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Principal environmental impacts on pipeline tracks as a result of mining operations and their mitigated actions

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Abstract

This study deals with the main environmental impacts and possible mitigation measures for many pipeline tracks, due to the mining of different substances in areas of interference between mining activities and mineral research and those resulting from construction and gas pipeline operation. By monitoring the identified interferences/disturbances, it was determined that although punctual and small in number, the extraction of mineral resources in the proximity of the gas pipelines could represent risks for the security of the undertaking. In general the risks are consequence either of the use of explosives or of induced erosive processes that could lead to pipeline instability. It is necessary to block the mining activities on both sides of the pipeline tracks in order to minimize risks to the pipeline, to others, to society, and to the environment. Also, the establishment of “flexible” track limits could be adopted in areas adjacent to the pipelines for the exploration of some mineral deposits, thus prioritizing security preservation with a minimum of socio-environmental impacts.

Keywords: gas pipeline, mineral extraction, environmental disturbance.

1. Introduction

Gas transport through pipelines together with the research and extraction of minerals in the same area are incompatible to some extent. This situation occurs due to disturbances or negative impacts resulting from the construction or operation of pipelines passing through areas of required mineral exploration. These impacts are due to eventual restrictions and operational impediments that hinder or prevent the continuity of the exploratory activity or cause limitations for the establishment of the real mineral potential of the required area (BIODINÂMICA, 2007). Excavation for research or mineral extraction along the pipeline tracks could cause the rupture of the pipes with risks for the workers and people living around the strip, as well as losses for the company of gas transport, and the whole society that uses this energy.

Mining activities, along with the generation and transportation of different kinds of energy, are considered to be a public utility or social interest and are

governed by specific laws, in particular the Decree Laws 3.365/1941 and 227/1967, the Laws 4.132/1962, 9.478/1997 and 12.651/2012, the CONAMA Resolution 369/2006, and the Articles 20, 21, 22, 23, 176 and 177 of the Federal Constitution. These legal regulations emphasize that both activities whenever possible must to be conciliated even though there exist opposing interests. The specific legislation, regulation opinions and jurisprudences present the solution for the conflict if there is no agreement.

For more than a decade, researchers of the Applied Geology Department of the Instituto de Geociências e Ciências Exatas of UNESP, Rio Claro (SP) performed surveys about the research activities and ore mining along the strips occupied by the gas pipelines: Bolívia-Brazil, Uruguai-Porto Alegre, Campinas-Rio de Janeiro, Cabiúnas-Vitória, Vitória-Cacimbas, Cacimbas-Catu, Cacimbas-Barra do Riacho, Caraguatatuba-Taubaté, Cabiúnas-REDUC, Japeri-REDUC, Paulínia-

Jacutinga, Rio de Janeiro-Belo-Horizonte and Maricá-COMPERJ and the strips of the Gas-Chemical UFN-IV and Petrochemical (COMPERJ) complexes. The objective of these surveys was to subsidize the Environmental Impact Studies necessary to obtain the licenses for installing and operating these gas pipelines.

These environmental impact studies intended to approach the interferences of the pipeline tracks with mining and/or mineral research activities since 1997, involving 14 already-constructed pipelines and those in the process of being implanted. These interferences were analyzed regarding the direct influence of the pipeline tracks over an area of 450 m on each side of the pipelines (FERREIRA *et al.*, 2010). Identifying the disturbances caused by mining activities on the pipeline tracks, the company responsible for the pipeline has the chance of managing possible conflicts, avoiding the interruption of the activity and ensuring the integrity for the pipeline's operation. On the other

hand, the management of the disturbances due to pipeline track construction over mining activities is also necessary, since it permits the orientation of the technical, administrative and juridical activities related to requisites for environmental licenses, which are gradually increasing in number and becoming more specific. Also necessary is the management of the liabilities associated with mining rights.

Recently, the State Foundation for

Environmental Engineering of Rio de Janeiro has begun requiring that surveys demonstrate the impacts of pipeline track construction in areas undergoing mining activities, including the volume of ore reserves to be blocked and its economic impact, similar to the requirements of the Environmental Impact Assessment referring to the gas pipelines located in the state of Rio de Janeiro (Figure 1) (FERREIRA, 2011).

With the objective of identifying and describing the impacts of gas pipeline construction on the various mining activities, this study sought to summarily present the main environmental impacts and the possible mitigating actions to solve the disturbances caused by the mining of different substances close to the pipeline track that were caused by the construction and operation of the gas pipelines over areas of mining and ore research activities.

2. Method

Upon identifying the mineral extraction areas in operation and those with probable future mining activities (including those with mining requests

and already-evaluated mineral deposits), monitoring was executed considering the mining method; for the eventual disturbances around the gas pipeline, monitor-

ing was executed by means of aerial and/or field inspections along the pipeline tracks. The monitoring procedures are listed in Table 1.

Table 1
Monitoring procedures of different mineral substances

MINERAL SUBSTANCE	MINING METHOD	AVERAGE BENCH HEIGHT	MONITORING PROCEDURE
Coal	Underground, room and pillars (with and without pillar retraction)	-	Watching for surface features that are indicative of ground sinking. Measurement of ground vibration levels.
Clay	Open-pit mining, multiple benches	4 m	Monitoring of the security strip for its preservation during mining advancement. Monitoring of the slope stability.
Clay	Strip mining	Average of 1 m to 2.5m	Monitoring of the security strip for its preservation during mining advancement. Monitoring of the slope stability and new transportation routes.
Sand	Dredging	1 m to 5 m	Monitoring of the mining procedures to inhibit them along the gas pipeline track. Watching for eventual exposition of the pipeline in the river bed.
Sand	Dredging (into submersed pit)	2 m to 10 m	Monitoring of the security strip for its preservation during mining advancement. Observation of the slope stability and new transportation routes.
Sand	Open-pit mining, single bench	1 m to 1.5m	Monitoring of the security strip preservation during mining advancement. Monitoring of the slope stability and new transportation routes.
Gravel	Strip mining	4 m	Monitoring of the security strip for its preservation during mining advancement. Monitoring of the slope stability and new transportation routes.
Gravel	Strip mining at the river bed	1 m to 5 m	Monitoring of the security strip for its preservation during mining advancement. Watching for river margin stability.
Gems: fluvial alluvium	Open-pit mining at the river bed or along their margins	1 m to 3 m	Monitoring of the mining advancement for slope stability.
Grit	Open-pit mining, multiple benches	10m to 15m	Monitoring of the security strip for its preservation during mining advancement. Monitoring of the slope stability. Measurement of ground vibration level caused by blasting when using explosives.
Limestone	Open-pit mining, multiple benches	10m to 15m	Measurement of ground vibration levels.
Granite/Gneiss Diabase/Basalt (Rocks for crushing)	Open-pit mining, multiple benches	10m to 20m	Measurement of ground vibration levels. Monitoring of the slope stability at the work-front for extractions positioned above the pipeline track.
Granite (Dimension stone)	Quarrying	4 m to 6 m	Measurement of ground vibration levels. Monitoring of the advancement of the extraction fronts that are generally scattered on the site. Monitoring of the slope stability and new transportation routes.
Granite (Hewn stones)	Open-pit mining, cut in blocks	1 m to 5 m	Measurement of ground vibration levels. Monitoring of the advancement of the extraction fronts that are generally scattered on the site. Monitoring of the slope stability and new transportation routes.
Mineral water	Spring water extraction	-	Flow measurement at the spring. Chemical and biological analysis of the mineral water.

Source: modified from Ferreira (2011)

3. Results and discussion

The impacts caused by the construction and implantation of pipeline tracks over mining activities that were identified during studies are small in number, restricted in area, and with a minimum socio-economic and environmental expression (Ferreira, 2011). Table 2 summarizes the main environmental impacts on the pipeline track due to mining, as well as the possible mitigation actions for each type of mineral substance and mining method.

Many areas blocked for future mining activities due to the construction of a gas pipeline contain deposits for usage in civil construction (sand, clay, grit, gravel, and granite). These

mineral deposits are considerable in areas surrounding the pipeline track (Ferreira, 2011). The main environmental concerns due to mining activities are caused by the extraction of sand and clay in alluvial plains, sand and gravel dredging in river beds, rock blasting with explosives and illegal artisanal mine activities (Figure 2). The environmental impacts caused by these activities along the gas pipeline tracks are generally restricted in area and are of different magnitudes, depending on the mining method used (FERREIRA *et al.*, 2014).

Dredging along the river banks can cause erosion at the head of the crossing pipelines, breaking them. In

both the mobile and anchored dredging processes, the main environmental impacts caused by these methods of mining are the erosion acceleration on the river banks and the desilting of the river bed, exposing the pipelines. Another impact observed is the use of the gas pipeline track as a place to deposit the material extracted.

In the case of dredging flooded pits, the environmental impacts caused to the pipeline tracks are related to the destabilization of the slopes on the sides of the pits (due to the difficulty to control the dredging), erosion on the sides of the pipeline tracks, implantation of new routes for transporting ore crossing the pipeline tracks, and

Figure 1
Granite body that interferes with the pipeline track. This interference was ignored in the research report for mine's reserve calculation and economic exploitation of the granite body located in Magé County, Rio de Janeiro State (Pipeline Cabiúnas-REDUC (GASDUC III)).

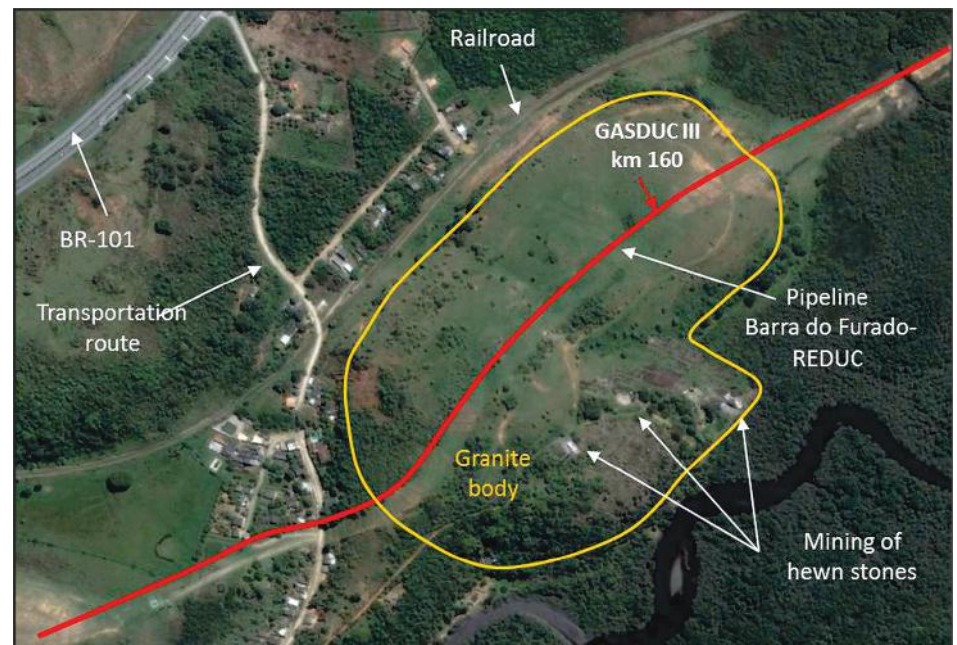
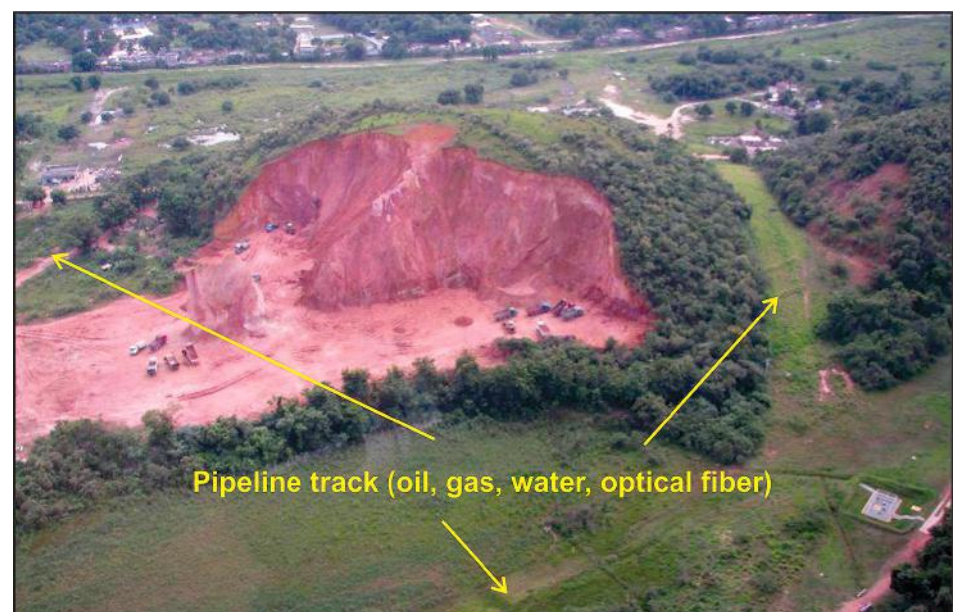


Figure 2
Unauthorized grit extraction surrounded by pipelines tracks (Cidade dos Meninos, Duque de Caxias County, Rio de Janeiro State).



the use of the strip itself as a means of transporting the ore, and usage as an access route for pipeline maintenance (Figure 3). Furthermore, in the case of liquid hydrocarbonate seepage, this material will directly affect the water table exposed in the pits and in some cases could connect to the local drainage network.

Among the mining operations that can cause damage to the pipeline tracks, those related to rock blasting with explosives must be emphasized,

due to the vibration of the ground adjacent to the blasting site, causing direct impacts on the pipes and indirect ones on the ground strip, which in turn accelerate landslides of soil and rock layers. Repeated ground vibrations due to frequent use of explosives for rock blasting can accelerate the fatigue of the pipes (FERREIRA, 2011).

The extraction of unconsolidated material for use in the maintenance of secondary roads or in landfills is one of the most frequent mining ac-

tivities along the pipeline tracks, and can cause environmental disturbances along the strips. In the case of open-pit mining, the advance of the extraction fronts in the direction of the gas pipeline tracks should be considered in a way to inhibit the mining activities in the bordering areas, since these areas could serve as destabilization points of the neighboring slopes, thus preventing the installation or acceleration of erosive processes that could affect the pipelines (Figure 4).



Figure 3
Sand dredging from submersed pits on the floodplain of the Iguaçu River, Curitiba County (Paraná State), that isolate the gas pipeline track Bolívia-Brasil (GASBOL).



Figure 4
Grit extraction in the Duque de Caxias County (Rio de Janeiro State), close to the gas pipeline track Japari-REDUC. The mining works extended to the boundary of pipeline track.

Table 2 part I
Main environmental impacts and mitigating actions for the different mining methods

MINERAL SUBSTANCE	MINING METHOD	ENVIRONMENTAL IMPACTS	MITIGATING ACTIONS
Coal	Underground, room and pillars (with and without pillar retraction)	Reduction of the shaft ceiling could cause sinking of the ground in mines with pillar retraction. Vibration due to blasting for disassembling the ore and host rock.	Pillar maintenance. Use of non-electric initiators and delays for reducing vibrations. Vibration levels cannot be higher than those determined in the specific study in accordance with ABNT standards.
Clay	Open-pit mining, multiple benches	Alteration of the ground topography could induce erosive processes. Exposure of the water table and vegetation removal.	Establishment of a strip blocking the mining activity on both sides of the pipeline track. Remodeling, stabilizing and revegetation of the lateral slopes (Environmental entities recommend an inclination of 1:2.5). Implantation of the drainage network.
Clay	Strip mining	Generation of irregular pits with exposure of the water table and vegetation removal.	Remodeling, stabilizing and revegetation of the lateral slopes; recuperation of the pits (Environmental entities recommend an inclination of 1:1 for slopes and a maximum pit depth of 2.5 m). Reinforcement of the pipes at crossings with the transportation route.
Sand	Dredging	Riverbank erosion, deepening of the ditch with eventual exposure of the pipeline and downstream silting. Vegetation removal and destabilization of the river banks.	Execution of the extraction at a minimum distance from the pipelines tracks and river banks, preserving their stability. Revegetation and execution of the erosion contention works. Establishment of a strip blocking the mining activity on both sides of the pipeline track (strip width must be determined in a specific study, in accordance with ABNT standards).
Sand	Dredging (into submersed pit).	Formation of flooded pits with varied dimensions (depth depending on the ore thickness). Erosion acceleration of the pit borders. Vegetation removal.	Inclination of 30% in the first 5 m to 10 m of the pit; maximum height of the embankment of the pit = 10 m; minimum distance of 25 m to 50 m between the pits and the property borders. Establishment of a strip blocking the mining activities along both sides of the pipelines.
Sand	Open-pit mining, single bench	Vegetation removal, topographic lowering with localized exposure of the water table. Formation of flooded pits. Localized destabilization of the lateral slopes along the pipeline tracks.	Revegetation and erosion contention works on the slopes close to pipeline tracks. Reinforcement of the pipelines crossing transportation routes. Slope rest angle of approximately 30°.
Gravel	Strip mining	Formation of flooded pits with varied dimensions. Water table exposure and vegetation removal.	Remodeling, stabilizing and revegetation of the lateral slopes; recuperation of the pits (Environmental entities recommend an inclination of 1:2 for slopes and a maximum pit depth of 2 m). Establishment of a strip 15 m wide blocking mining activities along both sides of the pipelines.
Gravel	Strip mining at the river bed	Modification of the geometry of the river bed. Vegetation removal.	Mining must be executed at a minimum distance from the river banks, depending on the width of the river. River banks must be stabilized. Establishment of a strip 15 m wide blocking the mining on both sides of the pipeline.

Table 2 part II
Main environmental impacts and mitigating actions for the different mining methods

MINERAL SUBSTANCE	MINING METHOD	ENVIRONMENTAL IMPACTS	MITIGATING ACTIONS
Gems: fluvial alluvium	Open-pit mining, at the river bed or along their margins	Generation of irregular pits with water table exposure. Vegetation removal.	Remodeling, stabilizing and revegetation of the lateral slopes (Environmental entities recommend an inclination of 1:2.5). Construction of dams to preserve the water quality.
Grit	Open-pit mining, multiple benches	Modification of local topography accelerating erosive processes. Generation of ground vibration due to blasting for the extraction of massive rocks.	Stabilization of marginal mining slopes (inclination consistent with type of terrain) and revegetation. Use of non-electrical initiators and delays to reduce vibration.
Limestone	Open-pit mining, multiple benches	Modification of local topography accelerating erosive processes. Generation of ground vibration due to blasting for the extraction of massive rocks.	Stabilization of the mining slope. Utilization of delays along the entire blasting line and non-electrical initiators for vibration reduction. Establishment of a security strip as per the specific study of the vibration levels, in accordance with the ABNT standards.
Granite/Gneiss Diabase/Basalt (Rocks for crushing)	Open-pit mining, multiple benches	Generation of ground vibrations due to blasting for the extraction of massive rocks accelerates erosive processes close to the pipeline track. Transportation routes could cross the pipeline track.	Utilization of delays along the complete line of blasting and non-electric initiators for vibration reduction. Stabilizing mining slope near the pipelines. Reinforcement of the pipelines at transportation crossing routes. Establishment of a security strip, which width must be determined by a specific study of the vibration levels in accordance with ABNT standards.
Granite (Dimension stone)	Quarrying	Acceleration of surface erosional processes. Production of a large amount of mining waste and removal of local vegetation. Production of ground vibrations due to low-intensity blasting using gunpowder to extract rock mass. Transportation routes that could cross the pipeline track.	Stabilization of the mining areas. Burying the mining waste and revegetation of the area. Reinforcement of the pipelines at the crossings with the transportation route. Vibration measurements in the case explosives must be done.
Granite (hewn stones)	Open-pit mining (cut in blocks)	Acceleration of surface erosional processes. Production of a large amount of waste. Removal of local vegetation. Generation of ground vibrations due to low-intensity blasting using gunpowder to extract rock mass. Transportation routes that could cross the pipeline track.	Stabilization of the mining areas. Burying the mining waste and revegetation of the area. Reinforcement of the pipelines at crossings with the transportation routes.
Mineral water	Spring water extraction	The water exploitation site and the protection area of the spring should not interfere with the pipeline track. The construction of the pipeline could impact the spring water, changing it recharge and modifying the water quality.	Perform a hydrogeological study before the construction of the pipeline track. Monitoring the spring conditions (flow, water quality) for a period not less than one year.

Source: modified from Ferreira (2011)

4. Conclusions

As a preventive action, it is interesting to require of the environmental entities, when applicable, studies about the possible impacts on the security of the gas pipeline.

As one of the principal results of the performed surveys, there is the need to block the mining activities on the sides of the pipeline tracks in order to minimize risks to the pipeline, to others, to society, and to the environment. This blocking aims to preserve the continuity of the pipeline activity, which ensures the supply of energy and the hydrocarbonate transport in

accordance to the norms and standards for security.

Among the mitigating actions, the establishment of “flexible” strip limits for the exploration of some mineral deposits could be adopted in areas adjacent to the pipeline, thus prioritizing security preservation with a minimum of socio-environmental impact. In the case of rock extraction using explosives, the settlement of the width of the strip depends on the mining method to be adopted for each deposit, and should be established based on technical parameters obtained from

specific studies and in accordance with the Brazilian standards ABNT NBR 9653:2005. In the case of mobile dredging on river bed and mineral water exploitation, the interferences should be analyzed case by case, since their features are peculiar.

The management of pipeline track interferences with mining activities is very important, since it supplies data for the technical, administrative and juridical orientation for compliance the conditions of environmental licenses and management of the liabilities associated with mining rights.

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