Mid Term Evaluation of Soil Piping in Highland and Foothills of Kerala to avoid Disaster

February

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DRAFT REPORT

Indian Institute of Public Administration

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Project Title:	Mid Term Evaluation of Soil Piping in Highland and Foothills of Kerala to avoid Disaster	
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IIPA Project Team

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Acknowledgement

The project entitled **"Mid Term Evaluation of Soil Piping in Highland and Foothills of Kerala to avoid Disaster"** was successful due to assistance received and time devoted by many prestigious personalities. Words are inadequate to convey the appreciation for all the help provided.

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List of Abbreviations

Abbreviation	Full Form
NCESS	National Centre for Earth Science Studies
NDMA	National Disaster Management Authority
SEOC	State Emergency Operations Centre
HVRA	Hazard Vulnerability and Risk Assessment
AWS	Automatic Weather Station
SDMA	State Disaster Management Authority
IIPA	Indian Institute of Public Administration

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Executive Summary

Kerala is a multi- hazard prone state. Floods, drought, landslides and man-made disasters are common in the state. Coastal erosion is recognized as a major hazard .Even though lightning is not recognized as a hazard, it takes an average toll of about 80 lives in Kerala. Landslides frequent the highlands during monsoon. Land- subsidence, first noticed in 2005 in the Thirumeni village near Cherupuzha, Kannur. Subsequent surveys reveal that the entire village is affected by the phenomenon. The underground cavities are being developed beneath busy roads (Tattekanni, Peringassery in the Idukki district) near to dams (Banasurasagar, Wayanad), houses (Udayagiri,

Thirumeni in Kannur). Out of the 14 districts 11 are affected by this process. In Wayanad and Ernakulam districts landslides were induced by this phenomenon. Apart from Pathanamthitta, gaping sub surface tunnels have been discovered at many locations in Kannur, Idukki, Thrissur, Wayanad, and Kozhikode districts.

According to the experts, during piping, large quantities of sand and clay beneath the surface get carried away by water, resulting in the formation of tunnel-like, structures. The process usually goes unnoticed as far as it is restricted to the sub-surface but pits appear when the surface becomes unable to bear the burden of the hollowness beneath caused by erosion. The sub-surface erosion as in piping, has an abundant content of loose pumice, volcanic ash and such materials. The Idukki hydel project reservoir alone stores more than 80 percent of the water held by all artificial reservoirs in the State. Piping is always a huge concern when it happens near huge dams according to the geologists.

One of the major threats that piping poses is that the vertical pits could widen leading to more earth cave-ins but scientists say that there is no pragmatic method to arrest the process.

Understanding the seriousness of the problem the Department of Revenue and disaster management has requested NCESS, National Centre for Earth Science Studies to prepare a programme to study this phenomenon. The NDMA, National Disaster management Authority was approached for funding and it was granted. Centre for Earth Science Studies (CESS), Trivandrum and SEOC, State Emergency Operations Centre, HVRA Cell, Hazard Vulnerability and risk Assessment Department of Revenue and Disaster Management, Government of Kerala are the participating organizations. So far no serious effort was taken to study this phenomenon from a disaster point of view. The project was started in August 2012 and is of three years duration, likely to be completed in August, 2015.

The study had the broad objectives of documenting the area affected by tunnel erosion/ piping in Kerala which would be evolved into the mapping technique to determine the extent of the underground pipes using geophysical and geological methods. Determination of various physical and chemical processes taking place in affected area to find the causes of piping and to suggest the mitigation measures were another objective of the study.

The midterm evaluation conducted by IIPA, envisages to map the defined objectives with a definitive scientific tool and analytical study which is most used and the best available method to substantiate the same. Mapping the first objective, that is to document the areas affected by tunnel erosion/ piping in Kerala. This was substantiated with CESS, Revenue department and with available newspaper reports which have been contributory in inventorying the area affected by tunnel erosion. This has been done by CESS, and it has developed the map of the soil piped affected area.

The second objective is to evolve a mapping technique to determine the extent of the underground pipes using geophysical and geological methods. The extent of the underground subsurface pipes depends a lot on the chemical characteristics of the soil. Literature studies show that sodic clay soils are most vulnerable to piping. NCESS, collected soil samples from different depths and at different locations and subjected them to chemical analysis to check the chemical properties of the soil. The geophysical surveys were carried out by resistivity meter to check for the variation in electrical resistivity of the ground. Resistivity Imaging helps in delineating the transitional boundaries. NCESS exploits the Resistivity imaging which is the best technique to check the geophysics of the soil. The resistivity studies were used to determine the nature and extent of underground pipes.

The third objective is to determine various chemical processes taking place in affected area in order to understand causative factors of piping .The depth and extent of the subsurface tunnels was estimated by the research team by using Push cameras for visual investigation of tunnel branches. The chemical validation of the soil to investigate the causative factors was done subjective to pH, electrical conductivity, total dissolved solids, organic matter content, organic carbon, XRF and XRD. The investigation of hydrological and meteorological data of any site is a must to understand the causative factors of piping. The hydrological and meteorological data were collected by NCESS by installing V-Notch and Automatic weather stations.

The fourth objective being to suggest mitigation measures to minimize or arrest this process. This activity of on –site mitigation is being conducted by NCESS at different sites including Ranni Taluk and Wayanad Districts. The mitigation work is being conducted along with Public works Department and some local bodies.

IIPA study team adopted the methodology of on –site visit of the soil- piped affected area and the site where mitigation trials have taken. Collection of secondary data on the soil piped affected area. Discussion with the research team and the communities living in the soil piped affected area. IIPA team selected the sites of the soil piped affected area. The soil piped area selected for the site visit were diverse in nature and magnitude. The sites selected had diversified problems and the probable causes were different. The selected soil piped area had strategic locations and affected the vicinity to a large extent. The sites selected ranged from agricultural lands to residential plots where soil piped area has caused huge losses in terms of productivity and yield of the land. The land being a very precious resource in Kerala is under huge pressure. The subsequent locations were also of strategic importance as they were residential localities and the natives have invested their lifetime savings in construction of their houses. The other site with Banasursagar Dam, in the vicinity, was chosen especially to investigate and observe the changes that might have occurred in the earthen dam impounding water to the tune of 209 million m^3.

Located in the Kottathalachimala, near Cherupuzha, Kannur this pipe is old and matured. At present soil erosion is very low inside the tunnel. The geophysical experiments were conducted at this locality. The tunnel opening is seen at the place where subsidence has taken place. Presence of bats in the tunnel is indicative of the presence of oxygen in the tunnel.2D resistivity surveys were conducted across known sections to determine the type of survey method suitable for pipe discovery. Geophysical surveys indicated that this tunnel is 50m in length and branching at the end is indicated. The tunnel attains a max dimension of 3 meters height and 4meters width. The sections clearly indicate that the Saprolite section of the laterite is eroded producing huge tunnels. Chemical analysis of the soil samples indicated the presence of Gibbsite and exchangeable sodium which are responsible for the mobility of the clay. This gives the clue for chemical amelioration as a mitigation method.

Subsidence crater at Kottathalachimala occurred in 2013. This is a well like land subsidence occurred near a house. Pipes are observed at the bottom. The out flow pipe is found cutting across a house. The residents of this house are evacuated during high rains.

Soil piping was first detected in this locality Chattivayal , Chemparathi in 2005. A newly constructed house owned by Mrs. Lissy Francis was totally damaged and became unfit for dwelling. All wells in this locality do not yield even during high rains. This entire area in this locality including village roads are affected by underground piping.

A meteorological station is established in this building for this project at Thirumeni. This location is selected for uninterrupted power supply. The meteorological data is being collected using an AWS, Automatic weather station .This AWS was supplied by the SEOC, Government of Kerala. Discharge data is measured at an outlet using a V -notch constructed for this purpose

IIPA team visited a newly affected site in the Kasaragod district. This is one of the recent subsidence occurred in the State. The subsidence has occurred adjacent to the house under construction. On inspection it was noticed that the main road has also been affected and the area has more than one pipe. One pipe is seen passing near the house. The entire one acre of land is not fit for any type of construction.

The team visited Ayyankunnu locality near Iritty in the Kannur district. A classic example of pipes affecting the ground water regime of an area. Most of the wells in this locality are affected by the soil piping processes. The team visited the pipe formations of nearby localities.

Here huge underground tunnels are developed making the area unfit for any purposes.

The longest earth Dam in India is situated very closed to the earlier location. This dam is built using locally available earth. This study has indicated that the soil has exchangeable sodium and it is dispersive in nature. So this dam is prone to soil piping and careful examination is required. The team discussed this matter with the Senior Engineers and ADM, Wayanad.

IIPA recommends/suggests the following based on the discussions with the project team of NCESS, Kerala, meeting the concerned officers, seeing the research reports of NCESS and observations of the on- site visits.

The soil piping is spreading like cancer in the subsurface soil without showing up any symptoms in the early stages. The soil piped tunnels are noticed eventually after the collapse of the roof top of the tunnels. Soil piping may lead to several disasters which has already begin to show up viz. the increased frequency of the tremors with greater intensity on the Richter scale. The incidences of land subsidence also shows an upward trend. Several houses have developed deep cracks in due course of time. The ground water regime of the area is also being affected, as many wells in the area are reported to be non -yielding despite deep digging.

The NCESS, Trivandrum and SEOC, State Emergency Operations Centre, HVRA Cell, Hazard Vulnerability and risk Assessment Department of Revenue and Disaster Management, Government of Kerala have been very effective and meticulous in mapping the soil piped affected area. The organizations have procured several instruments and high end gadgets such as geophones, push camera which have proved to be instrumental in analyzing the soil profile and establishing connect between soil pipes.

NCESS has also working to evolve suitable mitigation strategies of the soil piped affected sites. Although it is clearly reflected that the mitigation practices adopted is not a straight jacketed approach and *one – size fits all* phenomenon does not applies as the nature , cause , and the magnitude of the tunnel erosion varies from case to case.

IIPA also observed that the research team has at NCESS has been able to garner rapport with the local population thus enabling them to project and implement mitigation strategies launched from a pilot stage to mass scale thus strengthening the over- all effort which would help in averting the overarching disasters. The technical expertise along with the local support would also be instrumental in generating mass sensitization amongst the masses so as to sensitize them against the disasters which might stem from the soil pipes. This envisages to strengthen the disaster risk reduction.

The fortune of the local stakeholders is riding on high risk factors as they have invested their life time savings in these soil piped affected area. They are sitting on virtual ticking time bombs that might explode any instant taking heavy toll on life and property. Thus IIPA strongly recommends that soil –piping must be included in the list of disasters so that state may think for providing suitable/adequate compensation to the affected community.

As this scientific project is being studied by a research team, timely instalments of project will facilitate the smooth functioning of the project.

Looking at the nuances in the soil piped affected area it is also recommended that the study period may also be extended (no cost extension), if demanded by NCESS till March 2016. This will not have any additional financial implications on NDMA. The extension might facilitate the research team in coming up with concrete results and mitigation strategies using different concepts such as slope stabilization and using fly ash as a filler material in the land subsidence.

1. Introduction

1.1 Background and Context

A soil pipe is a large pore that is eroded internally. It is continuously sculptured by water. Just as river banks are shaped and eroded by the river itself, soil pipes underground are shaped and sculpted by the water that runs through them. Dispersive soils, those that are easily eroded, are ideal for soil pipe formation since water traveling through such soil can detach particles with little effort. The water-sculptured pathways can be initiated and formed through a variety of mechanisms. Water itself can initiate a soil pipe in some soils. It has also been seen that as plants die or trees get uprooted, their roots leave openings in the soil. Wildfires can burn up roots leaving holes behind. Animals can also help create soil pipes by burrowing and tunneling in the soil. These voids provide an opening for moving water and create ideal situations for soil pipe formation. Water-restrictive soil layers can also facilitate soil pipe formation. Soil horizons such as fragipans, clay layers, or bedrock block the vertical movement of water through the soil profile and force it to move laterally. By forcing water in a specific direction, it is more likely that internal erosion will occur and a soil pipe will form. Likewise, restrictive soil layers also restrict the growth of plant roots causing the roots to extend laterally. Soil piping also called tunnel erosion takes place beneath the surface of the earth and it normally goes unnoticed. Soil piping is like cancer affecting the soil. Early detection and diagnosis followed by treatment is must for preventing land degradation and disasters.

1.2 Pipe Formation

Piping is an insidious and enigmatic process involving the hydraulic removal of subsurface soil causing the formation of an underground passage. Since it happens in the underground, in many cases the phenomenon goes unnoticed.

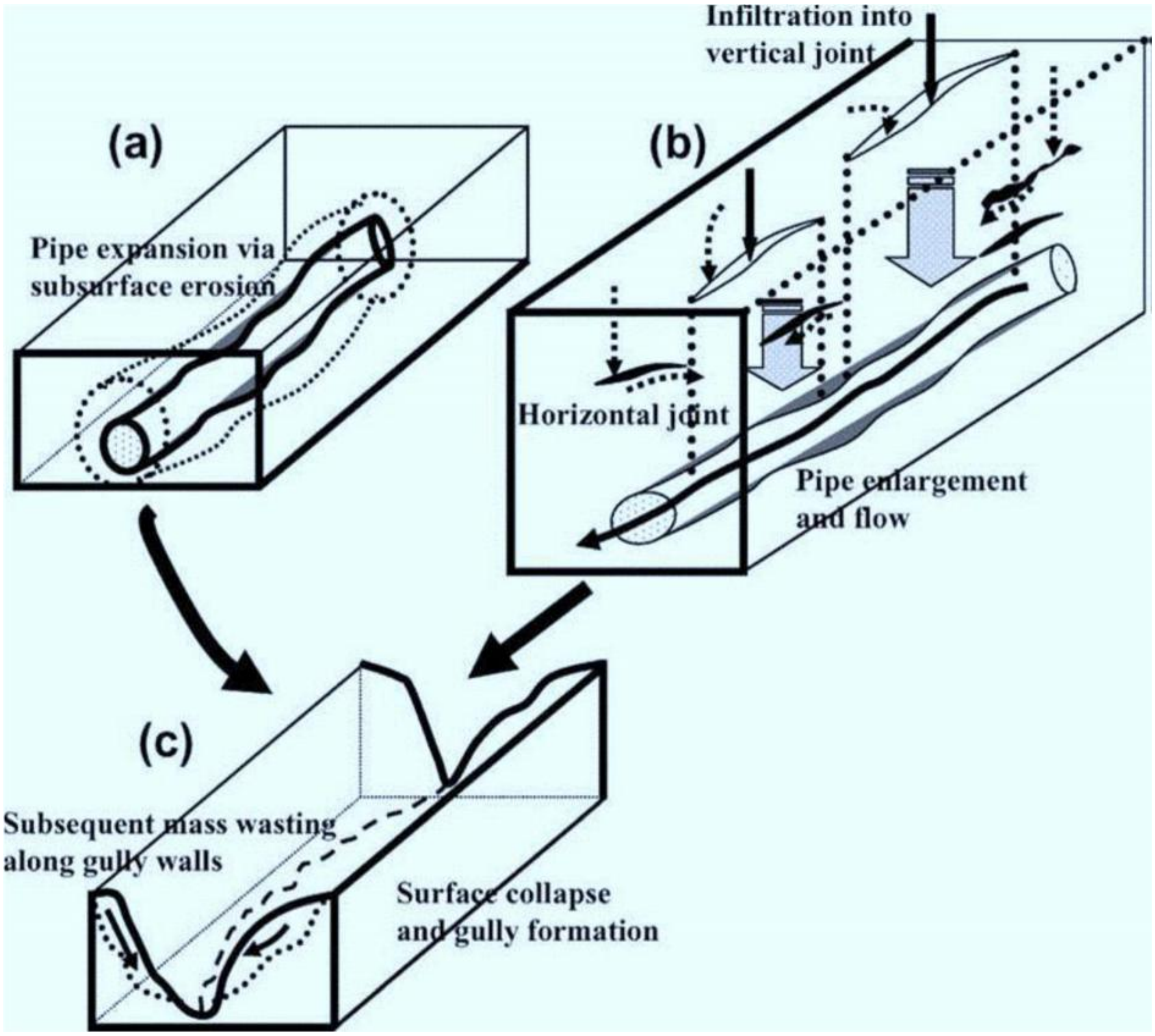


Figure 1: Soil Pipe Formation

1.1. Kerala's Vulnerability and need of the study

Kerala is a multi- hazard prone state. Floods, drought, landslides and man-made disasters are common in the state. Coastal erosion is recognized as a major hazard .Even though lightning is not recognized as a hazard, it takes an average toll of about 80 lives in Kerala. Landslides frequent the highlands during monsoon. Land- subsidence, first noticed in 2005 in the Thirumeni village near Cherupuzha, Kannur. Subsequent surveys reveal that the entire village is affected by the phenomenon. The underground cavities are being developed beneath busy roads (Tattekanni, Peringassery in the Idukki district) near to dams (Banasurasagar, Wayanad), houses (Udayagiri, Thirumeni in Kannur). Out of the 14 districts 11 are affected by this process. In Wayanad and Ernakulam districts landslides were induced by this phenomenon. Apart from Pathanamthitta, gaping sub surface tunnels have been discovered at many locations in Kannur, Idukki, Thrissur, Wayanad, and Kozhikode districts.

The cavernous gullies, more than 10-ft wide, have caved in at some places, threatening to degrade the land. According to the scientists, the tunnels are formed due to the erosion of clay-rich soil by an underground water source, possibly a stream percolating down from the surface through a crack. Soil piping starts with the water cutting out a channel as it enters the earth. The flow triggers a suction force, drawing in soil from the sides. Over time, the narrow channel is carved out into a larger pipe. As the pipe enlarges, the flow becomes more concentrated and turbulent. Sub surface pipes are known to extend some distance as a continuous channel or as a system of interconnected tunnels that form an extensive, branched network.

Kerala's Idukki district, home to the biggest arch dam in Asia and several other major reservoirs, has caused panic in the area due to the formation of deep well-shaped pits due to the phenomenon called soil piping. As per the media reports well-shaped pits with circumferences up to ten meters and depth up to 15 meters have appeared in a 20-hectare area in the Udayagiri area, lying near the giant Idukki arch dam.

The pits have formed in a straight line of about 500 meters from the top of a hill-slope to the valley, where the opening showed sand-mixed water seeping out.

According to the experts, during piping, large quantities of sand and clay beneath the surface get carried away by water, resulting in the formation of tunnel-like, structures. The process usually goes unnoticed as far as it is restricted to the sub-surface but pits appear when the surface becomes unable to bear the burden of the hollowness beneath caused by erosion.

The sub-surface erosion as in piping, has an abundant content of loose pumice, volcanic ash and such materials. The Idukki hydel project reservoir alone stores more than 80 percent of the water held by all artificial reservoirs in the State. Piping is always a huge concern when it happens near huge dams according to the geologists.

One of the major threats that piping poses is that the vertical pits could widen leading to more earth cave-ins but scientists say that there is no pragmatic method to arrest the process.

Understanding the seriousness of the problem the Department of Revenue and disaster management has requested NCESS, National Centre for Earth Science Studies to prepare a programme to study this phenomenon. The NDMA, National Disaster management Authority was approached for funding and it was granted. Centre for Earth Science Studies (CESS), Trivandrum and SEOC, State Emergency Operations Centre, HVRA Cell, Hazard Vulnerability and risk Assessment Department of Revenue and Disaster Management, Government of Kerala are the participating organizations. So far no serious effort was taken to study this phenomenon from a disaster point of view. The project was started in August 2012 and is of three years duration, likely to be completed in August, 2015.

2. Objectives

The study envisages to

1.
   - Document the areas affected by tunnel erosion/ piping in Kerala

2.
   - Evolve a mapping technique to determine the extent of the underground pipes using geophysical and geological methods

3.
   - Determine various physical and chemical processes taking place in the affected area in order to understand causative factors of piping

4.
   - Suggest mitigation measures to minimize or arrest this process.

3. Methodology adopted for Midterm Evaluation of the soil- piped affected area

The methodology adopted for the mid -term evaluation of the soil pipe affected area study comprises the following

- Mapping technology/ analytical studies with objectives
- On- Site visit of the soil -piped affected area
- Secondary Data of the soil pipe affected area
- Discussion with the research team involved in the study
- Discussion with the communities residing in the soil- piped affected area
- Site visit of Mitigation trials of some specific sites

3.1 Mapping technology/ analytical studies with defined objectives

The midterm evaluation conducted by IIPA, envisages to map the defined objectives with a definitive scientific tool and analytical study which is most used and the best available method to substantiate the same. Mapping the first objective, that is to document the areas affected by tunnel erosion/ piping in Kerala. This was substantiated with CESS, Revenue department and with available newspaper reports which have been contributory in inventorying the area affected by tunnel erosion. This has been done by CESS, and it has developed the map of the soil piped affected area.

The second objective is to evolve a mapping technique to determine the extent of the underground pipes using geophysical and geological methods. The extent of the underground subsurface pipes depends a lot on the chemical characteristics of the soil. Literature studies show that sodic clay soils are most vulnerable to piping. NCESS, collected soil samples from different depths and at different locations and subjected them to chemical analysis to check the chemical properties of the soil. The geophysical surveys were carried out by resistivity meter to check for the variation in electrical resistivity of the ground. Resistivity Imaging helps in delineating the transitional boundaries. NCESS exploits the Resistivity imaging which is the best technique to check the geophysics of the soil. The resistivity studies were used to determine the nature and extent of underground pipes.

The third objective is to determine various chemical processes taking place in affected area in order to understand causative factors of piping .The depth and extent of the subsurface tunnels was estimated by the research team by using Push cameras for visual investigation of tunnel branches. The chemical validation of the soil to investigate the causative factors was done subjective to pH, electrical conductivity, total dissolved solids, organic matter content, organic carbon, XRF and XRD. The investigation of hydrological and meteorological data of any site is a must to understand the causative factors of piping. The hydrological and meteorological data were collected by NCESS by installing V-Notch and Automatic weather stations.

The fourth objective being to suggest mitigation measures to minimize or arrest this process. This activity of on –site mitigation is being conducted by NCESS at different sites including Ranni Taluk and Wayanad Districts. The mitigation work is being conducted along with Public works Department and some local bodies.

3.2 On –site visit of the soil- piped affected area

3.2.1 Data base on Soil piping: Piping Locations

The map in the Fig. 2 shows the various districts of Kerala, affected by incidences of soil piping.

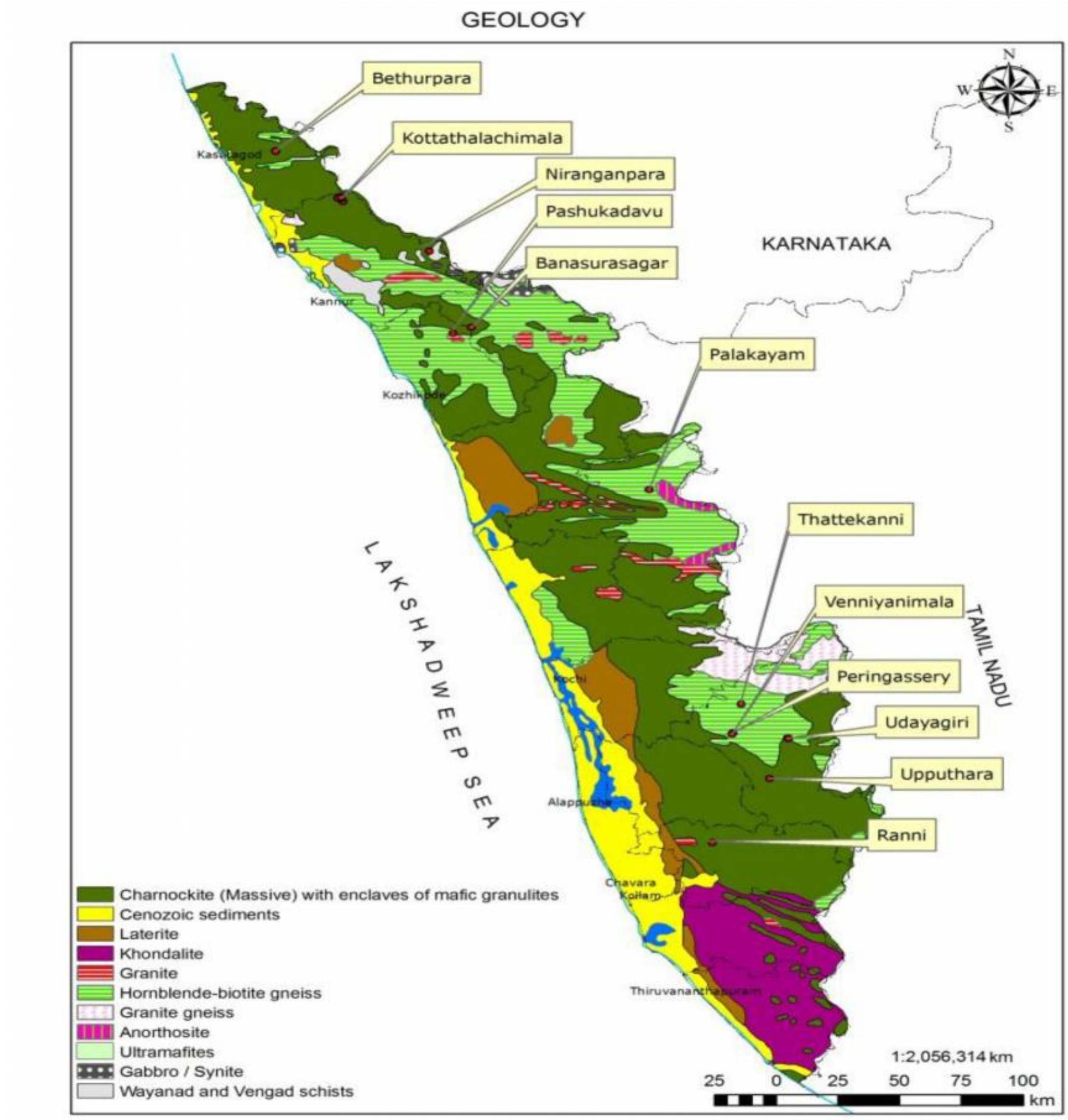


Figure 2: Map of soil pipe affected area

IIPA team selected the sites of the soil piped affected area. The soil piped area selected for the site visit were diverse in nature and magnitude. The sites selected had diversified problems and the probable causes were different. The selected soil piped area had strategic locations and affected the vicinity to a large extent. The sites selected ranged from agricultural lands to residential plots where soil piped area has caused huge losses in terms of productivity and yield of the land. The land being a very precious resource in Kerala is under huge pressure. The subsequent locations were also of strategic importance as they were residential localities and the natives have invested their lifetime savings in construction of their houses. The other site with Banasursagar Dam, in the vicinity, was chosen especially to investigate and observe the changes that might have occurred in the earthen dam impounding water to the tune of 209 million m^3.

3.2.1.1 Location: Kottathalachimala: Mamootil

District: Kannur, Taluka; Taliparamba, Village: Pulingome: Panchayat: Cherupuzha
Latitude: $12^{o}16'22.5"$
Longitude: $76^{o}25'21.8"$
Elevation: 236m

Tunnel entrance **linear extension of tunnel** **Tunnel inside view**

Figure 3: Different views of a matured pipe in Cherupuzha

Located in the Kottathalachimala, near Cherupuzha, Kannur this pipe is old and matured. At present soil erosion is very low inside the tunnel. The geophysical experiments were conducted at this locality. In fact this entire village is affected by soil piping process. The tunnel opening is seen at the place where subsidence has taken place. Presence of bats in the tunnel is indicative of the presence of oxygen in the tunnel. Since the tunnel is wide and accessible. 2D resistivity surveys were conducted across known sections to determine the type of survey method suitable for pipe discovery. Geophysical surveys indicated that this tunnel is 50m in length and branching at the end is indicated. The tunnel attains a max dimension of 3 meters height and 4meters width. The sections clearly indicate that the Saprolite section of the laterite is eroded producing huge tunnels. Chemical analysis of the soil samples indicated the presence of Gibbsite and exchangeable sodium which are responsible for the mobility of the clay. This gives the clue for chemical amelioration as a mitigation method. The lighting is artificially generated inside for the tunnel for inspection.

Figure 4: Discussion with Tehsildaar, Revenue officials and the local people

3.2.1.2 Location: Kottathalachimala: Myladoor

District: Kannur, Taluka ; Taliparamba, Villiage : Pulingome, Panchayat : Cherupuzha

Latitude: 12 16’01.7”

Longitude: 76 25’11.6”

Elevation: 384m

Figure 5: Inspection of a pipe outlet at Kottathalachimala

This is an outlet of the pipe, which is interconnected by a number of pipes. The discharge is perennial. This is demonstrated by the pumping out the water stagnated inside the outlet. This pipe draws water from a big catchment. It is also seems to have connection with ponds in this area which is indicated by presence of small fish in the discharge .

3.2.1.3 Location: Kottathalachimala, Kuttiyanikkal

District: Kannur, Taluka ; Taliparamba, Village : Pulingome,
Panchayat: Cherupuzha
Latitude: 12°16’16.0”
Longitude: 76°25’48.8”
Elevation: 418m

Figure 6: Subsidence crater at Kottathalachimala

This subsidence occurred in 2013. This is a well like land subsidence occurred near a house. Pipes are observed at the bottom. The out flow pipe is found cutting across a house. The residents of this house are evacuated during high rains.

3.2.1.4 Location: Chattivayal , Chemparathi

District: Kannur, Taluk Taliparamba , Village Thirumeni ,Panchayat : Cherupuzha
Latitude: N 12°15'36.0”
Longitude: E 75°26'45.7” Elevation: 414m

Figure 7: Subsidence affected house at Chattivayal, Chemparathi

Soil piping was first detected in this locality in 2005. A newly constructed house owned by Mrs. Lissy Francis was totally damaged and became unfit for dwelling. All wells in this locality do not yield even during high rains. This entire area in this locality including village roads are affected by underground piping.

3.2.1.5 Location: Kottathalachimala, Thirumeni Co-operative milk society building

District: Kannur, Village Thirumeni, Panchayat: Cherupuzha

Latitude: N 12º15'23.5”

Longitude: E

75º26'15.05”

Figure 8 : AWS, V-Notch and AWS display at Thirumeni

A meteorological station is established in this building for this project. This location is selected for uninterrupted power supply. The meteorological data is being collected using an AWS, Automatic weather station .This AWS was supplied by the SEOC ,Government of Kerala. Discharge data is measured at an outlet using a V -notch constructed for this purpose.

3.2.1.6 Location: Nelliyedukkam District: Kasaragod

Taluk: Vellarikund, Village: Kinanoor, Panchayat: Kinanoor

Latitude: 12°17’58.0”

Longitude: 76°13’02.5”

Elevation: 35m

Figure 9: Subsidence at a newly affected site at Kasaragod

IIPA team visited a newly affected site in the Kasaragod district. This is one of the recent subsidence occurred in the State. This has occurred on 8.10.2014. Subsidence has occurred in area owned by Sri Balan.V.K. The subsidence has occurred adjacent to the house under construction. On inspection it was noticed that the main road has also been affected and the area has more than one pipe. One pipe is seen passing near the house. The entire one acre of land is not fit for any type of construction.

3.2.1.7 Location: Niranganpara (Angadikadavu)

District: Kannur,Taluk: Iritty,Village: Ayyankunnu
Latitude: 12°17’58.0”
Longitude: 76°13’02.5” Elevation: 35m

Figure 10: A well being affected by soil pipes in village Ayyankunnu

The team visited Ayyankunnu locality near Iritty in the Kannur district. A classic example of pipes affecting the ground water regime of an area. Most of the wells in this locality are affected by the soil piping processes. The team visited the pipe formations of nearby localities. Here huge underground tunnels are developed making the area unfit for any purposes.

3.2.1.8 Location Banasura District: Wayanad

Taluk: Manathavadi

Village: Padinjarthara

Panchayat: Padinjarathara

Latitude: N 11°40'25.3" Longitude: E 75°58'04.0"

Figure 11 : Subsidence at Residence near Banasursagar Dam

During 2006 a subsidence had occurred in the compound of Liberty Manooty a resident of Padinjarethara Panchayat. Water started gushing out this subsidence pit. This flow of water continued for four months. This locality is located very close to the Banasurasagar Dam in the Wayanad district of Kerala. Mitigation of the subsided area was done with the help of Nirmiti Kendra, a Government agency without considering any causative factors. As a result of that, during monsoon water sprouts out from the reclaimed area. This indicates that the mitigation should be carried out using chemical amelioration and physical interventions. The second picture indicates a soil piping affected landscape. Close to this place, vertical cracks are observed on the walls of a house indicative of an impending danger.

3.2.1.9 Location : Banasursagar Dam

District: Wayanad,Taluk: Vythiri, Village: Padinjarthara

Panchayat: Padinjarathara,

Latitude: N 11°40'13.1" Longitude: E 75°58'11.0"

Figure 12 : Banasurasagar Dam

The longest earth Dam in India is situated very closed to the earlier location. This dam is built using locally available earth. This study has indicated that the soil has exchangeable sodium and it is dispersive in nature. So this dam is prone to soil piping and careful examination is required. The team discussed this matter with the Senior Engineers and ADM, Wayanad

Figure 13: Mitigation site

4. Observations

Soil erodibility in this area is clearly controlled by the sodium content and the presence of swelling clays. These factors determine the distribution and appearance of piping processes. Cracking in Holocene clay deposits, devoid of swelling clays, is related to high sodium content that confers a dispersive character. Clay dispersion causes loss of cohesion favoring piping. The soil piping as has been rightly called as the cancer of the soil and this analogous malignancy has already engulfed 11 districts out of 14 and only 3 districts are yet to be affected. The process is slowly spreading to the Western Ghats. Albeit soil piping has been reported as a global phenomenon with several regions viz. Australia, Spain, United Kingdom affected by the problem, the nature of the magnitude of the soil pipes in the state of Kerala is bewildering. This very characteristic draws attention towards this enigmatic phenomenon. The internal bleeding through the process of soil piping is extending to Karnataka in in the Coorg-Talkavery region. Based on the analysis, suitable recommendations would be suggested as mitigation strategy so as to avert the highlands of Kerala affected by soil piping. The cavities formed in underground can grow in size and may result in more land subsidence in future. Thus if left unattended, it might spread and destroy vast amounts of valuable arable land in Kerala. Thereby making it not suitable for cultivation, habitation, ground water resources or related activities.

The mid-term Evaluation highlights the following determinant factors that contribute towards the initiation and expansion of the piping process:

(1) The topographical characteristics

(2) Land-use

(3) Physical soil properties

(4) Chemical soil properties

(5) Environmental conditions

4.1 Topographical Characteristics:

Pipe or tunnel erosion is ascribed to concentrated subsurface flow through the material macro pores such as desiccation cracks or small rock fractures. The presence of sodium which is one of the characteristic feature of the soil of Kerala, The reactive double layer clay rapidly disperses creating enlarged subsurface pipes. (Rengaswamy *et al* 1984, Naidu *et al* 1995).

It has been observed that pipes do not develop, where infiltration rates are low and the gradients are very gentle, because without hydraulic gradient and a mechanism that focusses the infiltrating water which might be due to sharp permeability change between different soil horizons.

Thus measures must be taken to check the hydraulic gradient and water infiltration mechanism. The infiltration mechanism might be checked by creating diversions and channels using Bamboos as practices in Sikkim which may help in decreasing the soil infiltration. Piping appears to be linked to the low sloped terrace beds with significant hydraulic gradients generated by the drop between two cultivated terraces, thus accelerating the mechanical activity of water.

4.2 Land Use:

The characteristic appearance of piping is in cultivated fields. Terracing, this is an effective soil conservation practice, when the problem is surface wash erosion, has ironically reduced bulk density and increased hydraulic gradients through those material, accelerating the erosion of these sites by the piping process.

4.3 Physical Soil Properties:

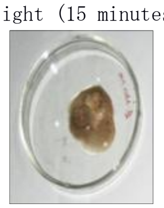
The secondary data collected through the discussion with the scientists involved in the study reflects that the difference in the structure, texture at variable depths favor pipe initiation. The soil is poorly structured at the surface and also lack depth with surface. The presence of expandable clay causes soil cracking and favors soil piping. The XRD results (shows that the presence of Gibbsite and zeolite. Gibbsite is a secondary mineral mainly of tropical and alteration product of many aluminous and alumina-silicate minerals under intense weathering conditions. Gibbsite indicates prominent leaching material which confirms the erosional activity in that region. Zeolite having the property of high porosity indicates the ability of storing water with in its pores and in conditions if the pores are completely saturated by water they start eroding. Presence of these clay minerals gives clear indication of soil piping in the affected area.

4.4 Chemical Soil Properties:

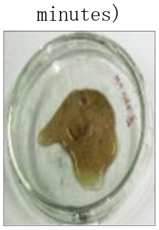
The most outstanding relation to the pipe formation is the presence of highly exchangeable Na percentage as it favors soil dispersion and initiation of the piping process at the subsurface levels. This observation has been further substantiated with the Dispersion Test, conducted by CESS .Soil erosion occurs in dispersive soils (Vacher et.al. 2004) which typically contain greater than 6.0% exchangeable sodium (ESP). These soils are known as sodic soils or Sodosoils (Isbell 2002), or in the past may have been referred to as Solodic,Solonetz or Solodized –solonetz (Doyle and Habraken1993).Other soils such as Vertisols , Kurosols and Kandosols may also contain sodic or dispersive soil layers. The soil aggregates easily dispersed when it was immersed with water. Hence the soil can be treated as a dispersive soil. Dispersion is an indicator of sodic soil as it occurs when sodium is present.

Nill (start)

Slight (15 minutes)



Moderate (40 minutes)



Severe (120 minutes)

Figure: 14 Dispersion test on a soil sample prone to piping, Peringassery Idukki

4.4 Environmental conditions:

The climatic characteristics of the place with high annual rainfall being to the tune of around 400 cm and the deep rooted vegetation also generates conditions conducive for piping. It is ironic that the management practices adopted in other area have actually exacerbated the problem.

4.5 Mitigation experiment Banasurasagar, Vythiri taluk Wayanad:

During 2006, a portion of the land belonging to Mr Mamooty a resident of the Padinjarethara village (Loc N 11°41'33" / E75°54'16") subsidided and water started gushing out with huge force. The water pressure was enormous and the discharge continued for months together. This indicates that the water is flowing under a very high hydraulic head. Interestingly this area is located very near to the Banasurasagar dam. Investigations revealed that this subsidence is also caused by soil piping. This locality is connected by an underground pipe downstream and emerges out as a spring.

1. Before Filling subsided area 2006 2. After filling subsided area 2014

Figure 15 : Subsidence at Banasurasagar, Vythiri taluk Wayanand

The process continued for few months and the discharge stopped leaving behind a subsidence pit connected upstream and downstream by small tunnels. The mitigation work was carried out by filling up by stones and earth. This is the practice carried out by the locals. This area will be under observation and if required chemical amelioration techniques will be adopted to prevent new erosion. Since the whole area is affected by soil piping the SDMA, State Disaster Management Authority is alerted for a detailed investigation of Banasurasagar dam site.

5. Recommendations

Soil Piping is growing on a large scale with almost over 11 districts affected out of 14 in Kerala. The data base created on the soil piping incidences is being gradually updated by incorporating new incidences. The incident occurred in July 2014 in the Niranganpara locality in Ayyankunnu panchayath, Thalasseri taluk in the Kannur district which evoked lot of media attention. A subsidence has occurred inside a well (GPS location is N12°02’09.4”E75°45’07.2”). The affected locality is in the foot hills and surrounded by hilly area. Piping has affected the saprolite portion of the laterite. Piping outlet is located at 120m north of this area. The soil is 1.5m thick and overlying the well-developed laterite. The slope of the terrain as well as the tunnel orientation is towards North West direction. The underground tunnels formed are found to be affecting the affecting the ground water storage of the wells in this area.

Inside view of tunnel

Piping affected well

Figure 16 : Soil piping affected well at Niranganpara, Kannur

5. 1 IIPA recommends the following suggestions based on the observations of the on-site visits.

The soil piping is spreading like cancer in the subsurface soil without showing up any symptoms in the early stages. The soil piped tunnels are noticed eventually after the collapse of the roof top of the tunnels. Soil piping may lead to several disasters which has already begin to show up viz. the increased frequency of the tremors with greater intensity on the Richter scale. The incidences of land subsidence also shows an upward trend. Several houses have developed deep cracks in due course of time. The ground water regime of the area is also being affected, as many wells in the area are reported to be non -yielding despite deep digging.

The NCESS, Trivandrum and SEOC, State Emergency Operations Centre, HVRA Cell, Hazard Vulnerability and risk Assessment Department of Revenue and Disaster Management, Government of Kerala have been very effective and meticulous in mapping the soil piped affected area. The organizations have procured several instruments and high end gadgets such as geophones, push camera which have proved to be instrumental in analyzing the soil profile and establishing connect between soil pipes.

NCESS has also evolved mitigation strategies of the soil piped affected sites. Although it is clearly reflected that the mitigation practices adopted is not a straight jacketed approach and *one – size fits all* phenomenon does not applies as the nature , cause , and the magnitude of the tunnel erosion varies from case to case.

IIPA also observed that the research team has at NCESS has been able to garner rapport with the local population thus enabling them to project and implement mitigation strategies launched from a pilot stage to mass scale thus strengthening the over- all effort which would help in averting the overarching disasters. The technical expertise along with the local support would also be instrumental in generating mass sensitization amongst the masses so as to sensitize them against the disasters which might stem from the soil pipes. This envisages to strengthen the disaster risk reduction.

The fortune of the local stakeholders is riding on high risk factors as they have invested their life time savings in these soil piped affected area. They are sitting on virtual ticking time bombs that might explode any instant taking heavy toll on life and property. Thus IIPA strongly recommends that soil –piping must be included in the list of disasters so that adequate compensation may be made to the concerned in case of causality.

The financial constraint is one of the major flaw which seems to be paralyzing the on -going research. The paucity of funds due to delayed release of installments has punctuated the study during its peak which is a major cause of concern.

IIPA recommends that the finances must be released for smooth furtherance of the research. Looking at the nuances in the soil piped affected area it is also recommended that the study must be granted an extension till March 2016 although with no additional financial implications on NDMA. The extension might facilitate the research team in coming up with concrete results and mitigation strategies using different concepts such as slope stabilization and using fly ash as a filler material in the land subsidence.

ANNEXURE