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LIFE CYCLE ASSESSMENT: COMPARING STRATEGIC OPTIONS FOR THE MAINS INFRASTRUCTURE – PART I

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ABSTRACT

This paper presents the preliminary results of a Life Cycle Assessment (LCA) study which aims to compare two different potable water pipe materials: ductile iron (DI) and medium density polyethylene (MDPE). Stages where environmental impacts may be reduced in the life cycle of these pipes have been highlighted. A takeback scheme between water companies and pipe suppliers has been identified as an environmental improvement to the current disposal stage of the pipe life cycle. Potential exists for dual-use or reuse of abandoned mains. © 1999 Published by Elsevier Science Ltd on behalf of the IAWQ. All rights reserved

KEYWORDS

Life cycle assessment; mains infrastructure; pipe materials; waste disposal.

INTRODUCTION

The water mains infrastructure was established in the UK in the eighteenth century, the impetus being to protect public health against diseases such as cholera. The historical development of this infrastructure has dictated that today Thames Water is responsible for 31,000km of water mains consisting of approximately 80% cast iron pipe. Many pipes in the network exceed the design life-span of 50 years (common to all pipe materials) and now a point has been reached where a critical number may be in need of repair or replacement. This is indicated by the burst rate. For example, within the region supplied by Thames Water, a record 4000 bursts occurred in a three week period during the winter of 1996/1997 which was eight times the norm. The volume of water lost exceeded the amount of water put into supply on the hottest day of 1996 (TWN, 1997).

The question is now being posed as to whether mains rehabilitation, structural repair, or replacement of water mains is the best way, both economically and environmentally, to address the problem of the mains infrastructure. The UK water companies must decide how to tackle this problem, which in the past has been approached by primarily considering logistical and cost criteria. It is the aim of this research to highlight the environmental impacts of the various pipe materials available for replacement, so as to inform the strategic decision making process. This paper reports the preliminary results of an ongoing LCA study of potable water pipes. To date work has focused upon the disposal stage of the life cycle, the main findings of which are reported and recommendations for improvements are outlined below.

METHOD – LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is a tool for evaluating the environmental performance of a product, process or service, starting from raw material extraction, through manufacture to use and final disposal. It is also known as a "cradle-to-grave" approach. This methodology enables identification of the major environmental impacts throughout the life cycle of a product, or process, and the assessment of the possibilities for affecting improvements. The LCA methodology is described in detail in SETAC (1993).

Discussion of the environmental impacts of different pipe materials dates back to 1993 (Hoffman, 1993). Since then, INTRON (Institute for Materials and Environmental Research, the Netherlands) has performed a LCA of concrete, clay and PVC sewer pipes. This study has been the subject of much controversy as results seemed to favour the funding body's product (ENDS, 1996). No work has been found to date that directly considers potable water pipes.

RESULTS AND DISCUSSION

LCA of pipe materials

The purpose of this LCA study is to quantify the environmental impacts occurring throughout the life cycle of the different pipe materials. The overall aim is to integrate this information with cost, performance and legislative criteria to aid decision making regarding future pipe installations. The results relate to the functional unit, defined as a 100m length of pipe delivering potable water under a minimum pressure of 10 bar, with an internal diameter of 100mm. Figure 1 illustrates the life cycle stages of a potable water pipe. The materials under analysis are ductile iron (DI) and medium density polyethylene (MDPE).

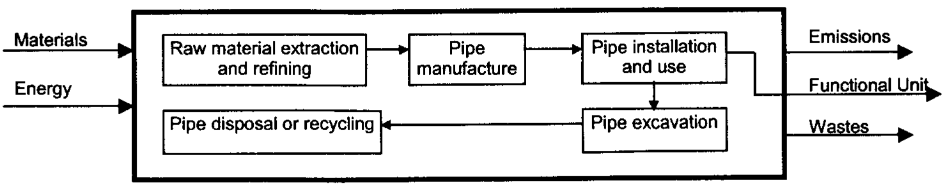

Figure 1. Stages considered in the life cycle of a potable water pipe.

Complete data sets for the manufacture of DI and MDPE pipes have been collated. Information regarding the transport of pipes from the manufacturer to Thames Water is currently being collated, as is the data for the "Pipe installation and use" and "Pipe excavation" stages of the life cycle (Figure 1). Analysis of the "Raw material extraction and refining" and the "Pipe manufacture" stages of the life cycle (Figure 1) yield the following results which are of particular interest.

Ductile iron pipe. The external protective coating of zinc contributes significantly to the total process energy required to manufacture the functional unit from raw materials (Table 1). This demonstrates that constituent materials, not the pipe manufacture, can significantly contribute to the environmental impacts of DI pipe, and therefore they should be selected with care. The pipe manufacturing stage makes the greatest contribution to global warming potential (Figure 2), therefore making improvements to this stage of the life cycle would present the greatest opportunity for reducing this environmental impact.

Table 1. Significant stages in the life cycle of DI pipe production, that contribute to the total process energy required for pipe manufacture

Life Cycle Stage	Percentage Process Energy
Incineration of Waste arising from the pipe manufacture	1
Production of bitumen (internal pipe coating)	4
Production of zinc (external pipe coating)	95

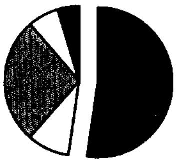

Figure 2. Percentage contribution to global warming potential - DI pipe production.

MDPE pipe. The production of polyethylene gives rise to a significant proportion of the environmental impacts. For example, it contributes to 74% of the total global warming potential caused by this system (Figure 3). Therefore, if improvements are to be made to the impacts of pipe production, the polyethylene manufacture would be the most appropriate stage of the life cycle to target.

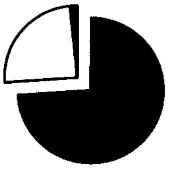

Figure 3. Percentage contribution to global warming potential - MDPE pipe production.

The disposal stage of the pipe life cycle: A case study

Introduction. The mass of waste currently recovered from maintenance of the mains infrastructure was calculated in the region managed by Thames Water. In addition, the mass of waste, which may be recovered but is currently being disposed of in an uncontrolled manner, was also calculated (Table 2). Wastes considered were straight pipe lengths and sluice valves; other waste sources such as pipe bends, T-pieces and butterfly valves were excluded.

Table 2. Quantity of waste currently being recovered and that which could potentially be recovered

Material Waste	Tonnage per annum
Current metal (cast & ductile iron) recovery	8
Estimated amount of additional metal waste available for recovery	841
Current plastic (MDPE & PVC) recovery	203
Estimated amount of additional plastic waste available for recovery	6
Estimated amount of waste generated from sluice valves (currently sent to landfill)	135

Current methods of pipe disposal were studied. Different business units within the company have a stake in the rehabilitation, repair and replacement of potable water pipes, and are therefore responsible for the generation of waste. Normal practice is to abandon replaced lengths of main in the ground as recovery is uneconomic. Waste arising from rehabilitation or repair is either buried on site, sent to landfill or sold for reprocessing. Sluice valves, of which there are many in the infrastructure (300,904 in number, ranging from

25kg to 1.6kg) are currently sent to landfill as separation of the different metal constituents is not economically viable.

Improvement options. Alternative options are being evaluated to determine the best environmental option for this stage of the pipe life cycle, including continuing current practice; reuse of the abandoned mains; centralised recovery of the waste to be sold to a waste processor for general recycling, or to a pipe manufacturer for reprocessing into pipes. The Secretary of State in the UK has advised that "scrap metal recovery is a source of benefit to the environment and sustainable development" (Controlled Waste Regulation, 1992; Circular, 1995). Therefore, current local recycling of recovered metal waste by the site contractors via scrap dealers, though uncontrolled, is a positive contribution to the environment. Water companies could improve upon this practice by collecting the waste and returning it to pipe suppliers, thereby exerting more direct control and closing the material-loop via a takeback scheme.

Recommendations - Reuse of abandoned mains. Although this is an option to potentially reduce the environmental impact of the disposal stage of the pipe life cycle, it is only applicable to significant lengths of main. Reuse is preferable to pipe recovery as it avoids environmental and economic costs of excavating the main. Examples of such avoided costs include: fuel consumption and emissions of travel to and from site; excavating to the main; recovering the main; backfilling and transporting the main for recycling; any associated traffic congestion due to the street works. Reuse is also preferable to abandonment as it avoids loss of a valuable material from the material cycle. There are various examples of such reuse. In the 1980s North West Water sold a disused pipe network, which was used to run the hydraulic lift system in inner city Manchester, into which telecommunication cables were laid (Caulderbank, 1997). A more recent example of dual-use is to be found in Tokyo (Nakazato, 1997) where communication cables have been fixed to the soffit of sewerage pipes. These examples demonstrate the potential for reuse of abandoned mains as valuable ready-made underground cavities.

Recommendations - Recovery. Recovery and recycling of metal waste (valves, customer connection chambers, pipes etc.) generated from repair work also has the potential to reduce the environmental impacts of the disposal stage. Manufacture of metal pipes by a cubilot production system is suitable for the reprocessing of metal waste into pipes. It is recommended that the waste is centralised and collected by (or delivered to) a metal pipe manufacturer with such a production system. The creation of additional transport would be minimised by reusing existing return journeys. This would represent a closed loop system, whereby waste is reprocessed into a similar product.

Thames Water currently operates a system of centralising and selling plastic pipe waste to a reprocessor for recycling. The centralisation step utilises existing transport journeys, minimising the environmental impact of the collection system. The feasibility of setting up a closed loop recycling system is constrained due to the strict public health regulation covering materials in contact with potable drinking water (Water Supply Water Quality Regulations, 1989). This current system should be expanded, with more control being exerted at site level to increase plastic recovery, thus reducing environmental impacts.

CONCLUSION

This study identified a significant pipe waste stream, so far overlooked. The LCA analysis of the pipe life cycle has highlighted areas where environmental impacts may be reduced. Alternative strategic options for managing the mains infrastructure, such as extended material recovery or reuse could result in environmental benefits.

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