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REVIEW OF EFFECTS OF LAND OIL SPILLS FROM TANESCO POWER DISTRIBUTIONSYSTEMS ATTRIBUTING TO ENVIRONMENTAL DEGRADATION IN TANZANIA

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ABSTRACT

The aim of this study was to review the effects of land oil spills from Tanzania Electric Supply Company (TANESCO) power distribution systems for the past ten years versus environmental degradation in the three districts of Arusha, Meru and Monduli in Arusha region, Tanzania. The study employed structured interviews, experiments, and office records to collect data on the effects of power distribution transformer mineral oils intended for cooling and insulation between windings but leaks posing land oil spills. Data analysis was performed on subsets of land surface-based oil spill effects on plants, soils and water bodies, and the results indicated that plants from forb species were affected much (13%) in the samples of (forbs, grass, shrubs and trees. Clay soils were affected by 12% in the group of clay, gravel, sand and silt soils. Ponds were affected much (14%) in the group of gullies, ponds and swamps where distribution transformers were installed. The variables for oil spill places were fitted with distributions, while Xlstat was used to generate result spreadsheets of oil spill series data based on the fitted distributions. The general results indicated that 51% of distribution transformers found with oil leaks were installed on improper soil surfaces affecting soils (16%), plants (17%) and water (18%). It is concluded that transformer mineral oil spills degrade the environment by posing health risks to human beings and biodiversity.

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INTRODUCTION

Electricity is essential for the development of residential, commercial, manufacturing and processing sectors. However, there are some challenges facing TANESCO in delivering its services for development in different sectors. These challenges include the following among others. According to Jevtić, *et al.* (2024), oil spill from transformers can pose environmental problems such as physical harm and toxicity to wildlife, destruction of critical habitat, destruction of food chains and ecosystem, affecting biodiversity and breeding, long term contamination of water, poisoning, as well as reproductive problems. Power distribution in Tanzania has increased drastically in recent years due to the introduction of rural electrification projects in 2008, solicited by the increase in consumptions of electricity thus pushing the Country to attain middle-income status by 2025 (URT, 2020). Currently in Arusha, Meru and Monduli districts, 11 kV Medium Voltage (MV) line is about 529 km, and 33 kV is about 1,230.67 km. The number of distribution transformers has reached 1,244 and 130,656 Tariff T0 and T1 consumers connected. According to TANESCO, (2023), about 32 distribution transformers of 11 kV and 103 of 33 kV voltage levels with sizes ranging from 50 kVA to 500 kVA were found defective that posed 52, 015 litres of oil spills from year 2013 to 2023. The increase in oil leaks at subsequent year was due to more extension of the MV line implying more oil spills if the causes are not combated (Table 1).

The evaluation of power distribution systems has proven instrumental in recognizing construction methodologies, maintenance approaches, and various irregularities that could lead to oil spills. This review enabled the screening of power distribution system populations to ascertain the extent and intensity of transformer oil spills, with the results serving as a foundation for developing mitigation strategies against environmental degradation. These strategies can be utilized as a framework for forecasting potential oil spill incidents both within the designated study area and in other locations. TANESCO (2023), established that the cause of defective transformers that led to land oil spills between 2013 and 2023 in Arusha, Meru and Monduli districts included improper construction practices, improper maintenance strategies and other anomalies. This review on the effects of land oil spills enabled revisiting the power distribution system populations to ascertain the extent and severity of adverse effects of transformer oil spills, with the results serving as a foundation for developing mitigation measures against environmental degradation. These counter measures can be utilized as a framework for forecasting potential oil spill incidents both within the study areas and in Tanzania at large. Land oil spills from TANESCO power distribution systems in Arusha, Meru and Monduli districts are increasing with the total number of defective distribution transformers having oil leaks. The parts of power distribution systems that form the basis for notably increasing and currently unmanageable land oil spills include MV lines (1,759.67 km), transformers (1,244) and consumer loads (130,656). The MV lines have contributed to defective transformers (135) found with leaked oils (52,015ltr) taken from year 2013 to 2023 (TANESCO, 2023). An oil spill released into the environment penetrates different structures affecting terrestrial life including humans, inland water bodies, plant species and soil types; hence a need for investigation of land oil spills versus environmental degradation (Freedman, 2018).

MATERIALS AND METHODS

The study area location includes Arusha, Meru, and Monduli districts situated at the coordinates 3°22.0002′ S 36°40.9998′ E, 3°22.0002′ S 36°40.9998′ E, and 3°22.0002′ S 36°40.9998′ E, correspondingly. According to the National Bureau of Statistics (NBS), in 2022, the combined population of these districts amounts to 1,008,706 people and 130,656 power consumers from two tariff groups denoted as T0 and T1. The sample size of the study was computed according to Kothari, 2014, as follows:

$$S = \frac{N}{P} \times n \tag{1}$$

From which 45 people in Arusha district, with a population of 449,518 were sampled. *S*=Sample size, *N*=Population of the group (449,518), *n*=Drawn from the group (101), *P*=Districts population (1,008,706). The study involved the 45 people as witnesses to acts of vandalism, chosen for structured interviews using a stratified sampling technique (Rahman, *et al.,* 2022) from wards of Moivo and Sokoni II wards in Arusha district. Maji ya Chai and Usariver wards from Meru district, MonduliJuu, and Sepeko from Monduli district were involved for field observations, testing, and measuring parameters. Specimens for observations, testing and measuring parameters included 4 species of plants, 4 types of soils, 3 water bodies, MV lines (4 km), transformers (9) of sizes ranging from 50 kVA to 500 kVA, mineral oils from transformers, land surface places (9) and consumer load tariffs (4). Observations, testing and measuring parameters included various samples of mineral oils from places of defective power distribution transformers, plants, soils and waters. The slope (*S*) increases as the land surface becomes more inclined, as stated by Farrar, *et al.* (2014). In the process, the (x, y) coordinates indicated the degree to which the oil spills spread across the inclined land surfaces and descended onto the ground. Following geometric principles, measuring the x and y axes from the coordinates (0, 0) to (x, y) determines the value of *S*. The magnitude of S differed based on the characteristics of the terrain or topography. Mathematical representation of the slope *S* resembled the gradient of linear algebra (Equation 2).

$$s = \frac{y-0}{x-0} \tag{2}$$

s = Slope *y* = Vertical axis *x* = Horizontal axis

The modality to obtain S in Equation (2) is used to get the horizontal lengths from the position of the oil leaked transformer as zero or reference point (0,0) using a tape measure as far as the destination of the oil spill (x, y). The horizontal lengths were x coordinates (abscissa). The vertical lengths were y coordinates (ordinates) measured from the ground level upward to the equilibrium point of the level meter, where the oil spill terminated. The *S* variables computed from each oil spill place referred to velocities of the travelling oil spills on slopes sampled from different places, indicating the data for the x and y coordinates and the corresponding S. Using the values of S, the values of V were computed from Equation (3) for regression analysis of the soil-based model (Farrar, *et al.,* 2014).

$$V = 4.92[S]^{\frac{1}{2}} \tag{3}$$

Data with oil spill lengths and velocities of oil spills could be used to compute the time the oil spills travelled to the destinations Equation (4) (Marija, 2019).

$$t = \frac{L}{V} \tag{4}$$

Computation of slope S for individual oil spills was referred to as Equation (2) where x is the oil spill length denoted as L and y the vertical displacement from where the oil spill terminates.

$$S = \frac{Y}{L} \tag{5}$$

Substituting Equation (5) into Equation (3) gives:

$$V = 4.92\left[\frac{Y}{L}\right]^{\frac{1}{2}} \tag{6}$$

Equation (6) was used as a tool for oil spill management to generate a regression analysis model from Analysis of Variance (ANOVA). The Velocity of an oil spill from Equation (6) was used to develop Equation (7).

$$V = \beta_0 + \beta_1 4.92\left[\frac{Y}{L}\right]^{\frac{1}{2}} + \cdots . + \beta_n \left[4.92\left[\frac{Y}{L}\right]^{\frac{1}{2}}\right] \tag{7}$$

V = velocity of the travelling oil spill, β_0 = Intercept β = Regression coefficient, *Y* = Vertical length at oil spill terminal and *L* = Horizontal length of oil spill. Proper selection of x and y coordinates may decide the speed and the spread of oil spills. The study seeks to develop a regression model as a tool for the ground on which the distribution transformer is positioned to zero the oil spill height (*Y*) within the MV line corridors The ground on which the distribution transformer is to be mounted requires careful selection of the type of soil. This chapter describes clay, gravel, sand, and silt soils. The suitable soil should allow for the effective implementation of the model. When mixed with water and cement in a good ratio, its particles must make a block of concrete that effectively fills the pore spaces.

RESULTS AND DISCUSSION

According to Vankore and Nikam, (2024), oil spills have a number of effects on the environment. On a basic level, oil spills damage waterways, plants and animals on the land. Further, when oils ring or machinery malfunction or break, thousands of tons of oil can seep into the environment. Habitats can be catastrophic; killing plants and animals; disturbing salinity/Potential of Hydrogen (PH) level, and pollute air, water and more.

Table 1. Leaked mineral oils from defective transformers

Year	Number of transformers	Leaked mineral oil litres
2013	7	3,055
2014	8	4,788
2025	9	4,245
2016	10	4,517
2017	13	4,788
2018	11	4,246
2019	14	5,329
2020	14	4,517
2021	15	5,058
2022	16	5,329
2023	18	6,143
Total	135	52,015

The review focused on open land surfaces to identify the effects of mineral oil spills from distribution transformers at Moivo and Sokoni II wards in Arusha district. The findings from both wards suggested that respondents lived in their places for more than five years and witnessed TANESCO teams with Police investigating transformers affected by vandalism. Further interviews disclosed transformer mineral oil in the street, such as cooking oil for frying potato chips. Some were sold as fuel for vehicles at a cheap price in the black markets. All interviewed 24 (53.33%) respondents at Sokoni II, and 21 (46.67%) respondents at Moivo had knowledge of distribution transformers and witnessed the transformer mineral oil theft. Further, a total of nine oil-immersed distribution transformers were damaged due to vandalism, with the majority of the incidents occurring in the Sokoni II ward, accounting for five transformers (55.56%) and the remaining four transformers (44.44%) in the Moivo ward. Four of the nine vandalised transformers were still operational and promptly repaired, with two located in Sokoni II and two in Moivo. However, the other five transformers, three in Sokoni II and two in Moivo were deemed irreparable and required replacement. Five distinct areas indicated the vandalised transformers, four in Sokoni II and the remaining in the Moivo Ward. Oil spills were detected in all nine locations, indicating a widespread environmental concern. The replacement and restoration of power to the vandalized transformers faced a significant delay of over three days, causing inconvenience and disruption to the affected areas. Based on the report, 51.11% of the respondents (14 from Sokoni II and nine from Moivo) reported that power was restored three days after the necessary arrangements for replenishing mineral oil. In contrast, 48.89% (10 from Sokoni II and 12 from Moivo). Notably, 57.78% of the respondents received information regarding power restoration from their local leaders, highlighting the importance of effective communication channels. Conversely, 42.22% relied on rumors, indicating a potential lack of reliable information dissemination in certain areas (Table 2).

Table 2. Witnesses on structured interviews Arusha district

Structured Interview		Wards/respondents		Total
		Moivo	Sokoni II	
Stayed period	>5Years	21	24	45
	<5Years	0	0	0
Informed on transformers		21	24	45
Informed on oil theft		21	24	45
Source of information for power restoration	Rumours	9	10	19
	Local leaders	12	14	26
Repplenishedtrasformers		2	2	4
New transformers		2	3	5
Replenished/power restored intervals	>3 Days	9	14	23
	<3 Days	12	10	22
Places with oil spills		4	5	9

Transformer mineral oils on plants, soils and water indicated that in all types of soils sampled, clay soils were much affected (12%), followed by silt soils (8%). In all types of water bodies sampled, ponds were much affected (14%), followed by swamps (12%). Meanwhile, in all plant species sampled, forbs that do not grow much tall were much affected (13%), followed by grass (10%) (Table 3).

Table 3. Oil leaked transformers on plants, soils and water places

Locations	Improper Soils (%)	Improper surfaces (%)	Improper concrete (%)	Total (%)
Clay soils	6	4	2	12
Gravel soils	3	2	1	6
Sandy soils	3	2	2	7
Silt soils	4	3	1	8
Total	**16**	**11**	**6**	**33**
Gullies	4	2	0	6
Ponds	6	6	2	14
Swamps	8	0	4	12
Total	**18**	**8**	**6**	**32**
Forbs	6	5	2	13
Grass	4	4	2	10
Shrubs	4	2	1	7
Trees	3	2	0	5
Total	**17**	**13**	**5**	**35**
Overall	**51**	**32**	**17**	**100**

The placement of secondary substations on sloping land surfaces may result in oil leaks that have the potential to reduce the width of the spill but increase its length, thereby reaching a distant area. It can lead to the contamination of plant species, particularly forbs and grass, commonly found on inclined land surfaces beneath secondary substations in Meru and Monduli districts (Plate 1). Around 11% of defective distribution transformers with leaks were found affecting clay soils (4%), gravel soils 2%, sand soils (2%) and silt soils (3%)

Plate 1. Inclined surface Improper ground-mounting

Field data in Meru and Monduli districts: The selection of load centres for the secondary substation did not consider the different soil types, including clay, gravel, sand, and silt. Clay soil retains liquids (in this case mineral oils when leaked) for long time, followed by silt soils. Sand and gravel soils, relatively retain liquids for a short time following the large spaces between particles. At least 16% of defective transformers with oil leaks affected clay soils (6%), gravel soils 3%, sandy soils 3% and silt soils 4%. Plinths and floors under which distribution transformers were mounted could be found with improper and weakly screed concretes, whereby crakes allowed penetration of mineral oils and reached various soli types, plant species and water bodies. Places found with improper screed concretes and so vast effects of mineral oils on plants and soils were those with soil types retaining liquids much longer than others. These included clay (2%), gravel (1%), sand (2%) and silt (1%), making a total of (6%). Plants included in this study were forbs (Colocasia and Sativa), grass (Poaceae), shrubs (Rhododendron) and trees (bamboo). Distribution transformers found on improper soil types were 17%, affecting forbs (6%), grass (4%), shrubs (4%) and trees (3%). Those found on improper land surfaces 13%, affected forbs (5%), grass (4%), shrubs (2%) and trees (2%). Only 5% of the distribution transformers at improper screed concretes affected forbs (2%), grass (2%) and shrubs (1%). No trees were found affected at improper screed concretes. Oil spills generate several environmental impacts and have become more common with the increase in petroleum extraction, refining, transportation, and trade. In soil, oil contamination increases water and nutrient availability and compaction, directly affecting plant growth and development. Different aspects of phytotoxicity can be observed and will vary according to the characteristics of soil and plants. Oil-contaminated soil also results in negative effects on biomass and changes in leaves and roots (Correa, *et al.,* 2022). Yadav, et al. (2023) stated that the release of crude oil into the environment introduces toxic compounds, such as Polycyclic Aromatic Hydrocarbons (PAHs), heavy metals, and volatile organic compounds, which can persist in soils long after the initial spill event. These contaminants can alter soil physical properties impeding water infiltration and reducing soil porosity. Oil penetration into the soil matrix can lead to the formation of hydrophobic layers, exacerbating issues related to water retention and affecting the availability of nutrients to plants. Further, the uptake of organic pollutants by plants from contaminated soils depends on abiotic factors that include physicochemical properties of the molecule and molecular weight and soil components (clays, iron oxides, organic matter) and biotic factors that involve transpiration rates on types and amounts of lipids in root cells, enzyme complements, root exudates and growth dilution. Song, *et al.* (2017) said that the evaluation of oil impact on soil ecology involves assessing the effects of oil contamination on the various components of the soil ecosystem, including plants, microorganisms, and invertebrates. According to Jha and Dahiya, (2022) responsiveness of vegetation to oil contaminant also depends on type of root system they contain. Further, as compared to plants containing stock roots, the plants having shallow roots are affected with oil spill. The oil spills show immediate influence on vegetation cover as within few days of the spill the vegetation turns yellow or brown in color, losing chlorophyll and falling of leaves. The presence of mineral oil in soil that is already contaminated can have detrimental consequences, including the immediate death of plants upon contact, the suppression of growth, and the inhibition of germination-fact that it enhances the inhibition of activities of the soil micro-organisms by delimiting free water supply and aeration (Pawar, 2015).The pH of oil spill-polluted places varied over a range of 5–8 affecting various types of soils (Table 4).

Table 4. Chemical properties of tested soils

PH	Clay	Gravel	Sand	Silt
Normal soil	5.75	6.98	6.56	5.92
Polluted soil	7.53	7.62	7.63	7.56
Increase (%)	31.19	9.17	16.31	27.70

Table 5. Oil spills from inland water bodies

Water bodies	Wards				Total (%)
	Maji ya Chai	MonduliJuu	Sepeko	Usariver	
Gullies	1.57	1.10	1.52	1.81	6.00
Ponds	4.04	2.34	2.95	4.66	13.99
Swamps	3.71	2.00	2.28	4.00	11.99

The ability of soil to allow water to flow through it is called soil permeability. Flow of water in soil takes place through void spaces, which are interconnected (Arunkumar, 2021). According to Darcy's law, gravel soil has the highest permeability of 100 cm/s, followed by sandy soil, which ranges from 10-2 to 100 cm/s. Clay soil has the lowest permeability, ranging from 10-6 to 10-4 cm/s, followed by silt soil, ranging from 10-4 to 10-2 cm/s. Permeability test methods performed included the constant head test method for permeable soils (k>10-4 cm/s) and the falling head test method mainly used for less permeable soils (k<10-4 cm/s) (viscosity (Al-Obaidi, (2018). The constant head and falling methods are used for permeability tests on contaminated gravel and sandy soil, while the falling head method was applied to test clay and silty soils. The experiments revealed that the permeability of the contaminated soil types exhibited varying degrees of decrease. The findings indicated that both clay and silt soils experienced a significant reduction in permeability, ranging from 10% to 20%. In contrast, the permeability of gravel soil decreased by 10%, while sand soil decreased by 1% to 10%. The decline in permeability for all soil types was attributed to transformer oil, which became trapped in the soil's pore spaces, consequently diminishing the pore sizes and impeding water flow through the soil.

Based on improper soil types, 18% of the defective transformers with oil leaks affected gullies (4%), ponds (6%), and swamps (8%). Those on improper land surfaces 8% affected gullies (2%) and ponds (6%). No distribution transformers were found under swamps at improper land surfaces. Only 6% of the defective transformers with oil leaks were found on improper screed concretes, with ponds (2%) and swamps (4%). No defective distribution transformers with oil leaks were found on or near gullies. Oil spills on water itself can severely contaminate beaches and sediment and causes serious harm to marine wild life (Vankore& Nikam, 2024). Further, it suffocates fish, get caught in the feathers of birds and mammals and block light from photosynthetic plants in water, disturbing the food chain. Samples from distribution transformer mineral oil polluted inland waters in gullies, ponds and swamps at Maji ya Chai, MonduliJuu, Sepeko and Usariver Wards were tested on physical, chemical and biological changes, and the results displayed. Test results indicated that ponds were affected much in all sampled wards. Usariver leads whereby pond samples were polluted to 4.66%, followed by Maji ya Chai (4.04%) and Sepeko (2.95%). Ponds were heavily affected, possibly because water was stagnant. Swamps were second from ponds, with Usariver ward heavily polluted (4.00%) again, followed by Maji ya Chai ward (3.71%) and Sepeko ward at somewhat 2.28%. Swamps tend to absorb and retain water for some time, and oil spills would likely have drained shortly underground. Swamps contain transformer oil, relatively similar to ponds, as water is stagnant. Gullies with average of 6.00% were not very much affected by oil spills, possibly because water therein is sometimes in motion (Table 5). Generally, the alarming situation did not affect MonduliJuu ward, although the obtained statistics are negligible. Water samples were collected from Maji ya Chai and Usariver wards in Meru district, MonduliJuu and Sepeko wards in Monduli district (Plate 3). The test results for Potential of Hydrogen (pH), temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) indicated that the BOD at a temperature between 260C and 290C was found between 100 mg/l and 140 mg/l. The greater the concentration of organic pollution in the water, the greater the oxygen demand of the bacteria. The thin oil layer on the water surface inhibited the growth of microbiology that grows in shallow waters (Singh, *et al.,* 2021). The COD was found between 98 mg/l and 550 mg/l. The EC was measured between 0.31 and 2.89 mmhos/cm from the TDS ion concentration within the water, which was between 227 mg/l and 252 mg/l. pH of polluted water became more basic between 7.68 and 7.96. The oil spill at Maji ya Chai was caused by leakage from the distribution transformer resulting from lightning. The transformer burnt due to overload, causing an oil spill at Sepeko Ward. Meanwhile, the oil spill at MonduliJuu was caused by a distribution transformer rupturing due to manufacturing defects. The PH values recorded were within the permissible level of the World Health Organization (WHO) (Haile & Endale, 2019). EC, TDS, and COD values increase significantly after plant exposure. High EC, TDS and COD are signs of pollution. The increase in EC indicates that most inorganic elements are abundant (Edema, 2012). Although the TDS values increased, they were still within the highest desirable limit of WHO (500mg/l) and classification scheme of African water within conductivities between 6,000 – 16,000μScm-1. Continuous pollution may rise and exceed WHO values (EPA, 2022).

CONCLUSION

Extension of power distribution systems to capture more power consumers, bears the increase in land oil spills associated with many more transformers and so adverse environmental effects. Chemical and physical properties of soil and water upon which plant and animal depend, are affected. Seed germination in plants is delayed and symptoms of necrosis, choruses of flower buds and inhibition of plant growth in areas with land oil spills. The movements of land oil spills towards humans are observed from internal and external transformer failure related causes. Meanwhile, the effects of land oil spills towards animals and humans are observed from the transformer corridors, which covered the land surfaces over which the distribution systems were constructed. The movements can be presented as a chain starting when the mineral oil leaks from the distribution transformers with fumes directly reaching the animal and human body through inhaling the atmospheric air or contact the leaks on the ground or nearby objects. The oil leaks dropping to the ground are absorbed into plants, soils and inland waters. Countermeasures should be instituted during construction practices and maintenance strategies along the power distribution systemsfor sustainable environments.

REFERENCES

Al-Obaidi, A. (2018). Soil Mechanics Notes Chapter Five (Permeability and Seepage through Soil). University of Tikrit, Iraq.

Arunkumar, S. (2021). Soil Water Movement – Saturated and Unsaturated Flow. Open Access Multidisciplinary Monthly Online Magazine Vol 2 Issue 11, pp. 29-33.

Correa, H. D. S., Blum, C. T., Galvão, F. &Maranho, L. T. (2022). Effects of Oil Contamination on Plant Growth and Development: A Review. Environmental Science and Pollution Research Article. Vol. 29, pp. 43501–43515

Edema, N. (2012). Effects of Crude Oil Contaminated Water on the Environment. Crude Oil Emulsions- Composition Stability and Characterization, pp. 170-180. DOI: 10.5772/36105.

EPA. (2017). Selected Analytical Methods for Environmental Remediation and Recovery. Washington DC: EPA.

Farrar, W. Galagan, C. Isaji, T. & Knee, K. (2014). GIS Technology Applied to Modeling Oil Spills on Land. [proceedings.esri.com/library/userconf/proc05 /papers/pap2129.pdf] retrieved on 01/01/2021.

Freedman, B. (2018). Environmental Science (Digital Editions). Halifax, Nova Scotia, Canada: Dalhousie University Libraries.

Haile, M. Z. & Endale, T. M. (2019). Analysis of Physico-chemical Characteristics of Water Collected from Different Sampling Sites of Lake Hawassa, Ethiopia. Journal of Environment Vol 9 Issue 2, pp 38-45 DOI: 10.5923/j.env.20190902.02

Jevtić, A., Stanković, V., Glišović, S. & Jovanović, E. (2024). Environmental Impacts of Substations: A Short Review. Ecological Engineering and Environment Protection, Vol. 1 Issue 2, pp. 5-11.

Jha, S. & Dahiya, P. (2022). Impact analysis of Oil Pollution on Environment, Marine, and Soil Communities. Advances in Oil-Water Separation. Elsevier Inc pp. 99-113. DOI:10.1016/B978-0-323-89978-9.00017-3.

Kothari, C. R. (2014). Research Methodology and Techniques (3rd Edition). New Delhi: NewAge International.

Marija, E. (2019). A Comprehensive Planning Framework for Urban Inland Oil Spill Management (PhD Dissertation). Ryerson University Toronto, Ontario, Canada.

NBS. (2022). Tanzania National Bureau of Statistics Census. [https://www.nbs.go.tz/index.php/en/census-surveys/...] site visited on 05/03/2024.

Pawar, R. M. (2015). The Effect of Soil pH on Bioremediation of Polycyclic Aromatic Hydrocarbons (PAHs). Journal of Bioremediation and Biodegradation, Vol 6 Issue 3, pp. 1-14. DOI: 10.4172/2155-6199.1000291

Rahman, M. M., Tabash, M. I., Salamzadeh, A., Abdul, S. & Rahaman, S. (2022). Sampling Techniques (Probability) for Quantitative Social Science Researchers: A Conceptual Guidelines with Examples. South East European University Journal. Vol. 17 Issue 1, pp. 41-51.

Singh, G., Singh, A., Singh, P. & Shukla, R., Tripathi, S. & Mishra, V. K. (2021). The Fate of Organic Pollutants and Their Microbial Degradation in Water Bodies. Banaras Hindu University, Varanasi, Uttar Pradesh, India: Institute of Environment and Sustainable Development.

Song B, Zeng G, Gong J, Liang J, Xu P, Liu Z, Zhang Y, Zhang C, Cheng M, Liu Y, Ye S (2017). Evaluation methods for assessing effectiveness of in situ remediation of soil and sediment contaminated with organic pollutants and heavy metals. Environment international, Vol. 1 Issue 105, pp. 43-55.

TANESCO. (2023). Report of Board of Directors and the Financial Statements, AR/PA/TANESCO/2022/23, pp. 1-203 URT. (2020). United Republic of Tanzania. Country Office Annual Report, pp. 1-9.

WHO. (2022). Guidelines for Drinking Water Quality (4th Edition - incorporating the 1st and 2nd addenda). Geneva: World Health Organization

URT. (2020). United Republic of Tanzania. Country Office Annual Report, pp. 1-9

Vankore, A. & Nikam, J. (2024). Oil Spills. International Journal of Multidisciplinary Education and Research. Vol. 9 Issue 1, pp. 45-47

Yadav, K. K., Sing, K. K., Yadav, A. S. & Kumar, D. (2023). The Ecological Impact of Oil Spills on Soil Health. Vigyan Varta an International E-Magazine for Science Enthusiasts, Special Issue 3, pp. 92-96.

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