

Abandonment Research and Environmental Impact Analysis for Retired Dong-Huang Pipelines

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Abstract. Nowadays, China is not experienced in the research and practice of the abandonment approaches to oil and gas pipelines retirement. Using the experience of the North America for reference in abandonment of onshore pipelines, including retired pipeline safety environmental disposal scheme choice, waste disposal technology and retired environmental impact assessment of the key problems were discussed. The comparatively complete construction technology was put forward to dismantle pipelines. Besides, the construction technology of filling the controlled low strength material to the decommissioning oil pipelines was put up. Based on the case of Dong-Huang pipeline abandonment, the selection disposal scheme was optimized, key construction practices such as the cleaning of pipeline residues and low strength controlled material filling pipeline were expounded, potential environmental influence of different disposal scheme was analyzed, besides, some measures were represented to prevent and relieve the pollution corresponding to the construction technology. Research results have guiding significance for perfecting safe abandonment research of domestic retired oil and gas pipelines.

1. Introduction

By the end of 2015, the accumulative length of in-service pipelines in Mainland China has been 120,000 kilometers [1]. Among them, there are over 10,000 kilometers land pipelines constructed in the 1970s and 1980s, and partial ones have been kept in service for more than 40 years, which brings noticeable potential safety hazard [2]: the aging and corrosion phenomena are critical, besides, there are more and more pipelines being destroyed and occupied. In 2013, Qingdao Economic and Technological Development Zone witnessed an explosion hazard, which is a wake-up call to society that it's time to pay attention to the safety problems of pipelines. When pipelines are aging severely or have no durable years left, which means they can't continue to operate safely, it's obliged to decommission them. But if decommissioning pipelines can't be dealt with properly, they may pollute surrounding air, soil and water bodies, even lead to safety problems like fires and explosions [3]. Now there is not much research and practice about how to deal with decommissioning pipelines in China, corresponding decommissioning technique research, systematic pipeline decommissioning technique and regulations are also in lack [4, 5]. Pipeline environment impacts evaluation mainly focuses on the construction and operation period, but not the decommissioning period. And environmental management rarely makes imperative requirements of decommissioning environment impacts [6]. Reasonable decommissioning plan and systematic and well-established decommissioning technique (including decommissioning technique and analysis of environment impacts) are the basis of decommissioning pipelines safely. The article is based on the case of Dongying-Huangdao decommissioning pipelines, choosing reasonable decommissioning plan and technique, to analyze environment impacts during decommissioning period and offer corresponding measures to prevent pollution and reduce negative impacts.



2. Decommissioning Pipeline Disposal Scheme and Selection Basis

The typical ways to decommission pipelines are dismantling and local decommissioning. Decommissioning pipelines and surface facilities can remove safety and environment hazards drastically. In China, the common way of decommissioning pipelines is totally dismantling, which needs large quantity of construction works, high costs, which exists potential safety hazard and environmental pollution. Local decommissioning concludes the process of pigging, segmenting, plugging and filling pipelines. And if necessary, corresponding technical measures are also needed. This way of decommissioning costs relatively low. Decommissioning plans should be decided on the actual conditions of pipelines. North America and other developed countries usually combine the two methods together to deal with practical projects [6]. Selection basis of pipelines decommissioning plans include:

The conditions of land utilization is a vital factor. When choosing pipelines decommissioning plans, it's vital to investigate present and future utilization planning of land to avoid negative effects caused by local decommissioning on land use (like excavation, pile driving and construction of underground engineering structure). According to utilization, land can be divided into agricultural land, non-agricultural land, etc. (like environmental sensitive region, road, railway, river and other facilities). Summing up other countries' experience of decommissioning pipelines, these types of land need to adopt the measure of dismantling: agricultural land that needs deep tillage in the future, non-agricultural land that plans to construct and land with pipelines which are buried in shallow embedded depth (less than 1 meter). The land, which is suitable to adopt the measure of local decommissioning, mainly concludes urban land, road, railway, river and other pipeline crossing parts, most of agricultural land and land with pipelines which are buried in deep embedded depth. Choose pipelines decommissioning plans on the basis of environmental impact assessment in environmental sensitive region, which is in high risk of land subsidence, soil pollution and groundwater pollution. Pipeline crossing parts (crossing river, road, railway and public facilities) are also suitable for these plans.

Actual condition of pipelines is also an important factor. When choosing pipelines decommissioning plans, issues like type of media, transportation technology anti-corrosion and insulation measures should be taken into consideration. For example, it's obliged to dismantle pipelines when residue contains toxic substance which is difficult to clean or conventional cleaning method can't meet environmental protection requirements. Pipelines, which can't be dismantled, should be sealed by nitrogen or through filling slurry [4,7,8].

Technical feasibility and economic factors should also be taken into consideration. Technical feasibility mainly focuses on evaluation of technology and mechanical equipment, including security, reliability, complexity, responsive capability and convenience. Economic factors are mainly affected by engineering budget evaluation, including resource consumption, valuation of wastes, remedial measures and security measures.

3. Construction Technology of Decommissioned Pipelines

3.1. The Demolition of the Decommissioned Pipelines

The technology of the demolition of the decommissioned pipelines include: the termination of the pipelines' transportation, the recycle and the disposal of the residues in pipelines, the recycling of decommission of pipelines. The aim of the termination of pipelines' transportation is to unload the pressure inside the pipelines, as well as construct a safe environment of working.

3.1.1. Recycling and Cleaning of the Residues in the Pipelines. Not only can the residues in pipelines make it difficult for the construction of wastes, but also it can cause the pollution, even lead to the safety accidents. Thus, it is an important process of the disposal of the decommissioned pipelines to recycle and dispose the residues in pipelines. The main methods of the recycling of the oil gas: the first method is to send the oil gas into the pipelines which without replacement through the special pipeline pump for plugging equipment, the second method is to put the residual oil gas into tanker to recycle. The different methods of cleaning residues on the basis of different medium of transportation: it is difficult for the pipelines of crude oil to be cleaned, so the method of combining physical cleaning with chemical cleaning can be used; as for other pipelines, for example, it is easier to clean the residues of product oil,

so the measure of nitrogen purging or using foam cleaner can be taken. In addition, an inspection is necessary after finishing the disposal, mainly to monitor the petroleum content in washing water.

3.1.2. The Recycle to the Dismantled Pipelines. The machine of excavation mainly include excavator, leveling machine and backhoe. Cutting pipelines and welding pipelines use the hydraulic plate shear and high pressure welding machine respectively. Caution is needed when excavating, in order to preventing the breakdown of pipelines and avoiding the residual pollution, that pollutes the environment. To make the transportation convenient, the pipelines can be cut before lifting demolition, and be removed from the scene timely. When the removed pipelines need to be stored, being directly exposed to the soil and water should be avoided. Post-settlement should be considered in the process of backfill, and the residues should be cleared thoroughly, in order to make sure that the ground has been recovered.

3.2. Construction Technology of Controlled Low-strength Material for Decommissioning Pipeline Filling

Construction technology of disposal on site mainly includes: the termination of the pipelines' transportation, the recycle, disposal, cut, sealing and the plugging after filling treatment of the residues in pipelines. According to the related criteria of oil and gas of pipeline abandonment of Canada, America, England and Australia, the common methods to abandon pipelines all have their requests and suggestions of disposal on site. Adopting the method of water injection, mud injection and Nitrogen injection sealing can guarantee the safety of disabled pipelines temporarily, but there are still some hidden troubles that the residues of pipelines may cause environment pollution. The pipelines should be abandoned after being solidified, filled and sealed when they still don't meet the request of environment protection after disposal, position cross makes it easier for settlement, or the diversion effect threaten the environment potentially.

Decommissioning pipeline filling can use the Controlled low-strength Material, which has the characteristics of high fluidity, low strength and long setting time. There is no need or just a little need of vibration under the deadweight. And it can flow automatically or pump to fill the abandoned pipeline and get to a high density. The relevant index is shown on table 1 [9]. Controlled Low-Strength Material can eliminate the hidden trouble thoroughly, filling material cannot cause the secondary pollution to the surroundings on the later stage, it can also prevent the ground setting.

Table 1. The Performance Indicators of CLSM Used for Filling Retired Pipeline

Filling material	0 min fluidity	30 min fluidity	0 min setting time	8 h bleeding rate	7 d Compressive strength	28 d Compressive strength
	/ mm	/ mm	/ h	/ %	/ MPa	/ MPa
CLSM	≥ 300	≥ 280	≥ 8	≤ 5.0	≥ 0.5	≥ 2.0

4. Disposal of Decommissioned Pipelines and Analysis of Environmental Impact during the Decommissioning Period of East Yellow Line

4.1. Case Outline

Dongying-Huangdao Crude Oil Pipeline (East Yellow Line for short), were completed and put into production in 1974 and 1986 respectively. In recent years, some pipelines have been heavily occupied and adjacent to buildings, which makes the pipeline difficult to overhaul and repair. There are more security risks. In order to ensure the safe operation, the construction unit intends to carry out safety hazard management for pipelines and oil transportation stations. Renovation project includes change lines locally and then build new pipelines and disposal of decommissioned pipelines.

4.2. The Disposal Plan of the Decommissioned Pipelines

The decommissioned pipeline adopts a scheme for dismantling and filling the disposed combination. The pipelines with demolition conditions are all dismantled; the pipelines that cannot be dismantled are filled with controlled low-strength material (CLSM). The disposition plan and the pipeline length condition are shown in table 2.

Table 2. Disposal Plan for Decommissioned Pipelines

Pipeline name	Removal Length / km	Filling treatment length / km
East Yellow Line	5.01	27.99
East Yellow Double Line	10.38	18.62

4.3. The Construction Technology of Filling Controlled Low-strength Material In-Situ Disposal

4.3.1. Nitrogen Replacement Oil Pumping. The two ends of the decommissioned pipe section are excavated for oil extraction operation pits (bottom 4 m * 6 m). Cleaning the anticorrosion layer of the valve position, and nitrogen replacement is carried out with the original equipment of the pipeline.; welding open holes, install DN 50 ball valve (pump valve) at bottom of pipe (from 1.5 m); after sealing open the hole with the special opening machine of the pipe, closed the pump valve. The other end of the pumping valve is connected to the pump, and opening the pump valve and pump, then Pumping crude oil into tank trucks for recycling.

4.3.2. The Nitrogen Pushes the Ball for Cleaning Oil. First, install the tee at the lower end of the pipe, and the ball tube is installed on the other side. Next, gasify the liquid nitrogen at the side of the tee and push the ball after pressure and remove the crude oil and gas in pipeline. Meanwhile, open the pumping device next to the ball tube. Then pull it in special tank truck for recycling. And then the receiver emits oil and gas. Finally, the number of promotion shall not be less than 3 times and ensure that oil and gas in the pipeline are drained, and fill the whole pipe with nitrogen.

4.3.3. Sectional Cutting and Sealing Pipeline. Combined with the layout of the site pipeline and use the filling performance of controlled low-strength materials to divide the filling construction segment, Each length L can be controlled at 600~1000 m.

Excavate the pit at the truncation point of the pipe, and the size and requirements are the same as the pumping pit. According to the local highs and lows of the survey pipeline, cutting and segmenting with mechanical cutting machine. Finally, install the grouting valve and exhaust valve at each high point. Mason butter mud wall at 300 mm from the pipe mouth at each pipe section, and install blind sealing tube. Meanwhile, the installed receiver can be reserved for sealing. Install DN 50 exhaust valve and observation valve respectively at each end of the pipe segment from the blind plate (or the receiver) inside 1-1.5 meters. The high point valve is used for exhaust, and the low valve is used to observe (and exhaust) whether the filler is full of ends. If the depth of the pipeline between the grouting port and the distal blind plate is undulating, and increase the installation of exhaust valve at a local high point exceeding the pipe diameter section.

4.3.4. Filling of Controllable Low-Strength Materials. Put the foam ball in the tee, and use the slurry pump truck fill in the controlled low-strength filling materials from the middle of the pipe continuously. Do well in on-site grouting quantity measurement, and ensure that grouting volume is matched with pipe capacity. Open exhaust valve and observation valve when filling. Next, confirm whether the filler arrives and fills the end position, the middle fluctuation segment and the high point. After each confirmation, turn off the end position observation valve, middle fluctuation section exhaust valve and high vent valve. Then stop grouting when filling is filled with pipe. Finally, through the check valve confirms that the material is solidified, and sealing and plugging. The construction section can be

continuously operated, and different construction sections can be operated simultaneously. Backfill the job pits after completing, and recover the site.

4.4. Environmental Impact Analysis of Pipeline Decommissioning Period

4.4.1. Environmental and Air Impact Analysis. In this case, the construction of the decommissioning pipeline is carried out little by little, there are a little sensitive points in the excavation section, and date of the work is generally 1-2 months. The impact on ambient air is mainly from the dust of trench excavation, dumping temporary piling up, backfill, vehicle transportation and so on. In addition, during the process trench excavation, a small amount fuel combustion flue gas will be generated during construction machinery operation, all of which are discharged at low attitude with a small amount of exhaust gas and a short impact time. The preparation of controllable low-strength materials preferred to select areas that far away from the residences and avoid personnel activities, which has short preparation time and the impact on the surrounding environment is small.

4.4.2. Environmental Impact Analysis of Surface Water. The wastewater generated during the construction period mainly comes from the domestic sewage of construction workers. The site does not set camp, and the accommodation of the construction staff is rented local hotels or houses. The construction section has the large disposability and the local discharge is very small. Domestic sewage relies mainly on the local domestic sewage treatment system, and has a slight impact on the surface water to environment. Construction should be strengthened management, prohibit the discharge of domestic sewage into nearby water bodies. Filing and curing pipeline construction section only at both ends of the construction activity, the middle of no construction activities and the construction of the two ends of the river should be avoided to ensure that the surface water has little effect.

4.4.3. Analysis of the Environmental Impact of Groundwater. The depth of buried pipeline is about 1.5m, and shallow's excavation does not involve underground aquifers. Have no influence on the groundwater environment. During the construction, the residual oil in the pipeline should be ensured not to drip and leak, so as to reduce the influence on the groundwater in the construction area.

4.4.4. Analysis of Sound Environment Impact. The source of noise in construction is mainly from construction machinery, such as excavators, hydraulic pipe-breaking machines, oil pumps, grouting machines and so on. The machinery, equipment and vehicles used in different construction's processes. Each construction's machine is approximated as a point source, and only the attenuation calculation of the distance is taken into consideration to obtain the noise contribution's values at different distances. The results are shown in table 3.

The standard of construction site boundary noise (GB 12523-2011) stipulates that the daytime noise limit of the construction site boundary is 70 dB (A) and night time of the noise limit is 55dB(A). As can be seen from Table 3, the noise of main construction machinery does not exceed the noise limit off daytime beyond 10m, and the noise of night time does not exceed 50 m. The impact of noise on the surrounding acoustic environment during construction is acceptable, but also short-term and reversible. Once the construction is completed, which will stop immediately.

Table 3. Estimated Value of Noise in Main Construction Equipment at Different Distances Unite: dB(A)

No.	The name of the machine	Noise values at different distances from the construction site				
		10 m	50 m	100 m	150 m	200 m
1	Bulldozer	52	38	32	28.5	26
2	Excavator	55	41	35	31.5	29
3	Pipe layer (crane)	52	38	32	28.5	26
4	Transport vehicles	60	46	40	36.5	34
5	Oil bump grouting bump	55	41	35	31.5	29
6	Diesel generators	60	46	40	36.5	34
7	Hydraulic pipe breaking machine	55	41	35	31.5	29

4.4.5. Environmental Impact Analysis. Take demolition measures to deal with decommissioning pipelines, and the process of digging will destroy the vegetation on the surface and will affect the construction of the soil within the scope of the filling controllable low-strength materials for curing treatment at both ends of the pipeline, which will have a small amount of ecology affected, but the middle area basically will not have ecological impact.

The soil and negation will be destroyed and disturbed, which in the excavation and backfilling construction zone. Especially in the excavation ditch about 2-3m in the range. The vegetation is severely damaged. The disturbance of soil makes for the structure, composition physicochemical properties of the soil. Furthermore, the properties of soil and the restoration and growth of natural vegetation were affected.

The plants affected by the destruction of construction sites are widely distributed and common species along the road, and distributed relatively evenly. The original vegetation is damaged locally, but it is not to change the species and composition in the area. Most of the pipe removed in urban areas, which will not cause damage to crops.

The destruction of natural vegetation in the construction area will cause some wildlife to lose some foraging places, habitats and active areas. Due to the very narrow area of destroyed vegetation, the adverse impact on the living environment of the animals is slight.

4.4.6. Impact Analysis of Solid Waste. The length removal of the pipe is about 15.39 km, according to the original welding position, 1283 scrap steel in total, the external environmental impact would be less, if the disposal of the qualified recycling unit was given to the qualified recycling department.

When installing a receiver device, welding flanges, attached to the pipe need to dismantle the original asphalt anticorrosive coating, quantity about 1 m³, oil-free by qualified recycling disposal recycling units, and contains oil leakage is to have the corresponding qualification of environmental technology companies collect disposal, after dispose of external environment.

The plugging operation produce no oil pollution when adopt airtight opening way. Place oil groove below the pipe cutting position, collect the dirty oil produced by cutting. In construction, there is no oil pollution, which has little impact on the external environment. A small amount of crude oil drips on the land surface in the construction of pipe cutting, the yield is about 3 m³, as hazardous waste, to have the corresponding qualification of environmental technology companies collect disposal, which do less damage to the external environment if being handled properly.

Domestic garbage produced by construction workers amount about 1.8 tons during 60 days, during the construction of decommissioning pipeline section. It will do less damage to the external environment if being collected and disposal by the local sanitation department.

The pipeline service a long time, punch stolen oil and pipeline leakage occurs frequently, which will pollute near soil. After excavation, the soil is repaired according to the soil condition in the trench, and the oily soil is taken out, which is collected and disposed by the environmental protection technology company with the corresponding qualification. After proper treatment, the external environment is less affected.

In the process of pigging, there is a part of oil pollution on the pipe cleaner, which belongs to hazardous waste and should be collected and disposal by the local sanitation department, thus do less damage to the external environment.

4.4.7. Analysis of Environmental Influence Factors of Filling Materials. The controllable low strength material is non-toxic and harmless, and the strength after filling and solidification is close to the soil strength, and the property is stable, thus it will not affect the environment. There is no oil and gas in the pipeline, after filling treatment, which has less impact on the environment.

5. Conclusion

The disposal scheme of decommissioning pipeline mainly includes demolition and disposal. The choice of disposal scheme mainly depends on the land utilization along the pipeline, the condition of the pipeline as well as the environmental impact assessment, while considering the technical feasibility and economic factors at the same time. The combined disposal scheme is not only capable to eliminate the safety and environmental risks, but also reduce the cost.

In view of the important link of the pipeline abandonment process, combined with the actual case of pipeline waste disposal in foreign countries, the pipeline shutdown, pipeline residue recovery and cleaning should be completed before or after the operation, thus it is suggested to adopt a combined cleaning method to clean up the whole line. Decommissioning pipeline demolition work carefully, to avoid leakage of residual pollutants, destruction of the environment, restoration of the ground. The construction technology of controllable low strength material for decommissioning pipeline is put forward. The controllable low strength material CLSM has the characteristics of high fluidity, low strength and long setting time, and can be compacted by self-flow or pumping to fill the waste pipeline.

The actual case in the east of the yellow line retired pipe is disposed, select the disposal scheme of combination, and discusses the key technology of filling pipeline cleaning, residue, analyzed the potential environmental impact of the pipeline retirement period, put forward the corresponding measures to prevent pollution and reduce the effect, to provide reference for the scientific disposal of waste oil and gas pipeline in China.

For the oil and gas pipeline should be abandoned, abandoned by plan reasonable, make the construction of a scientific and complete engineering, environmental protection design and decommissioning of environmental management, so as to guarantee the implementation of safety, environmental protection, economy of onshore oil and gas pipeline decommissioning.

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