristic ratios of PAHs and PAH profiles can be used in qualitative and quantitative source estimation. To test the effects of discharged gases from the Taq Taq oil field, the agricultural lands around the field were tested for PAHs.

Table 1: Mean, median, range and standard deviation of PAHs in soil samples (mg•kg-1)

	Mean	Median	Stdev	Range
Naphthalene	0.064	0.0615	0.010	0.052–0.081
Acenaphthylene	0.042	0.052	0.001	0.00 –0.054
Fluorene	0.054	0.053	0.003	0.051–0.060
Phenanthrene	0.075	0.071	0.015	0.058–0.098
Anthracene	0.066	0.065	0.012	0.051–0.087
Fluoranthene	0.069	0.067	0.014	0.051–0.090
Pyrene	0.067	0.0695	0.011	0.052–0.080
Benz(a)anthracene	0.053	0.056	0.008	0.000–0.076
Chrysene	0.078	0.078	0.007	0.065–0.090
Benzo(b)fluoranthene	0.069	0.067	0.006	0.063–0.077
Benzo(k)fluoranthene	0.078	0.0785	0.011	0.059–0.092
Benzo(a)pyrene	0.061	0.065	0.008	0.051–0.073
Indeno(1,2,3-cd)pyrene	0.056	0.0635	0.008	0.000–0.080
Dibenz(a,h)anthracene	0.000	0	0	ND
Benzo(g,h,i)perylene	0.058	0.058	0.002	0.055–0.060
Acenaphthene	0.000	0	0	ND
tPAHs	0.654	0.664	0.163	0.310–0.869

Most PAHs reach the soil via deposition from the atmosphere, and PAH concentrations in soils tend to increase with the increasing impact of industry, traffic, and domestic heating (Jones et al., 1989). It is known that low molecular weight PAHs are relatively more volatile and could potentially be evaporated by the high temperatures and solar radiation levels encountered in tropical soils. The mean, median, range and standard deviation of PAH concentrations detected in soil samples at each location in this study are presented in Table 1. Not all PAHs were detected at all locations, and ACP and DBA were not detected in any samples tested. The total PAH concentrations detected ranged from 0.310 to 0.869 mg•kg−1 dry weight, with an average value of 0.654 mg•kg−1. It was predicted that the black smoke released from the flare (Figure 1) would lead to higher soil contamination than detected in the soil samples tested. Because of the low number of samples tested, we cannot preclude that the sampling did not capture the complete contamination profile of the site. The profiles of total PAH concentrations for all locations are presented in Figure 9. The maximum total PAH concentration was detected at location 3, and the minimum concentration was detected at location 9. The high PAH concentration at location 3 is due to the wind direction from the flare towards that location. A two-dimensional map of total PAH distribution around the survey area is presented in Figure 10. The red color indicates the highest concentrations of PAH contamination and the green color indicates areas with low concentrations of PAH contamination. The potential risks from pollution are higher for residents and wildlife around the red zone in Figure 10.

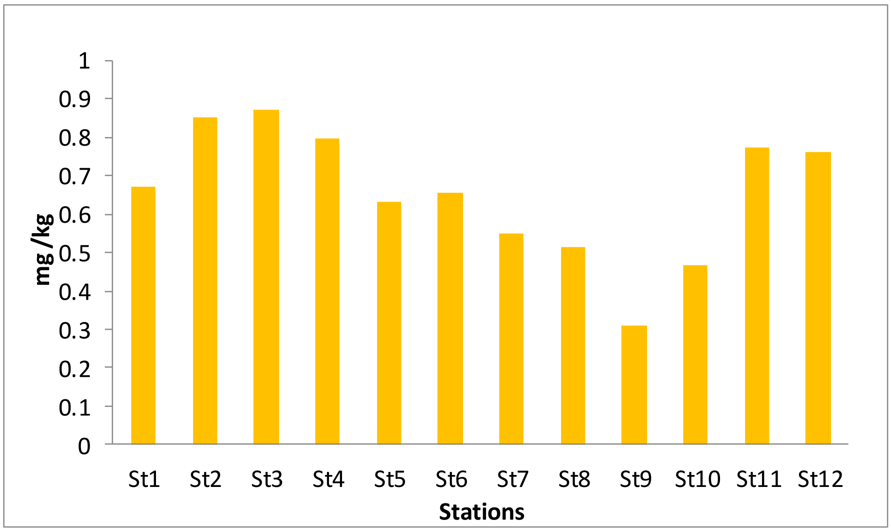

Figure 9: Typical PAH profile for stations

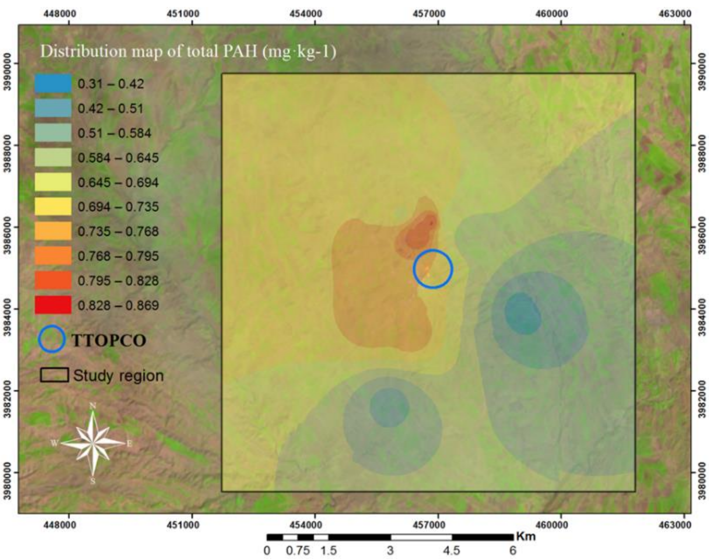

Figure 10: Distribution map of total PAH in topsoil in the vicinity of Taq Taq oil field

The relationships between total PAHs and specific PAHs that were detected in all locations are shown in Figures 8 and 9. The relationship of total PAHs with BkF and ANT is shown in Figure 11, whilst Figure 12 shows the relationship of total PAHs with NAP and PHEN. The graphs generally indicate a poor correlation of the specific PAHs with the total PAHs, as the latter is a summation of the total hydrocarbon concentrations. These charts are presented mainly to show the significance of the specific PAHs that were detected in all soil samples.

In the current study the soil contamination by PAHs in the agricultural lands arround Taq Taq field after decade was investigated. It has been reported that PAHs in soils might be further deposited on or accumulated into vegetables or other biota via food chains (Enuneku & Kubeynje, 2019).

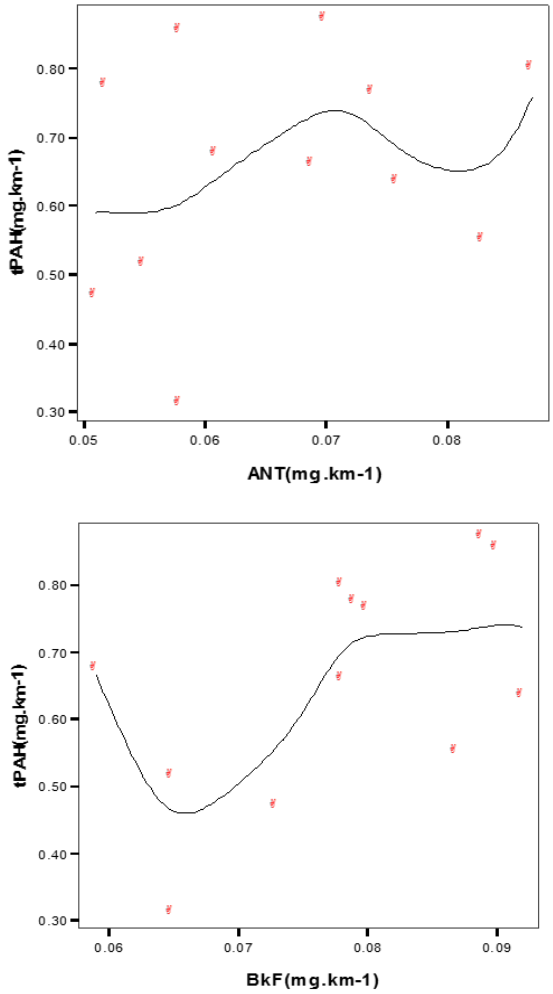

Figure 11: Total PAHs compared with (a) BkF and (b) ANT

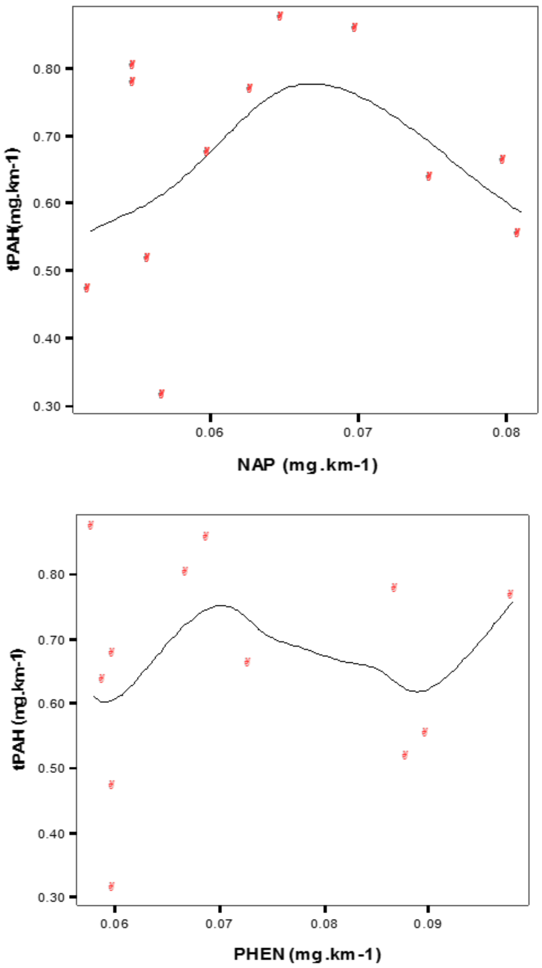

Figure 12: Total PAHs compared with NAP and PHEN

On an average discharge of 25MMcf/ day of flaring gas for 10 years, the vicinity of 1km is not recommended for agriculture, 2km distant from the flare could be contaminated. At 3km boundary the land is normal with warning signal of contamination. At these two locations it is better the product be tested before use. After 4km safe boundary for agriculture and the vicinity less contaminated, see figure 13.

There is also concern about the risk of pollution by discharge of PAHs from the flare is extended to the rivers, surrounding villages and cities.

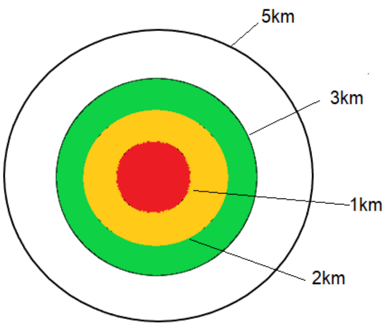

Figure 13: Boundaries around flare

6. Conclusions

This study investigated the risk of emissions from oil field flares on soil contamination. PAHs were detected in the soil surrounding the Taq Taq oil field. The maximum PAH concentration was detected at station 3, and the lowest concentration was detected at location 9. The detection of PAHs at several locations with no proximity to main roads and no other PAH sources in the area confirmed that the contamination resulted from combustion of the discharge gases from the oil field. Stations located northwest of the flare were more affected because of the prevailing wind direction around the flare site. In addition, it is concluded that the vicinity of 4km around the gas flare will be less affected and safe for agriculture.

It is suggested that deep research be carried out to investigate the effects of flare on the surrounding rivers, villages, cities, and crops with regular monitoring for the agriculture lands.

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