Comprehensive study on the detrimental effects of fossil fuel exploration and pipe laying in deltaic region

L Sandeep Khanna*, K Ramnath, J Monica, D Muthu and C Venkatasubramanian
School of Civil Engineering, SASTRA University, Thanjavur-613 401. India.

*E-mail: sandeep.star96@gmail.com

Abstract. Thanjavur is the “Granary of South India”. As the prosperous capital of Chola kingdom it was praised as “Chola Naadu Sorudaithu” (the land that had abundant food). Now, due to Cauvery water shortage issues, the farmers had to be content with single crop a year. Adding to the woes are urbanization and development programs which lack foresight or long term plans that exploit natural resources without a well-articulated thought process. Presently the net sown area in the deltaic region is about 11.87 lac hectares. In the guise of national interests, there is a pursuit of these regions by agencies- public sector undertakings with vested interests. The oil exploration in Cauvery basin (Narimanam block) by Public Sector Undertakings, estimated lignite reserves of 36000 million tonnes and gas reserves and 104.7 billion cubic metres (CBM Coal Gas Methane), which has placed the deltaic region in the corporate radar. Environmentalists and legislators have also turned a blind eye towards the detrimental aftermaths upon the execution of crude product explorations on our cultivable lands.

1. Introduction
The Geological Survey of India has identified fossil fuel reserves in the deltaic region. The government has hence commissioned agencies to extract these resources, impacting green fields and cultivable areas, food production and livelihood. Few of the factors that makes Tamil Nadu the focus region is the confirmed availability of large reserves of fossil fuels, cost benefit, high feasibility as the exploration is on shore compared to the difficult mountainous terrains (Assam) or offshore explorations (Mumbai) are high and favourable success rates. This project is vigorously pursued by the government due to national interests, soaring energy needs, demand for self-reliance, economic development and the need to utilize the indigenous resources.

2. Methodology
The source of information for this study were obtained from the existing data by government agencies Indian Meteorology Department and Directorate General of Hydrocarbons and also from direct site visits and laboratory tests. To study the effects of pipe laying, the undergoing project at Thirumakottai has been chosen was studied. Soil samples from the site were collected for this purpose. To study the effects of fossil fuel explorations, the abandoned drilling site at Thiruvanduthurai was studied. The residents of that village were interviewed. The groundwater samples were collected and laboratory
tests were conducted and studied for the change in basic parameters.

3. Overview of E&P companies in India
The Petroleum ministry of India has assigned two agencies for these projects- ONGC, the public-sector undertaking formed in 1956 whose core business is oil and gas exploration and extraction and GAIL, a public-sector undertaking formed in 1984 whose core business is gas transmission and marketing.

It started its exploration activities in Cauvery basin in 1965 to investigate the presence of oil and gas reserves. The first well was discovered in 1977 at Karaikal after which 50 unsuccessful wells were drilled. In 1985 oil discoveries were made in Kovilkalapal and Narimanam. Presently there are 200 oil and gas producing wells which provide 39 LCMD gas.

![Geological map of Cauvery basin](image)

Figure 1. Geological map of Cauvery basin

4. Case study of pipelining site
Place : Thirumakottai
Route : Thirumakottai TNEB Power Plant to Nallur GAIL Gas plant
Object of this scheme : Providing gas for electricity generation.
Mode : Laying a gas pipeline near to the existing pipeline laid in 2002
Pipe Dimensions : Clear length 40 ft, dia-1 foot (0.3048 m), length provided for welding- 0.5 foot, Total length of the pipe 41ft (12.49 m) length
Weld specifications : Fillet weld, after welding the 1 foot width provided is covered with a epoxy resin and is then laid.
Pit dimensions : Width: 5ft, Depth: 7ft pipe laid at 5ft from the top.
Details:
- A compensation of 10 to 40% of the land value as a one-time payment
- For the further digging or inspection only crop compensation is provided
- 13m width of land is acquired from the owner and only about few feet of land is actually used
- The digging and the closing of the pit will make the lower layer of the soil to lifted up to ground level which is saline which affects the fertility
- The improper compaction while closing the pit will lead to settling of land due to inundation or irrigation
- Trees cannot be grown near the pipeline as the roots spread out and affects the pipeline

5. Case study for exploration drilling

Place: Thiruvanduthurai
Location: Latitude: 10.650305° N, Longitude: 79.545655° E

Testimony: “To access the drilling site roads were laid through the agricultural land. The road itself caused extensive damage. Now the site is not under use. In Sendhamangalam also there was a similar site which is also not feasible. The hard rock a stratum under the ground has been shattered like glass for the exploration and the groundwater levels has gone down. Before this project groundwater level was at 30ft now the level has gone down below 80 ft and has become saline. More than these abandoned sites, the flaring in the sites are more dangerous and reduce rainfall. In Narimanam, Vellakudi and few other places there are active flaring sites. When they drill, the vibrations of the ground can be felt for few kilometers. Earlier per acre the farmers used to use only half a bag of Urea and one bag of Triphosphate, but now even after using advanced fertilisers they cannot have a good yield”.

Figure 2a. Pipes before laying
Figure 2b. Laid pipes at Thirumakottai
6. Detrimental effects
6.1. Change in rainfall pattern
The graph below is the plot between annual rainfall for the past 50 years[1]. The rainfall pattern between Thiruvarur and Thoothukudi is compared as both are in geographical proximity but Thiruvarur has considerable petrochemical exploration infrastructure whereas Thoothukudi has less or negligible petrochemical operations. The exploration and extraction process involves burning of residual gases from the well, known as flaring. The flaring operations emit considerable amounts of CO₂ and other greenhouse gases which has changed the climatic pattern, resulting in reduction in annual rainfall gradually. The exploration in Kaveri region was started in 1959 and has eventually increased to a current production of 176 MMCD. Due to flaring, rainfall in Thiruvarur district which was relatively higher than Thoothukudi district has fallen over the past decades. The difference in precipitation between Thoothukudi district and Thiruvarur district was plotted against number of years for five years since production. The plot showed that the precipitation in Thiruvarur has significantly reduced compared to Thoothukudi. Thoothukudi was chosen because it had similar climatic condition but with no exploration activities nearby. The reduction in difference shows that earlier Thiruvarur had higher precipitation when compared to Thoothukudi and has been reducing eventually.

![Graph showing the fall of annual precipitation in Thiruvarur over the years](image.png)

**Figure 3.** Fall of annual precipitation in Thiruvarur over the years
6.2. Soil fertility change due to oil exploration

When a drilling operation is not feasible the land is returned to the farmers. But the drilling mud are not disposed properly and is buried in the site itself. The laboratory test of drilling mud sample contained 156mg/Kg of cadmium in it. Cadmium is a micronutrient which is harmful for both plants and humans when it exceeds permissible limits. 0.8mg/Kg is the safe limit of Cadmium in soil. The plants can’t tolerate excess Cadmium in the soil and the yield becomes very poor[2]. This was visibly observed at the site of study.

6.2.1 Test results from Thirumakottai

| pH  | Salt | CaCO₂ | K  | P  | N   | SOIL |
|-----|------|-------|----|----|-----|------|
| 9.3 | 0.16 | No    | 55 | 40 | 72.4 | U1   |
| 8.4 | 0.15 | No    | 100| 30 | 78.8 | U2   |
| 9.4 | 0.32 | Yes   | 170| 5  | 40.4 | D1   |
| 9.4 | 0.19 | Yes   | 110| 5  | 40.4 | D2   |

(Tested at Rice Research Institute, Aaduthurai)

LEGEND:
U1 Soil specimen at ground level
U2 soil specimen at ground level
D1 soil specimen at a depth of 7m
D2 soil specimen at a depth of 7m
NPK in units of kilo/acre.

![Figure 4](image-url). Difference of annual precipitation between Thoothukudi and Thiruvan in mm plotted against years since beginning of operation.
Dissolved salts expressed as electrical conductivity, in units of dSm\(^{-1}\)

**Figure 5a.** Variation of NPK content

**Figure 5b.** Variation of NPK content

6.2.2 Inference from NPK test.
The NPK test result show that the Nitrogen and Phosphorus content of the soil is higher at the ground level than in the excavated part. Due to the excavation process the soil is overturned and the soil in the depth reaches the surface and the fertile soil gets buried. Nitrogen and Phosphorous content of soil is due to the presence of organic matter whereas the Potassium content is the intrinsic characteristic of the soil. So the Nitrogen and Phosphorous content of the topsoil is higher than the disturbed soil. This needs to be compensated with additional manure which further adds to the woes of the farmers

6.3. Improper land use
The success rates of exploratory drills is about 1/3rd. Out of 600 wells drilled, only 200 were successful and of these only 74 were active. Abandoned wells are not fully or properly restored to resume agriculture activities. Improper restoration is done without gravel red soil and pebbles. After drilling, the utility area is only 10% with 90% left unrecovered for social or environmental activities. 1 well requires 5 acres of land. Nearly 15 lac acres of cultivable land is lost in 25 years. Colossal loss of livelihood results from crop production loss per season.

6.4. Water quality deterioration
Drinking water scarcity is another social problem. Depletion of ground water table even at a depth of 1500 feet is reported, as a result of exploration. Contamination due to chemicals released while drilling (Cadmium, Mercury, Polycyclic aromatic hydrocarbon, Lead etc.) degrades groundwater quality as drilling involves use of various chemical admixtures and also the drilling wastes contains many hydrocarbons and radioactive metals[3].

6.5. Pollution and health hazards
6.5.1. Flaring effects. A waste gas flare affects the plant growth in the surrounding region. In a study conducted in Nigeria on Yam plantation the plant growth were suppressed with the proximity to the flaring site and the plant size increased with distance from the site. It is also observed that the nutritional value of the plants was altered due to factors like emission and change in temperature. The sugar and the protein content of the plant showed a significant change with proximity to the flaring site[4]. Flaring and other exploration activity has a negative impact on the net yield of the crops, i.e the produce per unit area of cultivable land [5] (Canice Sonny, 2014).
Water and air pollution take a toll on people’s health. Compressor station discharges organic chemicals into air which includes formaldehyde, benzene, nitrogen oxide and butane/propane which are toxic in nature. Health impacts of compressor station include hearing impairment, visual impairment, respiratory system impacts, headaches, decreased motor skills, irregular pulse, epidermal problems, dizziness and allergic reactions. Acute and chronic diseases include lungs, kidney and liver ailments.

6.5.2. Cancer.
Experimental results shows that the contact of crude oil with the skin of mice causes skin tumours[6]. Experimental studies shows that Volatile Organic Compounds (VOC) increases the chance of leukaemia and Polyaromatic Hydrocarbons (PAH) having carcinogenic effects on the labours working in petroleum industries. Benzene which is a VOC, is responsible for leukaemia[7].

Studies conducted in China show a high chance of leukaemia among oil field workers and studies across the world shows varied results, such as one study among petroleum and natural gas workers shows excess risk of testicular cancer in men[8].

Studies conducted in San Carlos, a village in north-eastern Ecuador reveals that water contamination due to oil extraction wells around the village causes cancer in various parts of body which has been increasing gradually[9].

6.6. Induced seismicity
Apart from crude oil, there are proven reserves of Coal-Bed Methane in the Cauvery Delta Region. The extraction of Coal-Bed Methane involves injecting water along with propellants and chemical admixtures at high pressure into the coal bed below the rock layers. The high-pressure fluid fractures the rock formation and forces the Coal Bed Methane from the ground. The pumped water deteriorates the soil pressure and the stress in the rock layers. The used waste water is again pumped into the deep sedimentary layers as it is very expensive to treat and dispose the contaminated water. The artificial change of rock stresses resulting from CBM is similar to the rock stresses induced from large
reservoirs.

The seismicity induced by reservoirs have been studied for a really long time and concluded to cause an increase in seismicity. Deep well injections have been directly linked with the increase in seismicity in Youngstown, Ohio [10] (Won-Young Kim, 2013). From the above seismic map of peninsular India it is clearly evident that there are four minor faults and three major faults in the Cauvery Delta Region. The risks of earthquake and related seismicity in the region are low as the region comes under zone- II of seismic risk (IS 1893, 2002). In the event of CBM extraction the stress variation in the faults may lead to induced seismicity in the region.

**Figure 7.** Major evolutionary units and associated tectonic features in the peninsular shield of India

7. Suggestions

- The pipeline can be laid on sides of the roads, causing only minimum disturbance to cultivable lands.
- The excavated soil should be properly refilled and compacted to retain the fertility of the soil such that the crop yield potential can be retained.
- Drilling mud should be properly disposed by reusing methodology.
- All excavation should be carried out during day time only to prevent or to decrease the impact of any accidents, either manually or mechanically.
- Refilling and consolidation of earth should be carried out during non-cropping season only.
- The farmers must be educated about the seriousness and safeness of the project.
● Safety and precautionary measures should be taught to the people of nearby community.
● Booklet, films, lectures, poster and discussions should be given through continuous education program.

8. Conclusion and Recommendations

It is acclaimed that these projects upon successful completion would supply clean and cheap fuel for industries in a faster and a safer manner than distribution by rail/road which requires extensive infrastructure and additional receiving facilities. Certainly, the secondary sector stands to benefit. However, the negative aspects outweigh the advantages claimed by proponents. Pipeline failures, accidents, spills and explosions can lead to property damage, loss of life and also impact health and habitat. continued excavation leads to further loss of fertility. Large amount of soil disturbance paves way to erosion and sedimentation, particularly in steeper regions and around water bodies. Rights of way on either side of pipeline for maintenance (cleared habitat) and fragmentation (of large areas into smaller ones) results in loss of habitat and adversely affects species movement.

Apart from health, safety and environmental concerns, there are valid apprehensions about the livelihood of present and future generations. It is a well-known fact that primary sector provides social security for the Indian majority. No compensation can ever make up for the loss of source of income or heal the pain of holding a condemned property by farmers. Primary sector is our lifeline, essential for our sustenance and self-reliance. Ironically the world’s largest solar power plant at Kamuthi (678 MW capacity) is in the same state. Given the abundant solar potential and wind potential, other forms of clean energy can be explored rather than investing in the Petroleum industry.

References

[1] Records of rainfall data http://www.indiawaterportal.org/met_data/
[2] Piotrowska M and Dudka S 1994 Estimation of maximum permissible levels of cadmium in a light soil by using cereal plants. Water, Air and Soil Pollution 73(1) 179-88.
[3] Asia I O, Jegede S I, Jegede D A, Ize-Iyamu O K and Akpasubi E 2007 The effects of petroleum exploration and production operations on the heavy metals contents of soil and groundwater in the Niger Delta Int. J. Physic. Sci. 2(10) 271-75.
[4] Lawanson A O, Lmevbore A M A and Fanimokun V O, The Effects of Waste-Gas Flares on the Surrounding Cassava Plantations in the Niger Delta Regions of Nigeria. 6th Symposium Proc. 41(3) 239-45. http://www.istrc.org/images/Documents/Symposiums/Sixth/6th_symposium_proceedings_0041_section_3_239.pdf
[5] Canice S N and Sonny A N 2014 Resource Productivity under Yam Based crop Mixture in crude and non-crude oil Producing communities of Imo State, Nigeria. Agricultura tropica et subtropica 47(1) 20-8.
[6] Wilson J S and Holland L M 1988 Periodic response difference in mouse epidermis chronically exposed to crude-oils or BaP: males vs females. Toxicology 50(1) 83–94.
[7] Austin H, Delzell E and Cole P 1988 Benzene and leukaemia: a review of the literature and a risk assessment Am. J. Epidemiol. 127(3) 419–39.
[8] Mills P K, Newell G R and Johnson D E 1984 Testicular cancer associated with employment in agriculture and oil and natural gas extraction. Lancet 28(1) 207–10.
[9] San S, Armstrong B, Córdoba J and Stephens C 2001 Exposures and cancer incidence near oil fields in the Amazon basin of Ecuador. Occup. Environ. Med. 58(8) 517-22.
[10] Kim W Y 2013 Induced seismicity associated with fluid injection into a deep well in Youngstown, Ohio. J. Geophy. Res.Sol. Ea. 118(7) 3506–18.