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LITERARY REVIEW

Environmental impact of trenchless technology

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Contents

Introduction

It is known that all things have an end, in the case of underground pipelines it is the end of their reliable operating lifetime, and their condition dictates a replacement. Replacement of existing pipes is a major part of the market for pipeline contractors in an advanced economy like the United Kingdom. Pipes can be more than 100 to 200 years of age typically and replacement is needed to preserve integrity of supply and mitigate against downsides such as leakage.

Pipes of this type were originally constructed using open trenches cut into the ground and most often used rigid materials like iron, and later materials like asbestos cement, before the advent of plastic solutions. Many such pipes for different services have been laid below ground and it is considered now to be a congested environment making replacement more difficult, particularly when there is little or no tolerance to interruptions to supply of key utilities.

It is reasonable to state that in the context of the United Kingdom, the advent of flexible plastic pipes, particularly polyethylene materials in long continuous coil forms, has changed the approach to replacement. Starting with the gas industry, and coincident with the move from towns gas to natural gas, smaller pipes became the replacement requirement and installation by threading new pipes inside the old pipes quickly became normalized. Trenchless technology, in this context known as slip lining, became mainstream for utilities.

Water companies quickly adopted variations of the technology as well, at the time for the serious cost benefits versus trenching, and the ease of replacement in the congested underground space. With large zonal replacement programs in the 1990's particularly, the use of slip lining, close fit lining, and more likely in this space, the use of pipe bursting became the first choice for replacing old pipes. And polyethylene pipe the first choice as the replacement material due to its inherent flexibility and availability in long coil forms.

It is important to be balanced in observations, there is no such thing as one form of 'open cut trenching'. Trenching is still used but it is more likely a form of narrow trenching would be employed by those seeking to minimize impacts of their operations. And for the smallest pipes, particular service and communication pipes to properties it is more likely that impact moling would be used, or mole ploughing on larger estates[1].

Trenchless technologies of the type described were originally developed to reduce costs and social impacts of utilities replacing aged assets, mostly in our urban areas[2, 3]. But they also reduce the environmental impact compared to trench-based placement of new pipes which has long been known but now becomes a source of renewed interest with commitments to net zero by national government.

In research literature, trenchless technology is often grouped and analysed as a grouping of techniques, this is not appropriate, as there are intuitively wide differences in impacts. So research papers must be carefully considered in drawing conclusions. In the case of this study, distinction is made between trenchless technologies that use the existing worn-out pipe as either a conduit, or as a guide for the new pipe being installed, that is the three techniques of slip lining, close fit lining and of pipe bursting. That is distinct from the technologies such as directional drilling, mole ploughing, impact moling or tunnelling for example, also termed trenchless but more likely to be optioned against trench installation being used for new pipes, or for replacement.

In older papers we noted that social and economic considerations were the primary objects for lining and bursting techniques. Environmental merits are mentioned but they have reference in their time period to generic phrases like "a significant reduction in CO_2 emissions" and "less harm to urban greenery" for example[4]. The aim of this study is to seek to understand the quantifiable environmental impact of slip lining, close fit lining and pipe bursting, generically our trenchless solutions. A literature review has been conducted to identify evidence for greenhouse gas emissions from all stages of the technique usage and reported herein.

Pipe bursting

Pipe bursting is recognized for its ability to provide a size for size replacement of an existing pipeline, or in certain cases, upsizing of the asset. It works with both brittle materials like cast iron and more ductile materials like ductile iron and steel. Hydraulic power is transmitted along rods to a splitting tool which is advanced through the old pipe. The old pipe is taken beyond its yield strain resulting in fracture and fragmentation of the material. A conical tool compresses the soil surround and fractures to form a channel below ground, through which a new pipe is simultaneously being pulled into position[5].

Literature review—Pipe bursting; Beale et al (2013)

In this study the reduction in CO_2 e emissions by using pipe bursting in place of trench methods is quantified. The study concentrates on Scope 1 emissions[6] which is specific to the on-site processes used by the two techniques being compared. It does not include aspects of the manufacturing or disposal of pipe materials for example, nor does it include the consequential impacts of the construction affecting traffic flow for example. The environmental impact was assessed using a planning tool known as PARMS, widely used planning software by UK designers in the water sector[7].

A specific scenario is modelled, comprising a pipe of 200mm diameter, length 200m, a depth of cover of 1.5m and access pits for the new pipe of 3.3m x 1.8m.

Specific to the Scope 1 scenario outlined, it was found that the CO_2 e emissions from use of the pipe bursting technique were 74% lower than had trenching techniques been used, or in CO_2 e terms a reduction from 26 tonnes to 7 tonnes by use of the technique.

Literature review—Pipe bursting; Joshi (2012)

In this study[8] specific reference is made to the impact on traffic flows[2] resulting from utility works to replace their pipelines. It is known that works often require closure of one lane in a carriageway for example. This results in traffic management and standing traffic as a consequence. The longer the works for example, the longer the duration of standing traffic as a direct consequence, this Scope 1 and Scope 3 emissions are recognized.

In this study traffic flows have been measured in the time period 8am to 6pm coincident with the site works. Emissions relating to the traffic flow are derived from fuel consumption based on carbon content of a gallon of either petrol or diesel, and the speed the traffic flows through the lane restriction. The carbon content of the fuel is then related to CO_2.

In addition to the traffic flow, the paper also considers the fuel consumption of machinery working on site, and both importing and exporting materials linked to excavation elements of the techniques being compared. One finding is that irrespective of the pipe replacement method, the consumption of fuel on site was greater than the consumption of fuel by cars negotiating the lane restriction in this study. But in relation to fuel from all sources, the use of pipe bursting resulted in 68-74% less fuel being used.

By simulating traffic flow at a single location, a specific scenario has been given which can limit comparability to other studies. Others though have considered different traffic plans[9]. It is sensible then to not extrapolate too far in conclusions, rather it is indicative of benefits. Environmental analysts have noted that in focusing on CO_2, relating to traffic, that this also misses the other gaseous releases and particulates. But a trend is nonetheless observable.

Literature review—Pipe bursting; Lu et al (2020)

In this study[10] a modelling analysis is performed to measure energy consumption and directly quantify carbon footprint impacts of pipe bursting. Consideration is given to manufacturing, transport and on site construction of the replacement pipeline (Scope 1 emissions). The paper assesses the influence of six variables; diameter, soil type, ground condition, surface type, pipe length and depth of cover.

The soil type and ground condition were found to affect the energy consumption. The greatest impact was when the ground included heavy soils, rocks, or water. Surface type and construction length were less significant variables in relation to the pipe bursting technique. All of which seems logical and intuitive. Because of the influence of the factors, the study found a range existing in relation to the benefit of pipe bursting compared to trenching, with energy consumption/carbon reduction of between 50 to 82%.

Literature review—Pipe bursting; Ariaratnam et al (2009)

In this study[11] similar scope 1 emissions were calculated for transport and installation of a replacement pipe, in this case a sewer pipe and a specific scenario – the replacement of a 200mm clay pipe with a 250mm polyethylene pipe, a depth of cover of 2.1m and an entry pit of 3.35m x 1.8m for the pipe bursting scenario.

In this study the older form of winching a splitting head was used and the winch is located in an existing manhole structure which is undisturbed by the process. In this study consideration is given to a number of pollutants released by fuels and engines associated with construction machinery which is more normal in life cycle analysis and environmental product declarations for example.

The authors found that particulate matter and carbon monoxide reduced by 74-85% using pipe bursting in comparison to trenching and concluded that greenhouse gas emissions reduced by 77%.

Literature review—Pipe bursting; Loss et al (2018)

In this study[12] a full life cycle analysis has been performed, although the focus is on construction and the usage and maintenance stages are omitted it should be noted. But potentially all three Scope emissions are contemplated. This study looks at two materials being replaced, these being cast iron or asbestos cement. It is noted that asbestos cement is viewed differently around the world in relation to its suitability for pipe bursting, more normally slip or close fit lining is preferred to avoid disturbing the old material.

The study identified that the largest environmental impact is fuel consumption linked to excavation of materials and removal of materials for disposal/recycling. This would seem intuitive when considered in a UK context when any material for backfilling trenches has to be imported from a grading facility. This imported material is self-compacting and will not result in settlement of the road surface for example following the utility works.

Whilst noting the reduction in emissions follows that of other studies in general, this work at least recognizes that fragmented pipe sections in the soil may cause damage to ecosystems which needs to be weighed in decision making, or to account for them as soil emissions in a life cycle analysis. Currently iron materials are considered reasonable by opinion leaders to remain in soil and be subject to natural degradation mechanisms but as noted, increasingly asbestos cement is not deemed acceptable, primarily due to the uncontrolled nature of health hazards for workers who may subsequently been digging and working in and around fragmented sections.

Slip lining

Where pipe bursting is more likely to be used by UK water utilities seeking size for size replacement, it is more likely that slip lining will be used by UK gas utilities, whose replacement pipes can be smaller. This recognizes a change in the medium that the original pipes were sized for, which was gas made from coal, to natural gas in the 1970's. Natural gas has a higher calorific value meaning less gas was needed to get the same amount of heat to residential buildings. Less gas meant smaller replacement pipes could be installed when the original pipes reached the end of their operating lifetime. Quite simply the old pipe is used as a conduit and a new smaller pipe is either pulled through, pushed through, or a combination of both depending on the size and length of the deployment.

It is often the case that old pipes that can no longer contain fluids at pressure are still able to support the soil structure, moving from tensile to compressive loading of the material. The old pipe may then be left as a conduit for the new. It is known that where concerns exist about the condition of the old pipe in this way, then either a close fitting liner will be installed, which we will describe later, or the annular space can be filled with a grout material. Grouted forms are not used in the UK.

Literature review—Slip Lining; Beale et al (2013)

Additional to pipe bursting, this study also used the PARMS tool to analyse the impact of slip lining a 200mm diameter pipe in the same scenario already described, although the entry pit for slip lining was sized as 3m x 1.5m in this example. Entry pits are sized to allow the, usually, polyethylene replacement pipe to form through natural curves from above ground to the entry into the old pipe. The length is usually a variable linked to the depth to which the pipe needs to descend.

In this scenario specific example, the slip lining solution results in CO_2 e reduction of 81% compared to the trench replacement scenario.

Literature review—Slip Lining; Lu et al (2020)

In this study the broader scope 1 emissions linked to manufacturing, transport and on site construction are considered for slip lining. For all scenarios, using pipes from 50mm to 300mm in this study, there is a reduction in energy and related emissions by slip lining rather than trenching, that range being 55 to 91%. The benefit is typically greater the smaller the diameter of the pipe being replaced by this methodology.

Close-fit lining

One of the advantages of a polyethylene material in the form of a pipe is the ability to temporarily change its dimensions or shape within certain limits. Common examples known by their tradenames in the UK are Rolldown and Swagelining. In both cases the pipe diameter is temporarily reduced by nominally 10-15% which allows it to be pushed or pulled inside an old pipe as if it were the previously described slip lining method. But once in the pipe will revert towards it original diameter and has the potential to become a tight fit inside the old pipe. Other forms, for example known by tradenames of Subline and Subcoil, have the pipe temporarily folded, then after insertion energized to unfold and achieve the same objective. The techniques are probably best suited where pipe bursting is not viable, for example with asbestos cement pipes, old pipes in soils with low/no compressibility, or pipes in close proximity to sensitive infrastructure like power cables[1].

Literature review—Close Fit Lining

There is a scarcity of literature dealing specifically with scientific based assessment of greenhouse gas emissions linked to this form of technology. Which may be reasonable given it represents a much smaller usage that the more commonly employed volume techniques of pipe bursting and of slip lining[13]. Were it be assessed, it is expected that benefit in greenhouse gas reductions would follow that of slip lining but would be a reduce saving, this would reflect the energy required on site to effect the temporary compression of the liner material itself. A potential research gap is therefore identified for consideration.

Discussion

It is clear that care should be exercised in using the term 'trenchless technology' in combination with a particular pipe and claims around greenhouse gas emissions, particularly if some form of scientific basis is required to back them up. There is no such thing as generic trenchless technology. This paper concerns itself primarily with a group of techniques that rely on the old pipe to form a conduit in the ground through which a new pipe is inserted, either by first fracturing and displacing the old pipe, or simply by pulling a smaller new pipe inside the old one. This needs to be distinguished in any assertions made on the benefits of a particular solution.

In the UK context, it is known that pipe bursting is the primary technique used by contractors to water utilities, the default model being to replace pipes at least with size for size comparable replacements. However, in contrast, the historical nature of the gas distribution grid means that replacing pipes originally sized for gas derived from coal can be achieved with smaller pipes now we have natural gas, thus the volume technique is slip-lining. These two techniques, having delivered social and economic improvements, offer a greenhouse gas emissions reduction which can be evidenced.

Depending on the pipe size, and taking account of a reasonable range of scenarios, slip lining appears the least energy intensive replacement with a new polyethylene pipe, with reductions in the range 55 to 91% across the studies reviewed. Pipe bursting, using a high level of energy for the fragmentation stage offers reductions of the order 50 to 82%. In both cases this is in comparison to the use of open trench cutting to install a new replacement pipe. It is noted that there is no scientific evidence yet in relation to close fit lining, but this is due to the lower level of usage rather than any perceived concern about the likely results.

Conclusion(s)

When discussing claims in relation to trenchless technology it is important to use scientific evidence, and to name the techniques rather than use the term generically.

In relation to pipe bursting with polyethylene pipe (the main technique used by water utilities in the UK), the likely emissions reduction compared to trenching are scenario specific, range between 50-82%.

In relation to slip lining with polyethylene pipe (the main technique used by gas utilities in the UK), the likely emissions reduction compared to trenching, again scenario specific, range between 55-91%.

It was found that the smaller the diameter of the pipe being replaced, the greater the benefit, which is also a reflection of the practical limitations of how narrow a trench could be.

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