

Qualitative Analysis of Physio-Chemical Parameters of Soil to Underline the Effects of Pipeline Laying on Soil Fertility



Anirbid Sircar, M. A. Shabiimam, Abdul Rasheed, Shaunak Mehta, Jaini Shah, Ankita Patel, Namrata Bist, Kriti Yadav, and Roshni Singh

Abstract Agricultural land constitutes the most important part of a geological component of a country in terms of economy and prosperity. The virtue of an agricultural land solely resides on the type and composition of soil type and quality of that region. The laying of an underground pipeline might affect the soil quality and productivity of the specific area. In addition to this, there is a potential threat of leakage of sediments, pathogens, sewage, waste water or hydrocarbons/chemicals, or other contaminants into the ground. The present study aims to investigate the effects of laying a hydrocarbon pipeline on the soil quality thereby its productivity in two different regions of Gujarat state (Gandhinagar, Bharuch) India. The post-employment effects of pipeline laying on soil quality and productivity were evaluated

A. Sircar · M. A. Shabiimam · N. Bist (✉) · K. Yadav · R. Singh
Pandit Deendayal Energy University, Gandhinagar, India
e-mail: namrata.bist@spt.pdpu.ac.in

A. Sircar
e-mail: anirbid.sircar@spt.pdpu.ac.in

M. A. Shabiimam
e-mail: shabiimam.ma@sot.pdpu.ac.in

K. Yadav
e-mail: kriti.yadav@spt.pdpu.ac.in

R. Singh
e-mail: roshni.singh@spt.pdpu.ac.in

A. Rasheed · S. Mehta · J. Shah · A. Patel
Gujarat Energy Research Management Institute, Gandhinagar, India
e-mail: abdul@germi.res.in

S. Mehta
e-mail: shaunak@germi.res.in

J. Shah
e-mail: jaini@germi.res.in

A. Patel
e-mail: ankita@germi.res.in

and the results were interpreted. The parameters for quality check of soil contamination due to pipeline laying included pH, electrical conductivity, organic matter content, available nitrogen, and heavy metal content. The results obtained suggested negligible degradation of soil quality by the underlying pipelines and provided positive results for utilization in several purposes including agriculture. The modelling and analysis of various parameters also supported the same.

Keywords Underground pipelines · Soil contamination · Soil quality · Soil productivity

1 Introduction

Natural gas has made its way into the domestic and commercial sectors as one of the most essential fuel sources for the mankind. Natural Gas Distribution or City Gas Distribution (CGD) is a developing business sector. Its objective is to give constant gas supply to domestic, commercial, and industrial consumers by means of Piped Natural Gas (PNG) and Compressed Natural Gas (CNG) (Kudaisya and Kar 2017). The city gas distribution consists of gas supply mains and service lines which are laid either underground or above ground. Generally, it is designed as a loop system, and pressure is maintained throughout the system to provide a constant gas supply (Sircar et al. 2017). Human interferences like laying of pipelines can have long-term effect on the landscape as well as the soil quality of the surrounding area. Some reports in literature suggested harmful effects of pipeline system on soil that included lower plant growth rate and less vegetation (Khasanova et al. 2017; Ryabukhina et al. 2017; Mayskiy et al. 2017; Zhang et al. 2019). Since, these can lead to reduced stability and productivity as well as soil deterioration and quality degradation. Hence, it is essential to carry out constant monitoring and evaluation of the changes of biotic and abiotic elements of the landscape due to external impacts (Halmová et al. 2017). In Gujarat, India, the genesis of soil is controlled by various macro and microclimates, topography, terrene, geology, and flora. At a given point of time and in a given area, soil characteristics are widely dependent upon natural influences and human activities. The types of soil found in Gujarat are black soil which is the leading soil type (Jangir et al. 2018, 2020; Sharma et al. 2019). Lateritic soil which is good for forests and vegetation (Zinzala et al. 2018). Alluvial soil which are low in nutrient content (Dadhich et al. 2018; Thokchom et al. 2017; Gohel and Singh 2018). Hill soil in the mountain areas with low productivity and desert soil with little or no vegetation (Shinde et al. 2020; Siddiqui and Fatima 2017). The presence of a gas pipelines can cause modifications in the soil content that can affect the flora and fauna of the surrounding (Halmová and Feher 2014). Therefore, there is a need for detailed investigation on the effect on physio-chemical factors of soil like pH, conductivity, organic nutrients, and heavy metals content by the laid underground pipelines.

The present study describes the effect of laid pipelines on soil quality and productivity in samples collected from two different regions of Gujarat, India, namely

Gandhinagar and Bharuch. The detailed analysis of soil quality was carried out using parameters such as pH, electrical conductivity (EC), organic matter content, heavy metals content, and nitrogen content in the affected samples. These results and analysis would suggest the long-term impact of pipeline networking on the vegetation, growth, and ecology of the biosphere as a whole.

2 Methodology

2.1 Sampling

The samples were collected from two regions including Gandhinagar and Bharuch. 5 samples were collected from Kalol region of Gandhinagar and 12 samples were collected from Bharuch region including onsite as well as offsite of the pipeline.

The location of soil samples was identified using Gujarat State Petronet Limited (GSPL) pipeline network map (Fig. 1). The locations were recorded in a Global Positioning System (GPS) unit for tracking, where samples had been collected. At the sample location, crop residue was removed from the soil surface. The soil probe was placed into the soil to the desired depth of around 1 m. The probe was placed vertically into the soil and it was not tilted to the side. The same process was followed at the new location. Between the two consecutive samples, 10 km of distance was kept. To obtain a homogeneous mixture, the soil was mixed thoroughly in the bucket with a trowel and placed in sample bag. After collection, the samples were stored in a refrigerator to reduce the chances of mould forming in the sample bag.

2.2 Parameters for Soil Quality Analysis

There are several parameters that suggest the nature, composition, and quality of soil responsible for their fertility and productivity. The parameters along with their procedures are discussed in detail.

2.3 pH

Electrometric method was applied for pH analysis using digital pH metre. The collected soil samples were dried, crushed, and separated from other impurities. Then, an aqueous suspension of soil was made and stirred for 1 h. After calibration, pH reading was taken and noted down.

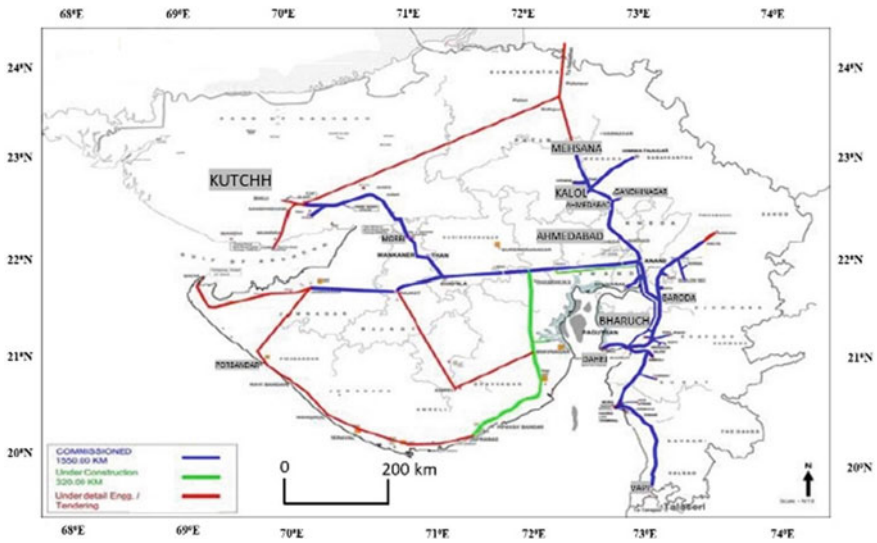


Fig. 1 Map of a gas pipeline network of Gujarat State Petronet Limited (GSPL) (<https://www.gidb.org/gas-pipeline-infrastructure>)

2.4 Electrical Conductivity

Argentometric method was performed for finding the chloride content using Standard Potassium Chloride Solution. 20 g of soil and 40 mL of distilled water (1:2) were transferred into a 100 mL beaker at $25\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$. The beaker was closed and placed in a horizontal position in the shaking machine and shaken for 30 min. The electrical conductivity of each sample was measured.

2.5 Organic Matter

After pre-treatment, a measured amount of soil sample was kept in a flask, 10 ml of 1 N potassium dichromate was added and the flask was spun lightly to dissolve the soil in the dichromate solution. Then, 20 ml concentrated H_2SO_4 (having 1.25% Ag_2SO_4) was poured into the flask and spun. After that, 200 ml of distilled water and 10 ml of orthophosphoric acid were added to obtain a precise point of the titration. Then 1 ml of diphenylamine indicator was added, and contents were titrated with ferrous sulphate solution until the colour was changed from blue-violet to green.

2.6 Available Nitrogen

50 g of wet soil was taken into the flask and 250 mL of acidified KCL was added and shaken for 1 h. After filtration, 2–4 g of magnesium oxide was added to the filtrate. 20 mL of 2% boric acid indicator solution was used. After distillation, 40 to 45 ml of distillate was collected in around 30 min. In the end, ammonia was titrated against 0.02 N H₂SO₄, and a blank correction was made for the final calculation.

2.7 Heavy Metals

Heavy metals like zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) were analysed by using Atomic Absorption Spectrophotometer (AAS). All samples were pre-treated using the microwave digestion method.

3 Results and Discussion

3.1 Soil Quality Analysis of Samples of Gandhinagar

3.1.1 Effect on Soil pH

The pH of soil samples collected from the Kalol region of Gandhinagar ranges from 8.5 to 9.5 which indicates that soil is alkaline. The hardness of groundwater needs treatment and remediation for application of water reservoirs of the region is required. The variable pH range in the samples was shown in Fig. 2c.

3.2 Effect on Soil Conductivity

The EC of soil samples varies from 0.06 to 0.18 mS/cm. This range of EC suggests that the soil is not saline in nature (Karlikar and Solanki 2014). The low salinity would be the result of low chloride content in soil samples. The conductivity of different samples is shown in Fig. 2d.

3.3 Effect on Soil Organic Content

Soil organic matter can affect two important characteristics of soil: (i) plant available water capacity and (ii) plant available vital nutrients, particularly nitrogen. Organic

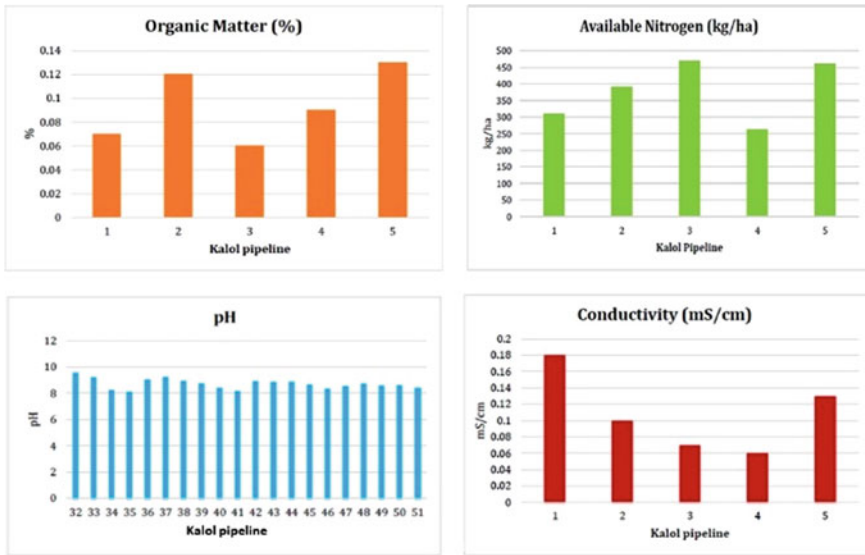


Fig. 2 a Organic matter of soil sample collected from Kalol region of Gandhinagar; b available nitrogen of soil sample collected from Kalol region of Gandhinagar; c pH of soil sample collected from Kalol region of Gandhinagar d conductivity of soil sample collected from Kalol region of Gandhinagar

matter content is also very less (0.06–0.13%). The organic content in the samples collected from different regions of Gandhinagar was shown in Fig. 2a.

3.4 Effect on Soil Nitrogen

Available Nitrogen in different soil samples of Kalol area ranges from 263 to 470 kg/ha suggesting moderate concentration of nitrogen in the soil. Nitrogen is one of the most essential soil components for plant growth since it forms a part of chlorophyll which in turn is involved in photosynthesis. Therefore, the results of the study reveals that the growth of the plants due to nitrogenous content in these areas remain unaffected by the pipeline looping. The samples nitrogen concentration is shown in Fig. 2b.

3.5 Effect on Heavy Metal Content

The soil of the Kalol region contains a low concentration of available phosphorus (14–19 kg/ha) and available potassium (7.89–18.83 ppm). The low concentration

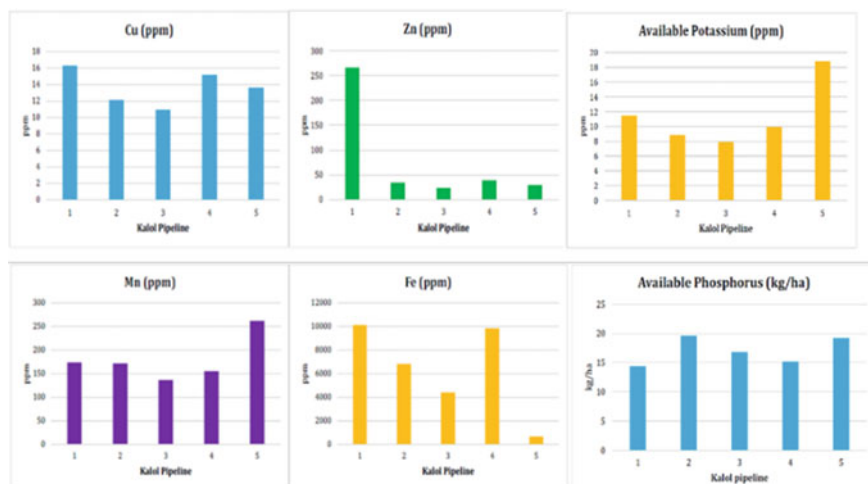


Fig. 3 Heavy metal content in soil samples of Kalol region of Gandhinagar

of phosphorus and potassium might be because of the temperature of gas passing through the gas distribution pipeline. For the reproductive development and consumption of proteins, copper (Cu) is significant (Karlikar and Solanki 2014). The copper content in soil samples collected from Kalol region of Gandhinagar is very high (10.91–16.29 ppm). The manganese concentration in the soil varies from 135.6 to 261.7 ppm, and it might be attributed to the corrosion of the pipeline (Miao and Wang 2016). Zinc is important for transportation of carbohydrates and also for the controlled utilization of sugars. Zn concentration in the soil of the Kalol region of Gandhinagar is 23.31–266.5 ppm which is quite high (Karlikar and Solanki 2014). The chemical composition of corrosion products on API steel pipeline liberates 56.06 wt% iron in the soil samples, Fe content is 644.4–10,090 ppm, i.e. 0.064–1.009 wt%. This high value indicates the effect of mild corrosion (Miao and Wang 2016). The heavy metal content of samples in Kalol region is shown in Fig. 3.

3.6 Soil Quality Analysis of Samples of Bharuch

3.6.1 Effect on Soil pH

The pH of soil samples collected from Bharuch region ranges from 8.0 to 8.9 which indicates soil alkalinity and hardness (Fig. 4a). The study suggested the scope of fresh water loggings which can be applicable for various purposes after treatment.

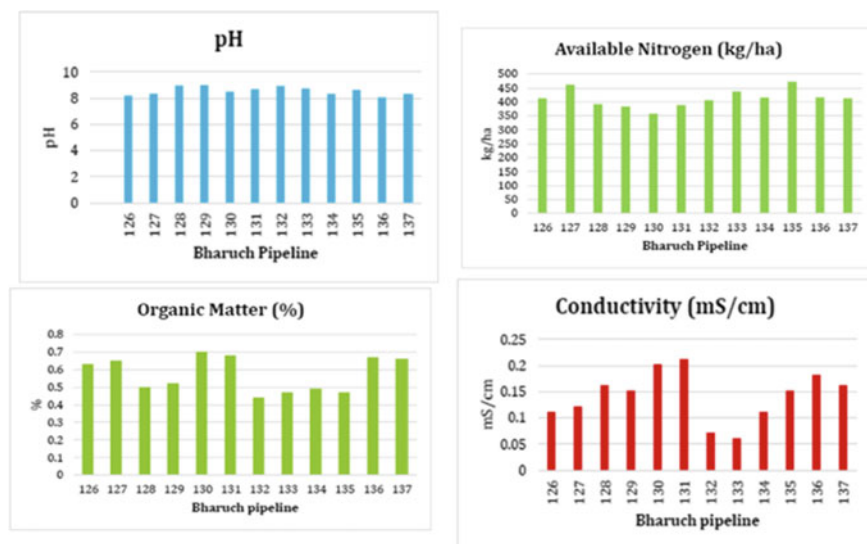


Fig. 4 **a** pH of soil sample collected from Bharuch region; **b** available nitrogen of soil sample collected from Bharuch region; **c** organic matter of soil sample collected from Bharuch-A region; **d** conductivity of soil sample collected from Bharuch region

3.7 Effect on Soil Conductivity

The EC of soil in Bharuch region varies from 0.06 to 0.21 mS/cm which is very less than the permissible limit (4 mS/cm) and hence salinity of soil in these areas is very low (Fig. 4d).

3.8 Effect on Soil Organic Content

In the soil samples collected from Bharuch area, organic matter concentration varies from 0.44 to 0.68% (Fig. 4c). This indicates low storage capacity of soil for essential nutrients and less retention potential for toxic elements. Hence, the area under study needs enrichment in organic content for better growth and productivity.

3.9 Effect on Heavy Metal Content

The concentration of the toxic heavy metals like Cd, Hg, As, etc., found to be negligible in the soil samples of Bharuch region indicating low toxicity level and proper

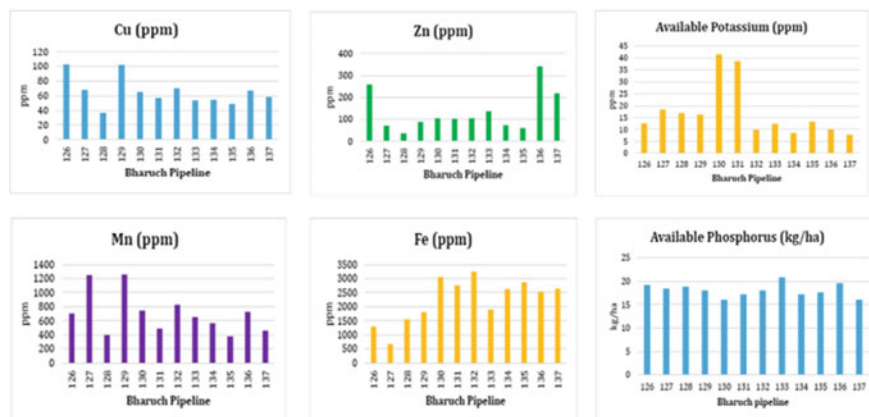


Fig. 5 Heavy metal content in soil samples of Bharuch region

growth. The other heavy metals like phosphorus content is 7.74–41.5 kg/ha, potassium content is 16–20.8 ppm, Cu and Zn contents are 36.32–102.7 ppm, and 36.25–339.8 ppm, respectively. Zinc is the component of the enzyme systems which control plant growth. Cu, K, and P are also important substitutes for growth and development of plants. These ranges suggest suitable plant growth with optimum metallic concentration in the soil samples with negligible effect of pipeline laying.

In case of Mn and Fe, the concentration is 375.2–1257 ppm and 669.7–3237 ppm, respectively. Their higher concentration suggests possible corrosion of underlying gaseous pipelines. The heavy metal content of various samples was shown in Fig. 5.

4 Conclusion

The present study summarizes the effect on physio-chemical parameters of soil samples collected from two different regions of Gujarat by the underlying pipeline channels. The higher pH ranges from 8.5 to 9.3 in samples of Gandhinagar region suggest alkaline nature and hardness in the groundwater of that area. The salinity of most of the soil samples is found to be low which could be related to low chloride concentration and hence feasible for vegetation.

Heavy metals like Cu, Zn, Mn, and Fe vary widely for all regions. The concentration of some of the most toxic heavy metals like Hg, As, Cd, etc., was found negligible which is a positive aspect of water resource exploration for that area. In all regions, the concentrations of available nitrogen, phosphorus, and potassium are moderate and sufficient enough as required. The availability of high nutrients increases the uptake quality and productivity of plants. The soil analysis has provided positive results for the utilization in agricultural purposes as soil productivity and nutrients are not

affected after laying of pipelines. The modelling and analysis of various parameters indicates positive results for the vegetation and agricultural use post pipeline laying.

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References

- Dadhich G, Patel PR, Kaluberne MH (2018) Farm level land suitability assessment for wheat and mustard crops using geomatics: a case study of Badipur village in Patan district, Gujarat. *Technol Driv Eng Growth* 93–98
- Gohel SD, Singh SP (2018) Molecular phylogeny and diversity of the salt-tolerant alkaliphilic actinobacteria inhabiting coastal Gujarat, India. *Geomicrobiol J* 35:775–789. <https://doi.org/10.1080/01490451.2018.1471107>
- Halmová D, Poláková Z, Končerková L, Fehér A (2017) Impact of operating temperature of gas transit pipeline on soil quality and production potential of crops. *Agric Pol'nohospodárstvo* 63:120–127. <https://doi.org/10.1515/agri-2017-0012>
- Halmová D, Feher A (2014) Effect of transit gas pipeline temperature on the production potential of agricultural soils. *J Centr Europ Agric* 15. <https://doi.org/10.5513/JCEA01/15.3.1481>
<https://www.gidb.org/gas-pipeline-infrastructure>
- Jangir A, Tiwari G, Sharma RP, Dash B, Paul R, Vasu D, Malav LC, Tiwari P, Chandran P (2020) Characterization, classification and evaluation of soils of Kamrej taluka in Surat district, Gujarat for sustainable land use planning. *J Soil Water Conserv* 19:347–355. <https://doi.org/10.5958/2455-7145.2020.00046.6>
- Jangir A, Sharma RP, Tiwari G, Dash B, Naitam RK, Malav LC, Narse R, Gautam N, Bhure S, Chandran P, Singh SK (2018) Characterization and classification of soils of Bharuch taluka in Bharuch district of Gujarat
- Karlikar BH, Solanki HA (2014) Estimation of micronutrients and physico-chemical analysis of soils of Gandhinagar district, Gujarat, India. *Life Sci Leaflets* 48:49–54
- Khasanova R, Suyundukov J, Semenova I (2017) Evaluation of the ecological state of soils in the steppe agro-ecosystems indicators of biological activity. *Bull Nizhnevartovsk State Univ* 1:103–108
- Kudaisya SK, Kar SK (2017) A comprehensive review of city gas distribution in India. *Nat Gas Mark India* 113–165. https://doi.org/10.1007/978-981-10-3118-2_7
- Mayskiy R, Ryabukhina M, Dodova M (2017) Ecological and economic modeling of the insects elimination effectiveness in the coniferous forests of the Orenburg region. *Vestnik Bashkir State Agrarian Univ* 1:101–103
- Miao J, Wang Q (2016) Corrosion rate of API 5L Gr. X60 multipurpose steel pipeline under combined effect of water and crude oil. *Met Mater Int* 22:797–809. <https://doi.org/10.1007/s12540-016-6175-6>
- Ryabukhina MV, Maiski RA, Salikhova RH (2017) Environmental risks of landscape botanical complexes and minimization of technogenic influence exerted by objects of oil & gas production in steppe zone of the Southern Urals. *IOP Conf Ser Mater Sci Eng* 262:012167. <https://doi.org/10.1088/1757-899X/262/1/012167>
- Sharma RP, Singh RS, Naitam RK, Singh SK (2019) Technique of large scale soil mapping using remote sensing satellite data in basaltic terrain of Peninsular region in the north-west Gujarat, India. *J Indian Soc Soil Sci* 67:151–159. 10.5958/10974-0228.2019.00016.1

- Shinde V, Singh M, Nandgude S, Bharti B (2020) Modeling the effect of conservation measures on potential soil erosion: a USLE and GIS approach. *Curr Sci* 119:00113891
- Siddiqui SA, Fatima N (2017) Indian soils: identification and classification. *Earth Sci India* 10:1–14
- Sircar A, Sahajpal S, Yadav K (2017) Challenges and issues in natural gas distribution industry. *STM J* 7:1–8
- Thokchom S, Rastogi BK, Dogra NN, Pancholi V (2017) Geotechnical investigations in the southern part of Ahmedabad district, Gujarat, India. *J Ind Geophys Union* 21:105–115
- Zhang P, Qin G, Wang Y (2019) Risk assessment system for oil and gas pipelines laid in one ditch based on quantitative risk analysis. *Energies* 12:981. <https://doi.org/10.3390/en12060981>
- Zinzala VJ, Patel AR, Saini LK (2018) Effect of sulphur and boron on growth, yield and economics of summer groundnut in clay loam soil of Dang district. *Trends Biosci* 11:919–922