Risk Assessment and Risk Management of PCBs in Gas Transmission Lines

Exponent®

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Prepared for

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Foreword

On April 7, 2010, the U.S. Environmental Protection Agency (EPA) issued an Advance Notice of Proposed Rulemaking (ANPRM) entitled *Polychlorinated Biphenyls (PCBs); Reassessment of Use Authorizations*. In this ANPRM, EPA proposes to reassess the existing PCB use authorizations under the Toxic Substances Control Act (TSCA), including the use authorization for PCBs in natural gas pipelines, air compressor systems, and porous surfaces. As part of this reassessment, EPA has proposed to revise and/or eliminate these use authorizations in a way that could significantly and dramatically impact natural gas pipeline operations. Natural gas pipelines have been subject to programs addressing PCBs for the past 30 years, starting with EPA's Compliance Monitoring Program (CMP) in the early 1980s to EPA's present comprehensive regulatory program, better known as the PCB Mega Rule.

The Interstate Natural Gas Association of America (INGAA) is a trade association representing virtually all interstate natural gas transmission companies operating in the United States. INGAA therefore has a direct interest in the EPA's ANPRM and accordingly has prepared comments in response. In support of these comments, INGAA has commissioned several independent experts to prepare "White Papers" providing key analysis of the complex issues raised by the EPA's ANPRM with respect to the presence of PCBs in the interstate natural gas pipeline system. These papers address pipelines and pipeline operations, the presence of residual PCBs in the pipeline system, the risks to health and the environment associated with PCB-impacted pipelines, the technical feasibility of removing increasingly diminished concentrations of PCBs and the anticipated economic impacts resulting from EPA's proposals.

Exponent was commissioned to analyze PCB toxicology and the exposure risks associated with residual PCBs in the interstate natural gas pipeline system, and other topics of relevance to the natural gas pipeline industry. While commissioned by INGAA in support of its comments, this report is an independent analysis, and its conclusions are based on the expertise of the authors.

Executive Summary

This paper provides information that can be used to judge whether current and future management of polychlorinated biphenyls (PCBs) in natural gas transmission pipelines[1] poses an unreasonable risk to human health and the environment. As described in the U.S. Environmental Protection Agency's (EPA's) Advance Notice of Proposed Rule Making[2] (ANPRM), the objective of the anticipated rulemaking would be to modify any of the regulations that apply to PCBs or PCB items, as necessary, if these uses present an unreasonable risk to human health and the environment. Such modifications would take into account conditions as they exist and as they are likely to exist in the future. EPA's stated concern is that, over the past 30 years, many changes have taken place such that the balance of risks and benefits from the continued use of remaining equipment containing PCBs may have changed. With respect to risk-related matters, such changes could include the emergence of new information about exposure and new knowledge about effects.

This paper examines exposure issues related to PCBs in natural gas transmission pipeline systems. It relies on information on how PCBs are currently managed by companies engaged in the interstate transmission of natural gas, to examine the potential for exposure to PCBs within the natural gas transmission system. That system includes the pipelines and related equipment (e.g., compressors). The analysis considers the most probable exposure pathways associated with current operations. To this end, input on PCB management operations was received from Environmental Health and Safety (EHS) and other operational personnel at various natural gas pipeline companies in order to provide a factual basis for the analysis of most exposure. Also considered was the temporal trend in exposure from the 1980s. As described in the paper and detailed elsewhere, PCB concentrations in pipeline liquids and associated exposures have been declining substantially for many years before the Mega Rule, and have continued to decline subsequent to its enactment. These declines in exposure and risk are important aspects for assessing the effectiveness of existing risk management procedures and for projecting risks into the future.

Existing risk and PCB management practices are important elements of pipeline operations and are described herein to provide context for assessing the current and future risks associated with the presence of PCBs in natural gas pipelines. The paper considers the potential for incidental exposure to liquids (pipeline liquids). The focus of the assessment is on the public, the pipeline worker, and the environment. Quantitative risk estimates for the pipeline worker are used not only to assess risks to these individuals, but to provide insights into risks to the public.

The paper also examines the health, safety, and environmental implications of pipeline replacement as a means to reduce the amount of PCBs within pipelines. Given the complexity

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[1] Unless stated otherwise, "natural gas transmission pipelines," "natural gas pipeline companies," and "natural gas pipeline systems" all refer to interstate natural gas transmission systems.

[2] Environmental Protection Agency, 40 CFR Part 761 [EPA-HQ-OPPT-2009-0757; FRL-8811-7]. RIN 2070-AJ38 Polychlorinated Biphenyls (PCBs); Reassessment of Use Applications. Advance notice of proposed rulemaking (ANPRM). Federal Register April 7, 2010. Vol 75 (66).

of pipeline systems, whole replacement of parts of the system may be needed to meet new regulations that require reductions in PCB inventories within the pipelines. This latter assessment identifies the factors that should be considered as part of regulatory decision-making. In particular, the paper points out the broad range of non-PCB related risks that can arise under a pipeline and equipment replacement program. This is important if the intent is to manage overall environmental and health risks. A narrow risk-based approach that considers only one aspect of a complex issue can easily miss important risk-related issues that can impact the public and the environment. This paper points out some of these other aspects. The paper also evaluates the use of the 50 ppm benchmark for PCBs in pipeline liquids with respect to its value as a risk management tool. In this regard, the effectiveness of this benchmark is examined with respect to providing protection of health and the environment, while at the same time leading to a continued reduction in PCB mass and concentrations within pipeline liquids.

Current PCB Management Practices for Natural Gas Transmission Lines

For the natural gas transmission pipeline systems that do have pipe segments with currently reportable PCB concentration (e.g., PCB liquids at ≥50 ppm), the practice is: 1) to collect and dispose of the liquids, and 2) to test, dispose, and/or clean pipe sections and equipment that is being removed from the system due to corrosion or other integrity issues or that requires maintenance and repair. These practices are performed in accordance with company best management practices and current PCB regulations (i.e., the PCB Mega Rule). Under normal natural gas transmission pipeline operating conditions, there is little potential for exposure to the residual PCBs in the system, and as time passes, the concentration of PCBs in these systems decreases as more and more PCB-containing liquid is collected and managed. Exposure to the PCBs is limited, because the PCBs are contained within the pipeline system where the public and the environment have little or no potential for exposure.

The pipeline companies implemented specific worker health and safety and environmental protection for potential PCB exposure or spills. This information was shared through industry-sponsored educational programs and technical seminars. EPA's PCB Mega Rule was promulgated in 1998. These regulations ushered in a successful regulatory framework that took advantage of the government's and industry's 17 years of knowledge about PCB impacted pipelines. For the past 12 years, these regulations have proven to be an effective tool for both EPA and industry to manage natural gas pipeline-related PCBs.

The interstate natural gas transmission industry is regulated by the Federal Energy Regulatory Commission (FERC). All pipeline operators must address PCBs in their FERC filings involving the replacement, abandonment by removal, or abandonment in place of facilities determined to have PCBs in excess of 50 ppm in pipeline liquids.

Potential for Exposure

This analysis considers the potential for PCB exposure to the public, the environment, and to maintenance workers who engage in a variety of activities that might bring them into contact with PCBs in the range of 50ppm. The value of 50 ppm defines the regulatory limit for defining PCB-impacted liquids. The analysis provides exposure estimates consistent with those performed in 1984 by Versar for EPA. Although the exposure and risk estimates have been developed for a PCB concentration of 50 ppm in liquids, they could be scaled up or down for higher and lower exposure concentrations because the calculated risks are proportional to concentration. For example, for an exposure concentration of 25 ppm, the risks would be one-half of those presented in the paper; at a concentration of 100 ppm, the risks would be twice those presented. For natural gas transmission lines, the PCBs of interest for exposure occur within liquids that are composed mainly of hydrocarbons that have dropped out of the gas system. Cleaning operations consist of draining liquids from the pipeline and placing them into containment (e.g., drums), removing and replacing filters, and placing the removed filters into containment for disposal, and pigging operations. Because liquids, residues, and filters removed and/or cleaned from pipelines are contained in accordance with regulatory procedures and industry EHS compliance plans, there is little or no opportunity for these PCBs to reach the environment or the public, from the time the PCBs are removed from the pipeline until they are disposed of in accordance with regulatory requirements.

The exposure assessment, based in part on assessment of worker exposure, indicates that exposures to the public and to the environment are negligible. This includes consumers of natural gas as well as individuals who may reside or work near areas where pipelines are being serviced. Exposures of workers who come into contact with PCB residues within pipelines as part of normal operations were evaluated for pipeline systems that are considered to be impacted with PCBs (>50 ppm in liquids). Activities that can lead to potential exposures of workers include pigging operations, removal of filters, and removal of liquids. Workers are protected from exposure by wearing personal protective equipment (PPE), including gloves. Workers wearing PPE when handling PCB-containing equipment should have negligible exposure via dermal and oral contact. In addition, because workers wear PPE to handle liquids regardless of PCB content, it is unlikely that there would be a “surprise” exposure to liquids that are thought to be clean of PCBs but actually contain some PCBs. Exposure estimates were developed for individuals who did not wear PPE, in order to derive an upper-bound, albeit aberrant, exposure event. This paper relies on the exposure estimates developed by EPA/Versar in 1984 and an updated exposure assessment that incorporates recent EPA policy on exposure assessment. Because cleaning and handling of liquids occur as controlled events, the exposure of the public and the environment to pipeline liquids is judged to be negligible.

Toxicity of PCBs Identified in Natural Gas Transmission Systems

The Aroclors® found in pipelines include Aroclors® 1242 and 1248 (used as lubricating oils); Aroclors® 1254, 1260, and 1268 may also be present. EPA’s cancer slope factor for Aroclor 1254 (54% chlorine content) was used for assessing cancer risks. If toxic effects are indeed related to the degree of chlorination, this should yield a somewhat conservative upper-bound value for the PCB mixture in pipelines, because these are composed primarily of Aroclors® 1242 and 1248 that respectively have 42% and to 48% chlorine content. This slope factor is the upper end of a range of upper-bound cancer slope estimates derived by EPA based on liver cancers in rats exposed to various PCB mixtures in laboratory studies. For cancer risks associated with inhalation, EPA notes that for evaluation of risks associated with inhalation of evaporated congeners, the middle-tier slope factor of 0.4 per (mg/kg)/day is used, and this was used in the assessment to translate EPA/Versar air exposure estimates into risk estimates for workers and for the public.

This paper also describes why the use of the Aroclor®-based approach is more appropriate than the dioxin-based approach for risk management purposes for PCBs in equipment and pipelines. The main reason is that while the dioxin-based approach has the appearance of providing more precision for estimating risks and for capturing particular types of effects, the dioxin-based method also introduces large uncertainties into the risk assessment and risk management process. The uncertainty is derived from a number of factors, but two are especially evident. First, the dioxin-based method is a "sum of the parts" approach for which the toxicity of the mixture is derived from individual toxicities of select compounds; second, the approach is linked to the toxicity of dioxin for which there is uncertainty at low-dose exposures. In contrast, the current Aroclor®-based approach relies on toxicity studies with the complete mixture, an approach generally considered superior to assessments of individual compounds within the mixture. Bbecause the current assessment relates to Aroclor® mixtures within a contained system as compared to PCBs in the external environment, there is less uncertainty in using the whole mixture Aroclor® approach as compared to the dioxin-based approach. Finally, the Aroclor®-based approach takes into account the toxicities associated with all compounds ("dioxin-like" as well as "non-dioxin like") present within the mixture. By relying on a whole mixture approach, the potential for inappropriately double counting toxicity, inherent in the dioxin-based approach, is avoided. The uncertainty already inherent in PCB risk assessment should be a key consideration with respect to modifying approaches for assessing toxicity of these compounds.

Although EPA has considered the human data inadequate for risk assessment, available studies suggest there is no positive correlation between cancer incidence and even relatively high PCB exposures in the workplace. Most noteworthy from the epidemiological data on PCBs and human cancer is the lack of a consistent outcome in the various studies. Among studies commonly cited as evidence for the human carcinogenicity of PCBs, no consistency can be found across the reported positive findings with respect to cancer type. Such data are suggestive of spurious associations or multi-chemical exposures and not consistent with a common causative agent (e.g., PCBs).

For evaluation of noncancer effects of Aroclors®, EPA has published a chronic reference dose of 0.00002 mg/kg-day for Aroclor® 1254. While this value is used in the assessment, it is noted that EPA derived this value by applying a number of uncertainty factors to available toxicological data. This yields a conservative value for use with worker populations. However, using this value yields an upper-bound estimate of risk.

Health and Environmental Risks: Current Operating Conditions

Exposure and risks to the public are estimated to be negligible. This includes exposure and risks to consumers of natural gas. That assessment is based, in part, on consideration of quantitative risk estimates for more highly exposed pipeline worker populations. For workers who use PPE, risks associated with PCB exposure are considered negligible, and risks to individual employees who do not employ PPE are not considered unreasonable. Risks to an individual who does not wear PPE are calculated by combining calculated estimates of exposure developed by EPA/Versar and an updated exposure assessment with toxicity values for cancer and noncancer endpoints. Toxicity values are developed according to EPA policy and are intended to represent an upper end of the potential toxicity of that chemical. Thus, they yield theoretical upper bounds on risks. This becomes an important consideration when these theoretical risk estimates are contrasted with risk estimates derived from measured accident and injury rates within the industry and for the public.

In general, the 1984 exposure estimates of EPA/Versar, adjusted for key updated exposure factors in accordance with current EPA policy, were very similar to those developed for an updated exposure assessment. The risk calculations based on updated exposure estimates show that if an individual does not wear PPE and comes into contact with liquids as a single inadvertent exposure event, all risks would be well below 10^{-6}, the low end of the risk range for exposures to 50 ppm PCBs in liquids. The calculations also show that this individual would not be exposed at a level that would exceed a hazard index of 1 for 50 ppm PCBs in liquids. However, to provide an upper bound on risks for workers engaged in normal pipeline operations, risks were calculated assuming that this individual never wears PPE and engages in liquid removal and other activities that bring him or her into contact with PCBs. For this purpose, information provided by the interstate natural gas pipeline industry was used to represent exposures during all activities that involve current management of PCBs. For risk assessment purposes, the estimated frequency used was once per month, or twelve times per year. This is the same frequency that EPA/Versar judged to be most representative of exposure. (They also considered a daily exposure.) The calculated theoretical annual cancer risk for an individual worker who does not wear PPE, with one year of monthly contact with PCBs in PCB-impacted equipment and liquids containing 50 ppm, is 4×10^{-7}. Because risks are proportional to exposure concentration, this risk estimate can be scaled up or down to reflect that other PCB exposures below and above the regulatory benchmark. However, it is apparent there is a margin of safety that covers PCB exposure concentrations greater than 50 ppm.

The calculated lifetime cancer risks associated with the 1984 EPA/Versar air exposure estimates for the worker were 5.6×10^{-6} for daily exposures and 2.9×10^{-7} for monthly exposures. Use of the most relevant cancer slope factor in conjunction with the most appropriate exposure frequency (monthly) results in estimated risks below EPA's acceptable risk range for the public of 10^{-6} to 10^{-4}, indicating very low risks. Even assuming a daily exposure, risks are within the acceptable range. The calculations performed for EPA by Versar assumed that individual workers would be exposed throughout their work life to a constant concentration of PCBs at 50 ppm. The updated risk estimates developed for this paper do not presume that this would be the typical case. However, even for the work life of an employee not wearing PPE (assumed by EPA and in our upper-bound calculation), the risks posed to workers are low and would not be judged to be unreasonable. The findings supported by these calculations are consistent with what is generally known about the low volatility of PCBs: EPA's "Regional Screening Levels" (formerly "PRGs") indicate that assessing risks from inhalation exposure to PCBs is appropriate only for the PCB Aroclor® mixtures designated as "volatile." These include Aroclor® 1221 and Aroclor® 1231, which are composed of the lower-chlorinated congeners, and which are not known to be associated with the pipeline industry. The low calculated risks to workers at the locations where exposure would be greatest indicates that exposures and risks will be negligible with increasing distance from the locations nearest to the potential source of exposure. The current PCB management practices for natural gas transmission pipelines, performed in accordance with existing PCB-related regulations, do not present an unreasonable risk to the environment or natural resources.

Health and Environmental Risks: Pipeline and Equipment Replacement

Pipeline and equipment replacement for PCB-impacted parts of the system may be driven by new PCB regulations that seek to achieve reductions in PCBs within the pipeline system. While these actions may reduce the inventory of PCBs in pipelines, they also create other risks to health and the environment over and above those that exist as part of the current management program. These additional risks should be factored into decision-making regarding the overall environmental/health costs and benefits of alternative management approaches.

For pipeline replacement, these additional potential risks to the public and the environment include the following:

- Traffic accidents associated with the increased truck traffic to haul the old pipe offsite and to haul the new pipe in for the replacement project. These risks are expected to increase for segments of pipeline replaced in urban areas where population densities are greater than in rural areas;
- Damage to sensitive habitats as the pipeline is excavated and replaced; and
- An increased carbon footprint for the replacement projects in comparison to baseline pipeline operation conditions.

A life-cycle approach could be used to consider these additional risks to the public and the environment. This would provide a more complete basis for comparing existing baseline risks which appear to be low or negligible to the risks associated with other regulatory-driven management approaches.

Risk Reduction with Time

The inventory and concentrations of PCBs in pipelines identified as PCB-impacted have declined steadily. The continual reduction of PCB mass and concentration is a reflection of the fact that PCBs are not an integral part of the operating system and that they are continually being removed. Thus, risk estimates for pipeline liquid exposures have declined by one or more orders of magnitude over the past 25 years. Because the management process is still underway, continued reduction in the PCB mass and concentrations are expected into the future. There does not appear to be a situation of aging infrastructure that would lead to an unanticipated increase in risks to workers, the public, or the environment.

Risk Management Considerations: Using 50 ppm as a Benchmark

This paper provides a review of the development of the 50-ppm value for PCBs that has subsequently been used for management purposes. The paper considers the effectiveness of this value for management purposes. In 1984, EPA's Office of Toxic Substances, through its contractor Versar, calculated exposures to materials containing 50 ppm PCBs, and these estimates were compared with updated estimates based on more recent EPA policy for exposure assessment. Both the EPA/Versar estimates and the updated estimates support the conclusion that current management practices for PCBs in natural gas transmission pipelines do not pose an unreasonable risk. They indicate that the 50 ppm benchmark has served as an effective tool for reducing the inventory and the exposures associated with PCBs within these systems.

Conclusions

The assessment supports the following conclusions:

- The current management practice has resulted in a substantial reduction of the PCB inventory within pipelines, the levels of PCB concentrations in pipeline liquids, and the volumes of PCB liquids to be managed. All of this reduces exposure levels, and as noted below, existing exposure levels do not pose an unreasonable risk. Continued implementation of the existing management practices will result in future reductions in the potential for exposure. The 50 ppm benchmark used for managing PCB-impacted liquids is health protective and appropriate for achieving reductions in PCB inventories and concentrations over time.
- Exposures to the public and the environment associated with the presence and management of PCB-impacted liquids within natural gas transmission pipelines are negligible.
- Exposures of PCBs to consumers, who use natural gas, are negligible.
- The frequency of exposure to PCB-containing media (e.g., liquids, soil, concrete surface, or indoor air) is very limited for natural gas transmission pipeline workers and exposures generally are controlled by the use of proper safety procedures, including the use of PPE and ventilation of compressor

buildings. For these reasons, PCB exposure risks are negligible for pipeline workers wearing PPE in compliance with current operational procedures.

- Workers typically wear PPE for handling pipeline liquids, regardless of whether PCBs are present. Thus, there is a low likelihood of a surprise exposure to PCBs in liquids that are thought to be below 50 ppm but that actually contain some PCBs (e.g., >1 ppm).
- The current EPA Aroclor® mixture-based policy for evaluating the toxicity of PCBs is appropriate, and provides a more than adequate basis for supporting sound risk management of PCB-impacted liquids in pipelines. There is no need to substitute a different methodology with greater inherent uncertainty than the existing method.
- Because PCBs in liquids and equipment are managed as part of controlled and deliberate events, exposures of the public, environment, and/or natural resources are negligible.

The assessment of exposure to PCBs present in natural gas transmission pipelines indicates that compliance with existing PCB regulations is producing continued reductions in the amounts of PCBs in pipelines, and in the potential for exposure to those PCBs. The assessment further indicates that existing and future exposures to PCBs present within the pipelines do not pose an unreasonable risk under current management approaches. Those management approaches are performed in compliance with existing EPA regulations.

1. Introduction

This paper provides information that can be used to judge whether current and future management of PCBs in natural gas transmission pipelines poses an unreasonable risk to human health and the environment. The pipeline system includes the pipelines and related equipment (e.g., compressors). This paper also considers whether the current management of PCBs in impacted pipelines, including the use of 50 ppm as a benchmark for PCBs in pipeline liquids, is appropriate and effective for reducing the inventory of PCBs and for protecting human health and the environment. The Aroclors® used as lubricating oils in pipelines primarily include Aroclor® 1242 and 1248. Lesser amounts of Aroclors® 1254, 1260, and 1268 also may be present. Aroclor® 1254 is associated with the Pydraul used in the air compressor systems. The reporting of Aroclor® 1260 is thought to be related to weathered 1254, or to be from a source where the original mixture may not have been pure. Aroclor® 1268 is associated with valve sealant.

As described in the U.S. Environmental Protection Agency's (EPA's) Advance Notice of Proposed Rule Making[3] (ANPRM), the objective of the anticipated rule making would be to modify any of the regulations that apply to PCBs or PCB-impacted items, as necessary, if these uses present an unreasonable risk to human health and the environment, taking into account conditions as they exist and as they are likely to exist in the future. EPA's stated concern is that, over the past 30 years, many changes have taken place such that the balance of risks and benefits from the continued use of remaining equipment containing PCBs may have changed. With respect to risk-related matters, such changes could include exposure and knowledge of effects.

EPA identifies certain exposure aspects of PCB risks considered in this paper. This paper considers the extent to which this concern applies to natural gas transmission pipelines. EPA further identifies aging infrastructure as a possible factor contributing to future releases of PCBs to the environment. This paper describes the risk of exposure to PCBs from the industry practices for maintaining the integrity of the pipeline infrastructure. This paper examines exposure issues related to PCBs in the natural gas transmission pipeline system and relies on information regarding how PCBs currently are managed by natural gas transmission pipeline companies. The analysis considers the most probable exposure pathways associated with current operations. Environmental Health and Safety (EHS) and other operational personnel at various companies provided input on PCB management operations to establish as factual a basis as possible for the analysis. As described in the paper and detailed by S.S. Papadopulos & Associates, Inc.,[4] PCB concentrations have been declining substantially for many years before and after implementation of the Mega Rule. These declines are considered in this report as they

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[3] U.S. Environmental Protection Agency, 40 CFR Part 761 [EPA-HQ-OPPT-2009-0757; FRL-8811-7]. RIN 2070-AJ38 Polychlorinated Biphenyls (PCBs); Reassessment of use applications. Advance notice of proposed rulemaking (ANPRM). Federal Register April 7, 2010. Vol 75 (66).

[4] S.S. Papadopolos & Associates, Inc., PCBs in the Interstate Natural Gas Pipeline System – Status and Trends (August 2010).

are important aspects for assessing the effectiveness of existing risk management procedures and for projecting future risks.

Existing risk and PCB management practices are important elements of pipeline operations and are described here to provide context for assessing the current and future risks associated with the presence of PCBs in natural gas pipelines. The report considers the potential for incidental exposure to liquids (pipeline liquids), air exposures associated with handling or spillage of condensate/liquids, and air exposures to consumers using natural gas.

The assessment uses existing Aroclor®-based toxicity values for estimating risk. The paper describes why use of these values is appropriate. To that end, a brief discussion is provided on why an alternative or supplemental approach based on “dioxin-like” compounds is not needed for sound health-protective management decisions and why that method actually might introduce more uncertainty into the assessment.

The paper begins with an overview of PCBs in pipelines and compressor stations. The paper then examines exposures under current operating conditions including those developed by EPA/Versar in 1984. This is followed by a discussion of toxicological implications. The exposure and toxicological information is then combined to assess health risks. The paper describes the relative risks of historical PCBs under current and future conditions. Because EPA regulations might result in more aggressive PCB management programs such as pipeline replacement, the paper examines the potential risks associated with that possibility. Finally, the paper reviews the adequacy of the current 50 ppm PCB value used to manage pipeline liquids.

2. PCBs in Pipelines and Compressor Stations

Overview

This section of the report provides details on the occurrence and management of PCBs in interstate natural gas transmission pipelines. The section provides context for considering current and future risks associated with these chemicals.

In the late 1950s, some pipeline companies began using lubricating oil containing PCBs in certain[5] centrifugal compressors, as well as PCB-containing sealant for valves that are located in the mainline pipeline. This use of lubricating oil in those particular compressors continued until approximately June 1972, when Monsanto stopped selling PCB lubricants, and PCB-laden oils in the compressor units was eventually replaced. The manufacture of valve sealant also stopped at that time, but interstate pipeline companies were not aware that PCBs were used in the manufacture of this sealant until much later. For example, the Interstate Natural Gas Association of America (INGAA) notified its members in 1991 about the presence of PCBs in certain kinds of valve sealant. Some INGAA members with trace amounts of PCBs in their pipeline systems do not have a purchase record of using either class of PCB-containing products (compressor oil or valve sealant), so the original source of PCB contamination in these systems is unknown.

For the purpose of this report, the presence of trace amounts of PCBs in transmission pipeline systems is considered with respect to two phases: 1) incidental pipeline hydrocarbon liquids[6] that may form periodically in the pipeline and 2) residual PCBs that have not been flushed during pipeline operations to locations where liquids can be removed from the pipeline. Each is discussed in turn.

The chemical properties of PCBs, and the physical properties of transmission systems, determine the importance of and distribution in each of these locations. The important chemical properties of PCBs for this discussion are as follows: 1) PCBs are lipophilic, meaning that they accumulate in organic substances such as oils, sealant, or the liquid phase of hydrocarbon liquids; 2) PCBs have low solubility in water and therefore tend not to enter the water phase of liquids. The important physical properties of natural gas transmission pipeline systems for this discussion are as follows: 1) Pipeline systems are highly contained, with only brief and occasional openings to the environment; 2) pipeline systems are complex, with many separate components; 3) pipeline systems are geographically distributed. This results in multiple miles of pipe, and includes pipes that are primarily below ground, but can protrude above ground.

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[5] It is estimated that a small amount of the total gas compressors in operation on the interstate natural gas transmission pipelines at that time used this lubricant in the compressor section of the centrifugal turbines.

[6] Natural gas contains trace hydrocarbon components that condense at temperatures and pressures that may exist at particular locations on the pipeline system.

PCBs in Pipeline Liquids

Sampling of pipeline liquids (liquids or legacy liquids) has been performed by interstate natural gas pipelines pursuant to a 1981 EPA voluntary request to all natural gas pipeline operators, as well as the requirements of both the 1981 Compliance Monitoring Program (CMP) involving thirteen interstate natural gas pipeline companies and the 1998 PCB Mega Rule.

Interstate natural gas pipeline companies have identified the lubricating oil systems of centrifugal pipeline compressors that could have used PCB-laden products, sampled the suspected lubricants, removed the PCB-laden lubricating products, and remediated the lubricating systems.

Based on this sampling, companies have identified the interstate natural gas pipeline segments where PCBs may be present at levels above 50 ppm in pipeline liquids. Pipeline liquids are removed and managed by filter/separators, pipeline drips, and diffuser tanks. Each compressor station is equipped with separators or drips and liquid accumulation tanks that remove pipeline liquids from the gas stream prior to recompression, to minimize damage to compression equipment. In pipelines that can be pigged,[7] squeegee and cleaning pigs that are pushed down the pipeline by gas flow remove some pipeline scale and debris, as well as resident pipeline liquids. In the segments of pipeline that contain PCBs at concentrations greater than or equal to 50 ppm, pipeline companies sample the liquids at each pig receiver trap or historical liquid collection point (separator, pipeline drips) to monitor the PCB levels of liquids recovered from the system. Pipeline liquids from pigging operations are pumped into the storage tanks and the liquids in the storage tanks are analyzed for PCBs. In addition, PCBs in liquids collected in filter/separators are also managed through proper removal, disposal, and replacement.

Bulk liquid movement down the pipeline can occur because of the shear stress of the natural gas flow on top of a pool of liquid at higher natural gas stream velocities. With increasing natural gas stream velocity, liquids climb the walls of the pipe tending toward an annular flow pattern. Elevation differences along the pipeline and obstructions tend to prevent downstream[8] travel of liquid pools. Liquid formation is undesirable for pipeline operations, because among other reasons, the interaction between the gas and liquid phase that causes the liquid transport also leads to a pressure drop along the pipeline and the need for increased gas compression, resulting in decreased operating pipeline capacity. This accumulation of pipeline liquid usually is mitigated by the periodic placement of liquid collection points, pipeline drips, and periodic pigging of the pipeline to push the liquid to separator locations.

[7] Natural gas pipelines were not originally designed to pass solid devices through the pipeline, because natural gas is compressible and large volumes of liquids are not expected to be in the pipelines. The Pipeline and Hazardous Materials Safety Administration has required that all new pipelines be piggable unless certain criteria are met, and most pipeline companies have gradually replaced components on legacy pipelines to allow pigs to be used.

[8] Downstream describes the direction of the flow of natural gas within the pipeline, rather than an elevation term typically described in liquid flow terms.

Residual PCBs

Residual PCBs may occur within solid organic deposits or scale on pipeline walls; on surfaces in compressors, valves, and other system components; and in minute amounts of undrainable liquid volumes inside compressors, valve cavities, and other system components. For several decades during which some systems had continual PCB loading from product use, PCBs diffused into relatively inaccessible locations. With the cessation of PCB product use, PCBs began to purge from the system by dissolving into hydrocarbon pipeline liquids (excellent solvents for PCBs), which are periodically removed from the pipeline system. Reduction of PCB concentrations in liquids requires continual diffusion of residual legacy PCBs from scaly surfaces within pipelines, and the removal of minute amounts of legacy PCB liquids. It is not surprising that reducing the concentration of PCB liquid samples takes time, because diffusion of PCBs into the system occurred over several decades[9].

PCB Management Practices for Natural Gas Transmission Lines

Many natural gas transmission pipelines have no detectable or very low-level PCB contamination, so no additional management action will ever be required for these pipeline systems. However, if the use authorization is set for <1 ppm, then even companies with "very low level PCB contamination" will be required to remediate. It should be noted that pipeline systems were not required to be characterized at EPA's currently proposed level of 1 ppm; therefore, the full extent of PCB presence in pipeline systems at the present time is unknown. For the limited number of natural gas transmission pipeline systems that do have PCB concentrations at currently reportable quantities (e.g., PCB liquids at ≥50 ppm), the standard practice is to collect and dispose of the liquids, and to test and dispose of or test and remediate pipe sections or other equipment that is removed because of corrosion or other integrity issues or that require maintenance and repair. These practices are performed in accordance with documented best management practices and the current PCB regulations (i.e., the PCB Mega Rule). Under normal natural gas transmission pipeline operation conditions, there is little potential for exposure of workers, the public, and the environment to the residual PCBs in the system, and as time passes, the total mass of PCBs in these systems decreases as more and more pipeline liquids act as solvents and the PCBs are collected and managed using best management practices.

EPA's PCB Mega rule was promulgated in 1998. These regulations ushered in a successful regulatory framework that took advantage of the government's and industry's knowledge base on pipeline PCBs accumulated over the prior 17 years. For the past 12 years, these regulations

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9 By way of illustration, suppose after some time, PCBs are contained in some small fixed volume, V, including on walls, etc. Suppose further that the limiting rate for PCBs being collected by pipeline liquids is diffusion through an area, A, associated with this volume. If the concentration in the volume is C and the diffusion coefficient is D, the mass flux velocity at time t is $F = AC\sqrt{\frac{D}{t}} = -V\frac{dC}{dt}$. Solving this equation gives $C = C_0 e^{-\frac{2A}{V}\sqrt{Dt}}$, corresponding to an exponential decay. The half-life of this decay is $t_{\frac{1}{2}} = 0.35\ \frac{V}{A}\sqrt{\frac{t}{D}}$. Thus, the half-life increases slowly with time, which is characteristic of diffusion situations.

have proven to be an effective tool for both EPA and industry to manage natural gas pipeline–related PCBs.

3. Exposure Assessment: Current Operating Conditions

Potential for Exposure

PCBs exist as legacy contaminants in the pipeline system. For natural gas transmission lines, most of the PCBs of interest for exposure occur within liquids that are composed mainly of hydrocarbons that have dropped out of the gas stream. Because PCBs are lipophilic, they become dissolved into this hydrocarbon mixture. This exposure analysis considers the potential for exposure of the public and the environment to these PCBs. The exposure analysis relies in part on the conceptual approach and associated exposure estimates developed for EPA in 1984. These estimates have been updated using current exposure factors and toxicity values for PCBs.

Pipeline liquids containing PCBs can gather at different points in the system in volumes of a few to tens of gallons. Cleaning of pipelines is an operational activity and because the PCBs cleaned from the pipeline are not permitted to disperse into the environment, the pipeline worker receives the greatest potential exposure. Because pipeline liquids containing PCBs are managed in accordance with regulations, the highest potential exposures are those that occur for pipeline maintenance workers. Therefore, exposure and risk estimates are developed for these workers as a basis for judging exposure not only to the workers but also as an upper bound on exposure that would occur for the public and the environment. Cleaning operations consist of periodic draining of liquids from accumulation points on the pipeline separators (pipeline drips) and placing them into containment (e.g., tanks or drums), removing and replacing filter elements and placing the removed filters into containment for disposal, and pigging operations that involve the generation of residues and the handling of the pigs. Liquids from filter/separators and pig receivers are typically pumped to aboveground storage tanks. This further reduces employee exposure. Based on discussions with pipeline EHS personnel, the combined exposure from these activities might be on the order of a few to perhaps a dozen times per year per pipeline maintenance worker. Exposure durations during these operations may be less than an hour to a few hours. Maintenance workers who are working on pipelines and equipment where PCBs are known or suspected to be present wear personal protective equipment (PPE) to avoid dermal contact. Moreover, because the liquids contain other hydrocarbons that may be hazardous to workers, PPE is a standard requirement for maintenance operations that might involve contact with liquids. This typically involves wearing gloves and appropriate outer wear.

Exposure to PCBs in Pipeline Liquids

Liquids, residues, and filters removed and/or cleaned from pipelines are contained in accordance with regulatory procedures and industry EHS compliance plans. Therefore, there is little or no opportunity for these PCBs to reach the environment or the public from the time the PCBs are removed from the pipeline until they are disposed of in accordance with regulatory procedure. The exposure analysis conducted for EPA in 1984 and updated in this paper considered exposure of pipeline workers to these liquids. The analysis examined the potential for exposure to PCBs at 50 ppm. The value of 50 ppm defines the regulatory limit for defining PCB-impacted liquids. Exposure and risk estimates for concentrations of PCBs that are less than or greater than 50 ppm can be scaled from the exposure and risk estimates provided in this report because exposure and risk are proportional to concentrations. The 50 ppm exposure concentration is used in this paper as this is consistent with the 1984 exposures estimates performed by Versar for EPA.

The activities that can lead to potential exposure of workers to liquids impacted by PCBs include pigging operations, removal of filters, and removal of liquids. Workers are protected from exposure by wearing PPE, including protective gloves. Workers wear PPE when managing PCB-containing materials, and are expected to wear PPE whenever workers are handling pipeline liquids regardless of PCB level. Based on the use of PPE for these operations, the following statements can be made about exposure to workers:

1. Workers wearing PPE when handling PCB-containing equipment should have negligible exposure via dermal and oral contact;

2. Because workers wear PPE to handle liquids regardless of PCB content, it is unlikely that there would be a "surprise" exposure to liquids that are thought to be clean of PCBs but actually contain some PCBs;

3. Dermal exposures and associated oral exposures (hand-to-mouth activity) might occur if individuals fail to follow requirements to wear PPE; this occurrence would represent an upper-bound, albeit aberrant, exposure event; and

4. Because cleaning and handling of liquids occur as controlled events, exposure of the public and the environment to pipeline liquids is judged to be negligible.

The statements above support the conclusion that exposure of the worker is controlled and negligible. Further, exposure of the public and the environment is negligible. However, this paper examines the magnitude of exposure associated with exposure events during which workers do not wear PPE. As noted above, this is an aberrant exposure event. Nevertheless, it provides a means of gaining insight into a quantitative upper bound to exposure to the pipeline worker under current operating conditions. Because the management of pipeline liquids would still be controlled, exposure of the public and environment to PCB-impacted liquids would still be negligible.

The following subsection provides the exposure factors and estimates developed for EPA and updated in this paper.

Exposure Estimates for PCB-impacted Pipeline Liquids Developed for EPA

EPA, through its contractor Versar, conducted exposure assessments for PCBs at concentrations of 50, 25, and 2 ppm.[10] The intent was to assess exposure associated with incidental production, recycling, and selected use authorizations. The exposure estimates provide insight into the reliability of the 50 ppm value as a benchmark for managing PCB-impacted pipeline liquids. The approach used for EPA is described below along with the exposure estimates. Brief notes are provided on how the exposure estimates were updated in this paper based on current EPA methodology for exposure assessment.

EPA/Versar dermal exposure estimates for pipeline workers exposed to PCB-impacted liquids incorporated the following exposure factors:

- Exposure frequencies of 12 days per year (once per month) and 240 days per year (daily) evaluated;
- Exposure duration of 38.5 years;
- 100% absorption through skin;
- 810 cm^2 of skin surface (all of both hands) with liquid thickness of 0.0016 cm; and
- Liquids density 1g/$cm.^2$

The resultant lifetime exposure estimate for liquids impacted with PCBs at 50 ppm was 3.6×10^{-4} mg/kg-day, assuming 240 days per year exposure and 1.8×10^{-5} mg/kg-day assuming 12 days per year of exposure. The 1984 exposure factors used by EPA/Versar for examining exposure to PCB-impacted pipeline liquids are relatively conservative compared to EPA's current exposure factors, which are used in this paper to update these same exposures. EPA/Versar relied on a scenario in which pipeline workers would be exposed daily over a period of almost 40 years, and that 100% of PCBs would be absorbed through the skin. Controlled management of PCBs by pipeline workers involves PPE and is much less frequent than that used for the 1984 EPA/Versar estimate (monthly versus daily). Further, EPA has developed more recent dermal absorption factors that yield lower exposure estimates than those that would have been calculated in 1984. EPA/Versar 1984 estimates of exposed skin surface for individuals who do not wear PPE are similar to those used in this paper to update the 1984 exposure estimate. In addition, the updated estimate also considers the potential for hand-to-mouth transfer, an exposure pathway included in current exposure estimates.

EPA/Versar inhalation exposure estimates for pipeline workers exposed to PCB-impacted liquids incorporated the following exposure factors:

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[10] Versar, Inc. 1984. Exposure assessment for polychlorinated biphenyls (PCBs): Incidental production, recycling, and selected authorized uses. EPA Contract No. 68-01-6271. Prepared for U.S. EPA Office of Toxic Substances, Exposure Evaluation Division, Washington DC.

- A calculated air concentration of 2.9×10^{-4} mg/m^3 associated with liquids concentration of 50 ppm;
- Exposure frequencies of 12 days per year (monthly) and 240 days per year (daily) evaluated;
- Exposure duration of 38.5 years; and
- 100% absorption through lungs.

The resultant lifetime exposure estimate via inhalation for liquids impacted at 50 ppm PCBs was 1.4×10^{-5} mg/kg-day, assuming 240 days per year on exposure and 7.2×10^{-7} mg/kg-day assuming 12 days per year of exposure. EPA/Versar considered that the daily exposure scenario was “quite unlikely.” They noted that data from natural gas transmission companies indicated that liquids cleanup occurred approximately monthly, and even then, there were not always liquids to clean. So the monthly scenario was considered more realistic.

The EPA/Versar inhalation exposure estimates are ~250 times less than the dermal exposure estimates, and thus make a negligible incremental contribution to exposure. Because exposure depends in large part on the presumed exposure concentration in air, a check was made of the value used by EPA/Versar. Page 214 of the Versar report states that, “[t]he maximum concentration of PCBs in the air above condensate containing 50 mg/kg PCBs is 2.9×10^{-4} mg/m^3 at 25 ^{0}C. If the PCB concentration in the condensate is 25 mg/kg or 2 mg/kg maximum airborne concentrations of PCBs are 1.4×10^{-4} mg/m^3 or 1.1×10^{-5} mg/m^3, respectively (see Attachment D).” From this statement, it appears that only temperature and PCB concentration in condensate are required to calculate a <u>maximum</u> indoor air concentration, given certain PCB and condensate properties. Note the absence of any reference to air exchange rate, room size, or wind speed. Note also that this maximum concentration appears to be proportional to the PCB concentration in condensate. It appears that the equation used to calculate the indoor air concentration, C_i, is simply equilibrium:

$$C_i = \frac{P_v}{RT} x_i \quad (1)$$

where x_i is the dimensionless mol fraction given by Raoult’s Law:

$$x_i = C_c \frac{MW_{condensate}}{MW_{PCB}} \quad (2)$$

The terms appearing in these equations are as follows:

- P_v= PCB vapor pressure mm Hg
- R=gas constant=62.3637×10^{-3} mm Hg-m^3/K^0-mol
- T=temperature=25C^0=298.15 K^0
- C_c=concentration of PCBs in condensate=50×10^{-6}, etc.

- $MW_{condensate}$=average molecular weight of concentrate
- MW_{PCB}= molecular weight of the PCBs.

Combining Equations 1 and 2 gives C_i in terms of mol/m^3. These are converted to units of gm/m^3 by multiplying by the PCB molecular weight in gm/mol. The result for C_i is therefore independent of the PCB molecular weight. This yields:

$$C_i\left(\frac{gm}{m^3}\right) = 2.6891x10^{-6} P_v(mm\ Hg) MW_{condensate} \quad (3)$$

These equations were checked by substituting C_i=2.9 × 10^{-4}mg/m^3= 2.9 × 10^{-7} gm/m^3 to obtain:

$$P_v(\text{mm Hg})\ MW_{condensate} = 0.1078 \quad (4)$$

Unfortunately, both parameters are unknown, insofar as what Versar actually used. However, it is reasonable to expect that the molecular weight of condensate cannot be too different from 100. Thus we estimate P_v~10^{-3} mm Hg. This is, in fact, the value given by Monsanto for Aroclor® 1242. Although ATSDR gives a smaller value of 4.06×10^{-4}, the ATSDR value might not have been available at the time Versar composed their report and the Monsanto value is more risk conservative.

Equation 1 is the most conservative formulation possible for calculating an air concentration because it corresponds to absolutely no ventilation, an inexhaustible supply of PCBs and condensate,[11] and instantaneous diffusion of PCB molecules from below the surface of the pool to the surface. Under the conditions assumed, as many PCB molecules are moving from the air into the condensate pool as are moving from the condensate pool into the air. Equations 1 and 2 also make the conservative assumption that PCB molecules affinity for condensate, their lipophilicity, does not affect their rate of volatilization.

It appears, therefore, that the air concentration derived by EPA/Versar is quite conservative. Given that the resultant exposure estimate is more than two orders of magnitude less than that associated with dermal contact, inhalation is a relatively negligible source of incremental exposure for pipeline workers relative to the dermal contact pathway. The inhalation exposure estimate is used later in this paper to consider risks to workers as well as to the public beyond the controlled locations where pipeline condensate is located.

Updated Exposure Estimates for PCB-impacted Pipeline Liquids

An updated exposure estimate for pipeline workers exposed to PCB-impacted liquids is examined not only to judge exposure to the workers, but also to consider the potential for exposure to the public and to the environment. Pipeline workers are considered the receptors

[11] Otherwise conditions in the condensate pool, both relative concentrations and pool size, would change as the room or environment filled with PCBs and other condensate chemicals.

that have the highest potential for exposure, and by quantifying that exposure, insights can also be gained into exposures to the public and the environment.

The 1984 exposure estimates developed by EPA/Versar were updated using current exposure assessment methodology. The updated estimate of exposure incurred by an individual who does not wear PPE assumes that the individual handles the equipment by hand, thus resulting in dermal contact. Because this individual handles equipment by hand, there is also the possibility for hand-to-mouth transfer of PCBs. For that reason, the exposure estimate includes an oral exposure component. The updated estimate assumes that dermal contact occurs through the hand, and exposure has been estimated using exposure factors developed by and/or accepted by EPA. Accepted exposure factors are used for the hand-to-mouth pathway. The surface area for dermal contact is estimated as the palms of the hands and 10% of the forearms. The oral ingestion exposure is estimated using a published estimate of the frequency of hand-to-mouth activity and the amount of skin contacted. Exposure estimates are provided in Attachment A (Table A1).

Annual exposure is estimated for the individual maintenance worker who does not wear PPE. For that estimate, it is assumed that contact with equipment and/or PCB-impacted liquids occurs 12 times per year. This provides a reasonable upper-bound estimate of an annual exposure for a worker involved in routine maintenance operations involving PCB contact.

4. Toxicological Considerations

Toxicity of PCBs Identified in Natural Gas Transmission Systems

The Aroclors® used in pipelines (as lubricating oils) primarily include Aroclor® 1242 and 1248. Lesser amounts of Aroclors® 1254, 1260, and 1268 may also be present. Aroclor® 1254 is associated with the Pydraul® used in the air compressor systems. The reporting of Aroclor® 1260 is thought to be related to weathered Aroclor® 1254 or to be from a source where the original mixture may not have been pure. Aroclor® 1268 is associated with valve sealant.

The standard procedure for a toxicity assessment is to identify toxicity values for carcinogenic and noncarcinogenic effects and summarize other relevant toxicity information. EPA has established procedures for conducting this assessment for the types of Aroclors® introduced into pipeline systems. Carcinogenic effects are evaluated through application of a cancer slope factor (CSF), and noncancer effects are evaluated by comparison of exposure estimates with a reference dose (RfD). The risk evaluation provided in this paper relies upon current EPA toxicity values and is consistent with standard practice. For PCB mixtures that are chlorinated above the 30% level, the standard practice is to use toxicity values that were derived based on higher chlorinated PCBs. Thus, because the Aroclors® under consideration here were all more than 30% chlorinated, the toxicity value for Aroclor® 1254 (54% chlorine content) is applied. However, if toxic effects are indeed related to the degree of chlorination, this should yield a somewhat conservative upper-bound value for the toxicity of PCB lubricants in pipelines, because these are composed primarily of Aroclors® 1242 and 1248, which are Aroclors® with lower levels of chlorine content (42% to 48%, respectively). Small amounts of other Aroclors® with higher chlorine content (e.g., 1254, 1260, and 1268) are also present in the pipelines.

As noted in the ANPRM and later in this paper, EPA is also considering ways to assess the presence of "dioxin-like" PCBs present within PCB mixtures. This method is judged to be less reliable for risk management purposes as compared to the current Aroclor®-based approach. This is mainly because of the greater uncertainty inherent in the dioxin based method. The uncertainty is derived from a number of factors, but two are especially evident. First, the dioxin-based method is a "sum of the parts" approach for which the toxicity of the mixture is derived from individual toxicities of select compounds; second, the approach is linked to the toxicity of dioxin for which there is uncertainty at low-dose exposures. In contrast, the current Aroclor®-based approach relies on toxicity studies with the complete mixture, an approach generally considered superior to assessments of individual compounds. Because the current assessment relates to Aroclor® mixtures within a contained system as compared to PCBs in the external environment, there is less uncertainty in using the whole mixture Aroclor® approach as compared to the dioxin-based approach. Finally, the Aroclor®-based approach takes into account the toxicities associated with all compounds ("dioxin-like" as well as "non-dioxin like") present within the mixture. By relying on a whole mixture approach, the potential for inappropriately double counting toxicity, inherent in the dioxin-based approach, is easily avoided.

Cancer Slope Factor (CSF) for Aroclors® for Dermal (and Associated Oral) Exposure

A CSF of 2 $(mg/kg\text{-}day)^{-1}$ is used to represent the potential for cancer risk to be associated with PCBs in natural gas transmission pipelines. This value is based on data for Aroclors® 1254 and 1260, and was applied to derive risk estimates for Aroclor® 1254 in oral and dermal exposures. (U.S. EPA 2010).[12] This slope factor is the upper end of a range of upper-bound cancer slope estimates derived by EPA based on liver cancers in rats exposed to various PCB mixtures in laboratory studies. Results ranged from 0.04 $(mg/kg\text{-}day)^{-1}$ for male rats exposed to Aroclor® 1016 to 2.2 $(mg/kg\text{-}day)^{-1}$ for female rats exposed to Aroclor® 1260 (U.S. EPA 1996).[13] EPA recommends using the highest of these CSFs, rounded to 2 $(mg/kg\text{-}day)^{-1}$, as the upper-bound CSF for evaluating food-chain exposures, sediment or soil ingestion, and dermal contact exposures (if a dermal absorption factor is used) for all PCB Aroclors® (unless congeners with more than four chlorines make up less than 0.5% of total PCBs) (U.S. EPA 1996, 2010). Consistent with that recommendation, a CSF of 2 $(mg/kg\text{-}day)^{-1}$ was applied in this assessment.

It is important to recognize that the CSF is intended by EPA policy to represent an upper bound on toxicity. This is an especially important consideration when assessing the utility of the current method in relation to a proposed new method involving explicit consideration of dioxin-like compounds. An implication of the proposed method based on dioxin-like compounds is that the existing Aroclor®-based method may underestimate toxicity of PCBs. Such a comparison ignores the fact that the existing Aroclor®-based method is based on a policy decision to assess theoretical upper bound risk. This policy is evident in the 1986 Cancer Risk Assessment Guidelines (U.S. EPA 1986)[14] that state, "[i]t should be emphasized that the linearized multistage procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis. Such an estimate, however, does not necessarily give a realistic prediction of the risk. The true value of the risk is unknown, and may be as low as zero."[15] Further, in the 2005 Guidelines for Carcinogen Risk Assessment, EPA recommends the following default position in assessing chemical carcinogenicity (U.S. EPA 2005)[16]: "When the weight of evidence evaluation of all available data is insufficient to establish the mode of action for a tumor site and when [it is] scientifically plausible based on the available data, linear extrapolation is used as a default approach, because linear extrapolation generally is considered to be a health-protective approach."[17]

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[12] U.S. EPA. 2010. Integrated risk information system—chemical files for Aroclor® 1254 and for PCBs. U.S. Environmental Protection Agency, Office of Research and Development, Cincinnati, OH.

[13] U.S. EPA. 1996. PCBs: Cancer dose-response assessment and application to environmental mixtures. EPA/600/P-96/001F. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington, DC.

[14] U.S. EPA. 1986. Guidelines for Carcinogen Risk Assessment. Published on September 24, 1986, Federal Register 51 (185):33992-34003.

[15] Id at 13.

[16] U.S. EPA. 2005. Guidelines for Carcinogen Risk Assessment. EPA Risk Assessment Forum. EPA/630/P-03/001B, March 2005.

[17] Id 3-21.

Cancer Slope Factor for Inhalation

EPA notes that, for evaluation of risks associated with inhalation of evaporated congeners, the middle-tier slope factor of 0.4 per (mg/kg)/day can be converted to a unit risk estimate of 1×10^{-4} per $\mu g/m^3$. This value was applied for evaluation of PCBs in air using the exposure estimate developed by EPA/Versar. As with the CSF used for dermal/oral exposure, this value is an upper bound on the slope derived from toxicity studies.

Noncancer Toxicity Value for Aroclors®

For evaluation of noncancer effects of Aroclors®, EPA has published a chronic reference dose of 0.00002 mg/kg-day for Aroclor® 1254, and this is the value used in this assessment. The RfD for Aroclor® (1254 mg/kg-day) was derived from a series of studies in which rhesus monkeys were fed (oral contact) Aroclor® 1254 for a period of 5 years, resulting in ocular, dermal, and immunological effects (Tryphonas et al. 1989,[18] 1991,[19] Arnold et al. 1993[20]). The chronic RfD of 0.00002 mg/kg-day was derived from a lowest-observed-adverse-effect level (LOAEL) of 0.005 mg/kg-day <u>through application of an uncertainty factor of 300</u>, including a factor of 3 to account for extrapolation from subchronic to chronic exposure, and two factors of 10 to account for inter-individual and inter-species differences in sensitivity. Because this RfD takes into account all potential endpoints, it is considered to be protective of all noncancer adverse effects associated with Aroclor® 1254. The RfD is also intended to be protective of the general population, including sensitive individuals, for a lifetime of exposure. Thus, this RfD leads to very protective management decisions for workers who are typically healthier and constitute a less sensitive segment of the population. However, by using this value in the analysis, risk estimates are derived that serve as an upper bound for other environmental exposures and for the public.

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[18] Tryphonas, H., S. Hayward, L. O'Grady, J.C.K. Loo, D.L. Arnold, F. Bruce, and Z.Z. Zawidzka. 1989. Immunotoxicity studies of PCB (Aroclor® 1254) in the adult rhesus (*Macaca mulatta*) monkey–Preliminary report. Int. J. Immunoph. 11(2):199–206.

[19] Tryphonas, H., M.I. Luster, G. Schiffman, L.L. Dawson, M. Hodgen, D. Germolec, S. Hayward, F. Bryce, J.C.K. Loo, F. Mandy, and D.L. Arnold. 1991a. Effects of chronic exposure of PCB (Aroclor® 1254) on specific and nonspecific immune parameters in the rhesus (*Macaca mulatta*) monkey. Fund. Appl. Toxicol. 16:773–786.

Tryphonas, H., M.I. Luster, K.L. White, P.H. Naylor, M.R. Erdos, G.R. Burleson, D. Germolec, M. Hodgen, S. Hayward, and D.L. Arnold. 1991b. Effects of PCB (Aroclor® 1254) on non-specific immune parameters in rhesus (*Macaca mulatta*) monkeys. Int. J. Immunoph. 13(6):639–648.

[20] Arnold, D.L., F. Bryce, R. Stapley, P.F. McGuire, D. Burns, J.R. Tanner, and K. Karpinski. 1993a. Toxicological consequences of Aroclor® 1254 ingestion by female rhesus (*Macaca mulatta*) monkeys, Part 1A: Prebreeding phase—clinical health findings. Food Chem. Toxicol. 31(11):799–810.

Arnold, D.L., F. Bryce, R. Stapley, P.F. McGuire, D. Burns, J.R. Tanner, and K. Karpinski. 1993b. Toxicological consequences of Aroclor® 1254 ingestion by female rhesus (*Macaca mulatta*) monkeys, Part 1B: Prebreeding phase, clinical and analytical laboratory findings. Food Chem. Toxicol. 31(11):811–824.

Uncertainties Related to Toxicity Values for Aroclors®

The risk estimates developed in this paper based on EPA/Versar and updated estimates are more likely to overestimate than underestimate risks associated with PCBs in liquids for natural gas pipeline transmission systems. The available literature regarding PCBs suggests that use of EPA's toxicity values for PCBs may tend to overestimate risks in human populations. Thus, use of these toxicity values provides a very conservative health-protective means to evaluate risks for pipeline workers who may contact PCBs during work on or around gas pipelines. Review of the human epidemiological studies, including large-scale studies of workers exposed to high levels of PCBs, does not provide evidence that PCBs cause cancer in humans (Golden and Kimbrough 2009,[21] Taylor 1988;[22] Kimbrough et al. 1999;[23] Swanson et al. 1995[24]). Nor do the available studies provide credible evidence of a causal link between PCB exposure at environmental levels and adverse noncancer effects (ACC 2001[25]).

Uncertainties related to CSF for Aroclors®

Use of the EPA CSF of 2 $(mg/kg\text{-}day)^{-1}$ likely substantially overestimates the potential carcinogenicity of all PCB Aroclors® considered here, based both on the epidemiologic evidence and on the studies in animals. Specifically, EPA indicates that the data from human populations are inadequate to determine carcinogenicity (U.S. EPA 2010). As described above, the current toxicity values do not incorporate the considerable body of available literature on human populations exposed to PCBs. Existing epidemiological data, whether considered individually or assessed using a weight-of-evidence approach, strongly suggest that PCBs are not human carcinogens. A number of large, well-conducted epidemiological studies have failed to find a statistically significant relationship between exposure to PCBs and cancer (e.g., Zack and Musch 1979;[26] Gustavsson et al. 1986;[27] Nicholson 1987;[28] Taylor 1988; Kimbrough et al.

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[21] Golden. R. and Kimbrough R. 2009. Weight of evidence evaluation of potential human cancer risks from exposure to polychlorinated biphenyls: An update based on studies published since 2003. Critical Reviews in Toxicology, 2009; 39(4): 299–331.

[22] Taylor, P.R. 1988. The health effects of polychlorinated biphenyls. Harvard School of Public Health, Boston, MA.

[23] Kimbrough, R.D., M.L. Doemland, and M.E. LeVois. 1999. Mortality in male and female capacitor workers exposed to polychlorinated biphenyls. J. Occup. Environ. Med. 41(3):161–171.

[24] Swanson, G.M., H.E. Ratcliffe, and L.J. Fischer. 1995. Human exposure to polychlorinated biphenyls (PCBs): A critical assessment of the evidence for adverse health effects. Regul. Toxicol. Pharmacol. 21:136–150.

[25] ACC. 2001. Noncancer effects of PCBs—a comprehensive literature review, including comments of the General Electric Company on the January 10, 2001, use authorization for, and distribution in commerce of, non-liquid polychlorinated biphenyls. Docket No. OPPTS-66009F and G. Attachment 1: A weight-of evidence review of the potential human cancer effects of PCBs. American Chemistry Council.

[26] Zack, T.A., and D.C. Musch. 1979. Mortality of PCB workers at the Monsanto plant in Sauget, Illinois. Monsanto Internal Report.

[27] Gustavsson, P., C. Hogstedt, and C. Rappe. 1986. Short-term mortality and cancer incidence in capacitor manufacturing workers exposed to polychlorinated biphenyls (PCBs). Am. J. Inc. Med. 10:341–344.

1999). Taylor (1988) involved a cohort of 6,292 persons employed for at least 3 months during the period 1946–1976 at the General Electric Company's Hudson Falls and Ft. Edward facilities, which are known to have potential exposures of workers to PCBs. This study showed no increase in cancer mortality or in overall mortality compared to national averages. All totaled, as PCB exposure increased, the numbers of overall cancer deaths and lung cancer deaths decreased. A follow-up study was conducted by Kimbrough et al. (1999) to evaluate the cohort studied by Taylor (1988) using a retrospective mortality design. This study determined that overall mortality for the total cohort was significantly lower than that for the general population, as was the mortality for all cancers.

Although EPA has considered the human data inadequate for risk assessment, available studies suggest that there is no positive correlation between cancer incidence and even relatively high PCB exposures in the workplace. Most noteworthy from the epidemiological data on PCBs and human cancer is the lack of a consistent outcome between studies. Among studies commonly cited as evidence for the human carcinogenicity of PCBs (Bahn et al. 1976,[29] 1977;[30] Bertazzi et al. 1987;[31] Brown 1987;[32] Sinks et al. 1991;[33] Yassi et al. 1994;[34] and Loomis et al. 1997[35]), no consistent finding can be found across the reported positive findings with respect to cancer type. Such data suggest spurious associations or multi-chemical exposures, and are not consistent with a common causative agent (e.g., PCBs). Kimbrough et al. (1999) note that:

> To date none of the reported elevations in cancer mortality have been successfully replicated, even within individual cohorts (e.g., Brown [1987]).…[T]he lack of consistent findings with respect to occupational PCB exposure and mortality in studies conducted to date would suggest a lack of an association.

Even if one were to accept the animal data as reflecting the potential for human carcinogenicity, use of the upper-bound CSF of 2 (mg/kg-day) $^{-1}$, which was based on the most potent Aroclor®

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28 Nicholson, J.W. 1987. Report of the special panel on occupational PCB exposure and various cancers: human health effects and carcinogenic risk potential of PCB. Mount Sinai School of Medicine (August). Reprinted in the Ontario Gazette in the Matter of Section 86p of the Workers Compensation Act (December).

29 Bahn, A.K., I. Rosenwaike, N. Herrmann, P. Groger, J. Stellman, and K. O'Leary. 1976. Melanoma after exposure to PCBs. N. Engl. J. Med. 295:450.

30 Bahn, A.K., P. Grover, and I. Rosenwaike. 1977. PCB and melanoma. N. Engl. J. Med. 296:108.

31 Bertazzi, P., L. Riboldi, A. Pesatori, L. Radice, and C. Zocchetti. 1987. Cancer mortality of capacitor manufacturing workers. Am. J. Ind. Med. 11:165–176.

32 Brown, D.P. 1987. Mortality of workers exposed to PCBs—an update. Arch. Environ. Health 42:333–339.

33 Sinks, T., G. Steele, A.B. Smith, R. Rinsky, and K. Watkins. 1991. Westinghouse Electric, Bloomington Indiana health hazard evaluation and technical assistance branch DSHEFS, NIOSH: Risk factors associated with excess mortality among polychlorinated biphenyl exposed workers. HETA 89-116-2094.

34 Yassi, A., R. Tate, and D. Fish. 1994. Cancer mortality in workers employed at a transformer manufacturing plant. Am. J. Ind. Med. 25:425–437.

35 Loomis, D., S.R. Browning, A.P. Schenck, E. Gregory, and D.A. Savitz. 1997. Cancer mortality among electrical utility workers exposed to polychlorinated biphenyls. Occup. Environ. Med. 54:720–728.

(Aroclor® 1260) in the laboratory tests, would substantially overestimate the carcinogenic potential of other PCB Aroclors®, such as Aroclor® 1248. In addition, because the reported CSFs for Aroclors® 1260 and 1254 show variability in carcinogenic potential (i.e., upper-end CSFs for Aroclor®1260 ranged from 0.2 to 2.2, and those for Aroclor® 1254 ranged from 0.1 to 1.5), use of this CSF would also likely overestimate the carcinogenic potential of those Aroclors®, even in rats.

In summary, an objective review of the existing PCB occupational studies leads to the conclusion that exposures that are orders of magnitude greater than environmental exposures do not cause cancer in humans. Therefore, the excess cancer risk estimates derived in this assessment represent upper bounds on risk in light of the lack of cancer findings in human populations. Based on this observation, the existing approach for assessing PCB-related risks and the associated appropriateness of using the 50 ppm benchmark appears to be more than adequate for risk management purposes. It also appears unlikely that a different approach based on adding up compounds (i.e., the dioxin toxicity equivalent approach) adds value for guiding existing management programs for contained PCBs. That approach might, in fact, introduce large un-quantified uncertainties into the risk management of PCBs.

Uncertainties in EPA's Noncancer Toxicity Value for PCBs

Uncertainties related to EPA's RfD for Aroclor® 1254 suggest that this value may overestimate risks for human populations exposed to Aroclors®. Therefore, it likely provides a conservative estimate of risks that would yield very health protective risk management decisions for PCBs. The RfD for Aroclor® 1254 is derived from a study in which monkeys were fed Aroclor® 1254 for a period of 5 years, resulting in an ocular exudate, prominence and inflammation of the Meibomian glands, distortion in nail bed formation, and impaired antibody response to immunization with sheep red blood cells (Tryphonas 1989, 1991a,b; Arnold et al. 1993a,b). The effects were seen at the lowest dose tested, 0.005 mg/kg-day, and a dose-dependent response was demonstrated (U.S. EPA 1998[36]). An uncertainty factor of 300 was applied to the monkey LOAEL of 0.005 mg/kg-day to arrive at the EPA RfD of 2.0×10^{-5} mg/kg-day for Aroclor® 1254.

The EPA RfD for Aroclor® 1254, however, is based on an effect level substantially lower than the majority of effect levels reported in the toxicological literature on PCBs. In an exhaustive review of the toxicological effects of PCBs, ATSDR (2000)[37] makes very clear that rhesus monkeys have an unusual susceptibility to the effects of PCBs, as compared with other mammals. Responses and associated dose levels reported by Tryphonas (1989, 1991a,b) and Arnold et al. (1993a,b) are well below those observed in other laboratory animal species and humans. The apparent sensitivity of monkeys to PCBs is highlighted by the fact that rodents, on

[36] U.S. EPA. 1998. Risk assessment guidance for Superfund. Volume I: Human health evaluation manual (Part D, standardized planning, reporting, and review of Superfund risk assessments). Interim Report. EPA/540/R-97/033. U.S. Environmental Protection Agency, Office of Emergency Response and Remedial Response, Washington, DC.

[37] ATSDR. 2000. Toxicological profile for polychlorinated biphenyls. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry.

which the RfDs for the majority of environmental toxicants are based, appear to be 25- to 2000-fold less susceptible to toxic responses of PCBs. Data from long-term feeding studies with Aroclor®1254, as reviewed by ATSDR (2000), suggest that the use of rodent data would lead to much higher RfDs, in the range of 0.5 to 30 mg/kg-day. Thus, a rodent-based RfD would be at least 50-fold higher (i.e., less stringent) than the current EPA RfD, which was derived from effects observed in monkeys.

Even accepting the primate data, the uncertainty factor of 300 used to derive the RfD is judged to be quite conservative in light of human and animal data that suggest that elements of the applied uncertainty factor are unnecessary. The uncertainty factor is currently composed of four components:

- A factor of 10 to account for sensitive individuals;
- A factor of 3 for the extrapolation from rhesus monkeys to humans;
- A factor of 3 for the use of a LOAEL, rather than a no-observed-adverse-effect level (NOAEL); and
- A factor of 3 because of the use of subchronic data rather than chronic data.

The product of the individual factors – 270 – is rounded up to the total uncertainty factor of 300. The uncertainty factor of 300 provides what is considered an ample margin of safety in the use of data from monkeys for the assessment of human health hazards. Therefore, the use of this value for assessing risks of PCBs in natural gas pipelines likely overestimates rather than underestimates risks. Uncertainty factors are meant to account for potential sources of uncertainty in the extrapolation of animal data to humans, in the absence of available data characterizing the actual health hazards of exposure to the chemical of concern. The appropriateness of the factors used for deriving an RfD for PCBs has been questioned when there are ample data characterizing the human health effects of PCBs following human exposure to these compounds (Lewis et al. 1990;[38] Dourson et al. 1996[39]).

In the case of PCBs, available exposure data are adequate to demonstrate that rhesus monkeys are more sensitive than humans to toxic effects of PCBs (Kimbrough 1995).[40] Therefore, an uncertainty factor of 3, to account for the monkey-to-human extrapolation, is likely quite

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[38] Lewis, S.C., J.R. Lynch, and A.I. Nikiforov. 1990. A new approach to deriving community exposure guidelines from "no-observed-adverse-effect levels." Regul. Toxicol. Pharmacol. 11,314–330.

[39] Dourson, M.L., S.P Felter, and D. Robinson. 1996. Evolution of science-based uncertainty factors in noncancer risk assessment. Regul. Toxicol. Pharmacol.
24:108–120.

[40] Kimbrough, R.D., M.L. Doemland, and M.E. LeVois. 1999. Mortality in male and female capacitor workers exposed to polychlorinated biphenyls. J. Occup. Environ. Med. 41(3):161–171.

conservative and could be 1 or less than 1. The observations in several studies of long-term occupational exposures to PCBs have also eliminated much of the uncertainty pertaining to the long-term health hazards for the endpoints measured, and thus, the use of an uncertainty factor for the extrapolation of subchronic study data to predicting chronic health effects is unnecessary.

Therefore, an RfD of 2.0×10^{-4} mg/kg-day for the rhesus monkey data, derived with an uncertainty factor of 30 rather than 300, would still be protective of human health effects while being 10-fold less stringent that the current RfD. Confidence in this alternative RfD is supported by an extensive animal and human database on the adverse effects of PCBs, which clearly demonstrates the unusual susceptibility of monkeys from the studies used in EPA's RfD derivation. This uncertainty represents an additional, but unwarranted margin of safety to the noncancer risk assessment of PCBs, and lends additional confidence to the conclusion that marginally acceptable hazard quotients associated with human exposure to PCBs do not represent a concern for human health effects.

5. Health and Environmental Risks: Current Operating Conditions

In this section of the paper, the exposure estimates and toxicological values for PCBs are combined to derive estimates of risk. The purpose of this assessment is to determine whether there is an unreasonable risk to the worker, public, or the environment under the current PCB management plan for natural gas transmission pipelines. This evaluation is accomplished, in part, by considering the risks to workers, the individuals considered to have the highest exposures. As already noted, because PCB-impacted liquids are managed as deliberate and controlled events, exposure to the public and the environment is negligible. Nevertheless, it is useful to examine this by considering exposures and risks to pipeline workers as bounding estimates for other receptors, including the public.

Exposure potentially occurs when liquids are removed from the system by workers (e.g., at drips or separators). The frequency of exposure to PCB-containing media (e.g., liquids, concrete surface, or indoor air) is very limited for natural gas transmission pipeline workers, and exposures are generally controlled by the use of proper safety procedures, including the use of PPE. For these reasons, PCB exposure risks to pipeline workers wearing PPE in compliance with current operational procedures are negligible. However, as noted in the exposure assessment section, exposure estimates were developed for an individual who does not wear PPE (Attachment A, Table A1). This provides a way to quantify an upper bound on potential pipeline worker risk from release of PCBs. This estimated risk should be well above that of the average worker managing PCB-impacted pipeline equipment, filters, and liquids.

Risks to an individual who does not wear PPE were calculated by combining estimates of exposure with toxicity values for cancer and noncancer endpoints. The risk estimates are summarized in Table A2 within Attachment A. As noted earlier, the toxicity values are developed according to EPA policy and are intended to represent an upper end of the potential toxicity of that chemical. Thus, they yield theoretical upper bounds on risk. This can become an important consideration when these highly theoretical risk estimates are contrasted with risk estimates derived from measured accident and injury rates within the industry, and to the public and environment.

For cancer risk, the upper bound associated with the highest CSF extrapolated from animal studies is used to calculate the risk of cancer from human exposures to PCBs, in accordance with EPA policy. However, it should be remembered that the actual risk from low-dose exposures could range between zero and this upper-bound value predicted by these toxicity values and exposure estimates. For noncancer risks, the RfD is used to evaluate potential risks.

Although pipeline worker exposure and risks are assessed and managed in accordance with OSHA regulations, EPA's risk assessment approach was used to provide estimates and comparisons compatible with considering risks to the public at large. To that end, EPA's risk range of 10^{-4} to 10^{-6} (one in ten thousand to one in a million) is used to place risks in perspective. Generally, EPA would judge that lifetime cancer risks that are less than 10^{-6} are considered *de minimus* for the public, while risks of chemical exposures that are at or greater than 10^{-4} indicate that intervention is warranted. Between this risk range, risk management decisions would account for the nature of exposure, conservative aspects of estimates, population size, the receptors, and other factors. For noncancer risks, assessments are made relative to a hazard index of 1. If exposure is less than a reference dose, and the hazard index is <1, the exposure is considered too low to present a risk; if the hazard index is >1, there is a potential for risk, but the magnitude of the risk is unknown because of the simple dichotomous nature of the risk statistic and the uncertainty values incorporated into the reference dose. The risk estimates associated with the EPA/Versar exposure estimates are presented first. This is followed by risk estimates for an updated exposure assessment.

Calculation of Risk Based on EPA/Versar 1984 Exposure Estimates

The 1984 report prepared for EPA on exposure to 50 ppm PCBs provided an exposure estimate, but that report did not include a translation to risk. Presumably, EPA examined that separately. However, the EPA/Versar exposure estimates presented earlier in the paper are used here to calculate cancer risks. Using the upper-end CSF of 2.0 per mg/kg-day, lifetime risks to workers for exposure via the dermal pathway were 7.2×10^{-4} for a daily exposure and 3.6×10^{-5} for a monthly exposure. As noted earlier these exposure estimates are based on the assumption that 100% of PCBs are absorbed. In addition, EPA/Versar recognize that a monthly exposure is a more appropriate exposure frequency. As pointed out in the updated risk calculation, consideration of these factors leads to lower risk estimates. In any case, even considering 100% dermal absorption, the upper bound risks to workers exposed to PCB-impacted liquids with 50 ppm on a monthly basis throughout their work history falls within EPA's 10^{-6} to 10^{-4} risk range.

For inhalation exposures, a lower CSF is appropriate, in accordance with EPA policy. The appropriate slope factor is 0.4 per mg/kg-day. The lifetime risk using this CSF is 5.6×10^{-6} for daily exposures and 2.9×10^{-7} for monthly exposures. Use of the most relevant CSF in conjunction with the most appropriate exposure frequency (monthly) results in estimated risks below EPA's acceptable risk range for the public of 10^{-6} to 10^{-4}, indicating very low risks. Even assuming a daily exposure, risks are within the acceptable range. The calculations performed for EPA by Versar assumed that individual workers would be exposed throughout their work life to a constant concentration of PCBs at 50 ppm. The updated risk estimates presented in this paper do not presume that this would be the typical case. However, even for the work life of an employee not wearing PPE (assumed by EPA and in the upper-bound calculation herein), the risks posed to workers are low and would not be judged to be unreasonable. These calculations indicate that exposure to the public is negligible because residents and/or people who work near areas where PCB-impacted pipeline liquids are being managed would experience substantially lower exposure concentrations. Even if exposed to the air near the management area, risks to the public would be low and well within acceptable levels established by EPA.

The updated risk calculations, using updated exposure factors (Attachment A), show that if an individual does not wear PPE and comes into contact with liquids as a single inadvertent exposure event, all risks would be well below 10^{-6}, for exposures to 50 ppm PCBs in liquids (refer to Table A2 within Attachment A). The calculations also show that this individual would not be exposed at a level that would exceed a hazard index of 1 for 50 ppm PCBs in liquids. However, to provide an upper bound on risks for workers engaged in normal pipeline operations, risks were also calculated assuming this individual never wears PPE and engages in liquid removal and other activities that bring him or her into contact with PCBs. For this purpose, information provided by the pipeline industry was used to represent exposures to all activities that involve current management of PCBs. For risk assessment purposes, this frequency was selected to be once a month, or twelve times per year. This is the same exposure factor that EPA/Versar used for its exposure calculation. The actual exposure frequency may be less than monthly or, in some cases, it may be greater.

The calculated theoretical annual cancer risk for an individual pipeline worker who does not wear PPE, with one year of monthly contacts with PCBs in PCB-impacted equipment and liquids containing 50 ppm, is 4×10^{-7} (see Tables A2 within Attachment A). The calculated annual noncancer risk for an individual who does not wear PPE while participating in the management of PCB-containing liquids and cleaning on 12 occasions per year is well below a hazard index of 1 for individuals who handle liquids or PCB-impacted equipment at 50 ppm PCBs. Because management of PCB-containing liquids occurs in controlled situations, the public does not come into direct contact with this material. Because workers wear PPE, risks are reduced. Therefore the risk estimate indicates that, even if workers did not wear PPE, risks to these individuals would be low. It follows that risks to the public are also correspondingly low and as noted earlier, negligible. Thus, under current PCB management practices for natural gas transmission pipelines, the current management practices, performed in accordance with existing PCB-related regulations, do not present an unreasonable risk to human health.

6. Health and Environmental Risks Associated with Pipeline and Equipment Replacement

This section discusses the potential types of health and environmental risks associated with replacement of parts of the pipeline system in the event that new regulations compel such action. While this is treated in a qualitative way in this paper, quantitative assessments are also possible and could be developed to contrast the existing management program with a program that requires pipeline replacement.

Risks Associated with Pipeline Replacement

The following is a description of the risks associated with replacing pipeline and associated equipment impacted with PCBs if this is an outcome compelled by new regulations. Pipeline and equipment replacement might be the only alternative available if new regulations require more rapid reductions in PCBs within the system than those that are occurring under the current PCB management programs being undertaken by the companies. Because of the complexity of pipeline systems, whole replacement of pipelines and equipment may be the only means of accelerating reductions of PCBs. Even with this approach, there may be eventual recontamination from other parts of the system. Nevertheless, it is instructive to consider the additional risks that arise as part of a regulatory-driven pipeline replacement program.

If portions of natural gas pipeline are replaced, the potential for exposure to the PCBs in the system would be expected to be greater than baseline operating conditions. It is expected that the segments of pipe that will be targeted for replacement will be in areas where PCB contamination is more likely, which would be near locations where liquids form, which would include low points in the system, and where drips are located. Regardless of the PCB exposure potential, there will be the inherent risk of physical hazards to workers because of the nature of repair operations, which include the use of heavy construction equipment to remove and replace the pipeline segment. While best management practices will be used to reduce exposure to the PCBs and the physical hazards associated with pipeline segment replacement, risks could be substantially higher than baseline operating conditions.

Pipeline replacement projects by their very nature are labor intensive and would involve large carbon equivalent emissions and resources compared to baseline operating conditions. Pipeline replacement projects require many labor intensive tasks including the following:

- Excavation of the old pipe with heavy motorized construction machinery;
- Removal of the old pipe (normally in 40-ft segments) with heavy motorized construction machinery;
- Trucking the old pipe segments to an offsite testing and decontamination facility;

- Trucking the old pipe segments to the point of end use (recycling center or new use point);
- Installation of new pipe segments and related components; and
- Hydrostatic pressure testing of new pipeline section.

For this reason, the carbon footprint of such replacement is an important consideration when reviewing the risk-benefit of the project. The carbon footprint associated with a major construction project would be expected to be higher than the footprint associated with the baseline management program.

In addition to the consideration of increased resource requirements, large replacement projects have the potential for increased risks to the public living in the area of the pipeline replacement project. The potential for PCB exposure to the public would be minimal based on the nature of the replacement project, because PCBs would be at low concentrations on the interior of pipe sections removed from the site. However, there would be a large increase in truck traffic in the area of the replacement project as old pipe sections are trucked offsite and new pipe is trucked onsite. While best management practices would be used to reduce the risk, there would inevitably be an increased risk of truck accidents for the public living in the area of the project. This risk would be increased for pipelines that are replaced in urban areas where population densities are greater and thus the risk of an accident with construction-related truck traffic would increase.

Because of the intrusive nature of pipeline replacement, disturbance to the natural environment in the pipeline right of way would be expected, which would also increase the risk associated with replacement of this pipe. While new pipelines are routed around sensitive environments, older pipelines constructed prior to the 1970s and 1980s, when many of the environmental regulations were promulgated, did not always avoid sensitive environments. For this reason, if older pipelines are targeted for replacement, there may be significant non-PCB-related environmental damage to sensitive habitats that needs to be weighed and considered. An Advanced Notification is required to the FERC[41] whenever pipeline replacement projects exceed $8 million, and all projects must comply with "Standard Environmental Conditions for All Blanket Projects," which includes an extensive list of state and federal environmental regulations.

In summary, a qualitative approach was used to assess risks to the public associated with pipeline replacement projects that may result from new PCB regulations. As described above, the chemical risks associated with PCB exposure to the public or the environment are expected to be minimal because the public and environment would not be exposed to PCBs at the concentrations to which workers have the potential to be exposed. However, pipeline replacement brings with it increased physical or chemical risks for both the public and the environment, irrespective of the residual PCBs present in the pipeline system.

[41] (§) 2.55(b) of the Federal Energy Regulatory Commission's regulations (18 CFR 2.55(b)

Pipeline replacement involves the following additional risks to the public and the environment:

- Traffic accidents associated with the increased truck traffic to haul the old pipe offsite and to haul the new pipe in for the replacement project. These risks are expected to increase for segments of pipeline replaced in urban areas where population densities are greater than in rural areas;
- Damage to sensitive habitats as the pipeline is excavated and replaced; and
- An increased carbon footprint for the replacement projects in comparison to baseline pipeline operation conditions.

These additional risks to the public and the environment must be considered to accurately review the risk-benefit of actions that are required in the face of new regulations. The physical hazards to workers, the public, and the environment associated with replacing the pipeline are likely much greater than the chemical hazards associated with the residual PCBs present within the pipeline.

7. Risk Reduction with Time

The inventory and concentrations of PCBs in pipelines identified as PCB-impacted have been declining steadily.[42] For example, in one pipeline system evaluated by S.S. Papadopulos & Associates, Inc., median concentrations have declined from 1,000 to 10,000 ppm measured in the 1980s to around 25 to 200 ppm in recent measurements. The continual reduction of PCB mass and concentration is a reflection of the fact that PCBs are not an integral part of the operating system, and they are continually being removed. Thus, risk estimates for pipeline liquid exposures have declined by one or more orders of magnitude over the past 25 years. Because the management process is still underway, continued reductions in the PCB mass and concentrations are expected. For these reasons, any projection of risks associated with the presence of PCBs in pipelines must recognize that the exposure regime is continually decreasing. Because interstate pipeline companies manage the integrity of the pipelines and the fluids within them, it is projected that the current very low risks will continue to decline even further. There does not appear to be a situation of aging infrastructure that would lead to an unanticipated increase in risks to workers, the public, or the environment. Instead, the pipeline companies invest in maintaining the infrastructure needed to service their customers. Pipeline maintenance, repair and replacement is carried out as part of continual operations.

[42] S.S. Papadopulos & Associates, Inc., PCBs in the Interstate Natural Gas Pipeline System – Status and Trends, (Aug. 2010).

8. Risk Management Considerations: Using 50 ppm as a Benchmark

Historical Basis

Congress enacted the Toxic Substances Control Act (TSCA) in 1976, authorizing EPA to secure information on all new and existing chemical substances, and to control any substances that were determined to cause unreasonable risk to public health or the environment. With limited exceptions, TSCA banned the manufacture, processing, distribution in commerce, and use of PCBs other than in a "totally enclosed manner." Section 6(e) of TSCA explicitly required EPA to promulgate regulations for marking, processing, distributing, using, and disposing of PCBs. Subsequent PCB regulations were published pursuant to TSCA Section 6(e).

Establishment of the 50-ppm Cutoff

The first PCB regulation promulgated under TSCA 6(e) was the 1978 PCB Marking and Disposal rule.[43] However, later that same year, EPA released for comment the proposed *PCBs Manufacturing, Processing, Distribution in Commerce and Use Ban* regulation (the Ban Rule). The Ban Rule, finalized in May 1979, identified and established a 50-ppm regulatory cutoff for application of the rule.[44] The Ban Rule designated all intact, non-leaking capacitors, electromagnets, and transformers, other than railroad transformers, as "totally enclosed," which allowed their use without restrictions or conditions. It also authorized the use of PCBs under specific conditions and time constraints for 11 activities, including a temporary authorization for natural gas pipeline compressors until May 1, 1980, to allow time to drain and refill them with non-PCB fluids. [45]

As described in the Support Document/Draft Voluntary Environmental Impact Statement to the Ban Rule, the 50-ppm cutoff is based on technical, administrative, and background considerations.[46] The Support Document states, "The 50 ppm PCB concentration has been chosen to represent the level at which EPA can regulate PCBs. EPA believes that it would be technically impossible and administratively unreasonable to establish a separate level to define each type of PCB mixture or PCB exposure." EPA noted that because of the ubiquitous presence of PCBs in the environment as a result of past uses, and their persistence, regulating them below a "background" or "ambient" level would not be "reasonable or feasible to control." The Support Document summarized PCB levels in urban settings, and in particular in municipal

43 43 FR 7150

44 44 FR 31514

45 44 FR 31536

46 U.S. EPA. 1997. Support document/draft voluntary environmental impact statement polychlorinated biphenyls (pcbs) manufacturing, processing, distribution in commerce and use ban regulation (Section 6(e) of TSCA). U.S. Environmental Protection Agency, Office of Toxic Substances.

sludge, in which concentrations range from trace levels to 30 or 40 ppm, with relatively few samples exceeding 50 ppm. Thus, EPA concluded that the previous definition of 500 ppm was too high by an order of magnitude, and concentrations above 50 ppm were likely affected by sources other than background.

Application to Natural Gas Transmission Systems

In 1980, the Environmental Defense Fund challenged several provisions of the Ban Rule. As a result, the U.S. Court of Appeals for the District of Columbia ruled that there was insufficient evidence in the record to support several provisions of the rule, and struck down specific provisions, including the regulatory cutoff of 50 ppm. EPA addressed the deficiencies identified in the court challenge with a new "Uncontrolled PCB's Rule,"[47] promulgated in 1982 with subsequent amendments. In particular, under a 1984 amendment, EPA authorized the use of PCBs in natural gas pipelines at less than 50 ppm under certain conditions and restrictions, pursuant to 40 CFR Section761.30(i).[48]

In 1981, sampling showed that some natural gas transmission pipeline liquids had PCB levels exceeding the 50-ppm cutoff previously established for PCB waste as part of the Ban Rule.[49] EPA determined that this constituted a use of PCBs in a "non-totally enclosed manner," in violation of the Ban Rule. EPA, in conjunction with the industry, created the Compliance Monitoring Program (CMP) for 13 major natural gas transmission companies known to have elevated levels of PCBs in their systems. The CMP required each company to monitor their pipelines, and if pipeline liquids continued to exceed the 50 ppm PCB concentration level, they were to develop plans to ensure proper storage and disposal of PCBs, contain PCB contamination to limited areas of the transmission system, eliminate any further entry of PCBs into the system, and remove remaining PCB contamination from the system. The program also required that these companies monitor their removed pipeline liquid for PCBs and report the results quarterly to EPA. The number of companies in the CMP was reduced after monitoring results showed that PCB levels had declined or that originally elevated values were outliers and did not represent the actual pipeline concentrations.

1998 – "Mega" Rule

In 1998, EPA promulgated significant changes to PCB regulation under TSCA with final publication of the "PCB Disposal Amendments," or the "Mega Rule."[50] The Mega Rule clarified use authorization for all gas pipelines, including natural gas distribution systems (which were not part of the CMP), and management of their PCB-containing liquids according

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[47] 47 FR 37342

[48] 49 FR 28172

[49] Calhoun, M. 1996. 1996 Revision to the 1981 PCB Compliance Monitoring Program (CMP) for 10 interstate natural gas transmission pipelines. Memorandum from Michael Calhoun, Multimedia Enforcement Branch, to Melissa Marshall, Director, Multimedia Enforcement Branch, U.S. Environmental Protection Agency.

[50] 63 FR 35384

to TSCA. The Mega Rule carried over the 50-ppm cutoff, but also authorized use with PCBs greater than 50 ppm in natural gas systems under certain conditions.

The 50-ppm Value for PCBs in Liquids is a Health-Protective Management Benchmark

This paper is informed by exposure and risk assessments carried out by EPA/Versar and updated estimates. The assessments are in general agreement. This section of the paper considers whether current management practices for PCB- impacted gas transmission pipelines are protective of human health and the environment. The evaluation provided in previous sections indicates that the current management practices do not present unreasonable risks to health or the environment. This is based on the following aspects of the assessment already presented:

- The current management practice has resulted in a substantial reduction of the PCB mass within pipelines, the levels of PCB concentrations in pipeline liquids, and the volumes of PCB liquids to be managed. All of this reduces exposure levels, and as noted below, existing exposure levels do not pose an unreasonable risk. Continued implementation of the existing management practices will result in future reductions in the potential for exposure.

- The frequency of exposure to PCB-containing media (e.g., liquids, soil, concrete surface, or indoor air) is very limited for natural gas transmission pipeline workers, and exposures are generally controlled by the use of proper safety procedures, including the use of PPE and ventilation of compressor buildings. For these reasons, PCB exposure risks to pipeline workers wearing PPE in compliance with current operational procedures are negligible.

- Pipeline workers typically wear PPE for handling pipeline liquids, whether or not PCBs are present. Thus, there is little likelihood of a surprise exposure to PCBs in liquids thought to be below 50 ppm but that actually contain some PCBs (e.g., >1 ppm).

- If a worker fails to wear PPE and is exposed to PCBs via dermal or oral contact, that exposure event would not result in risks that exceed the risk benchmarks that EPA typically considers for judging health risks (1×10^{-6} for lifetime cancer risk, and a hazard index of 1 for noncancer risks). Even if an individually repeatedly fails to wear PPE and is involved in routine handling of liquids and equipment, and is exposed each time (frequency of 12 exposures per year), cancer and noncancer risks are still low.

- Because PCBs liquids and equipment are managed as part of controlled and deliberate events, exposures of the public, environment, and/or natural resources are negligible.

- Exposure of pipeline workers to air inside compressor buildings does not result in risks that exceed EPA benchmarks.

- Air concentration levels that might occur within compressor buildings would also not pose a risk to the public, even if the public were breathing undiluted air inside the buildings.

The assessment of exposure to PCBs present in natural gas transmission pipeline systems indicates that compliance with existing PCB regulations is resulting in continued reductions in the amounts of PCBs in pipelines, and in the potential for exposure to those PCBs. The assessment further indicates that existing and future exposures to PCBs present within the pipeline systems do not pose an unreasonable risk under current management approaches. Those management approaches are performed in compliance with existing EPA regulations.

Table A1. Values used for daily intake calculations for contact with liquids

Exposure Route	Parameter Code	Parameter Definition	Units	50 mg/L limit	Rationale/ Reference	500 mg/L limit	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	CL	Chemical concentration in liquid	mg/L	50	Federal Register	500.00	Federal Register	Chronic Daily Intake (CDI) (mg/kg-day) =
								((C_{liquid} x CF x AF x SA x EV x EF x ED)
	CF	Conversion factor	L/mL	1.00E-03	--	1.00E-03	--	(BW x AT))
	SA	Surface area of the palm of the hand	cm^2 / event	183	CPSC 2003	183	2q	
	LR	Loading Rate for liquid onto skin	ml/cm^2	0.0069	Gujral 2008	0.0069	Gujral 2008	
	FH	Fraction of hand contacting mouth	unitless	0.06	NUS Tetra Tech (2000)	0.06	NUS Tetra Tech (2000)	CDI cancer -lower concentration single day=
	EV	Daily hand-to-mouth events	events/day	4	NUS Tetra Tech (2000)	4	[b]	8.5E-09
	EF	Exposure frequency	days/year	1–12	Baseline	1–12	Baseline	CDI noncancer -lower concentration single day=
	ED	Exposure duration	years	1	Baseline	1	U.S. EPA 1997a	5.9E-07
	BW	Body weight	kg	70	U.S. EPA 1997a	70	U.S. EPA 1997a	
	AT-C	Averaging Time (Cancer)	days	25,550	U.S. EPA 2000	25,550	U.S. EPA 2000	
	AT-NC	Averaging Time (Noncancer)	days	365	U.S. EPA 1989	365	U.S. EPA 1989	
Dermal	CL	Chemical concentration in liquid	mg/L	50	Federal Register	500.00	Federal Register	Chronic Daily Intake (CDI) (mg/kg-day) =
								((C_{liquid} x CF x AF x SA x EF x EF x ED)
	CF	Conversion factor	L/mL	1.00E-03	--	1.00E-03	--	(BW x AT))
	SA	Skin surface area of palms and 10% of forearms	cm^2/event	314	U.S. EPA 1997 and professional judgment	314	U.S. EPA 1997	CDI cancer -lower concentration single day=
	LR	Loading Rate for liquid onto skin	ml/cm^2	0.0069	Gujral 2008	0.0069	Gujral 2008	8.5E-09
	ABS	Dermal absorption factor - PCBs	unitless	0.14	U.S. EPA 2000	0.14	U.S. EPA 2000	CDI noncancer -lower concentration single day=
	EF	Exposure frequency	days/year	1–12	Baseline	1–12	U.S. EPA 1991[a]	5.9E-07
	ED	Exposure duration	years	1	Baseline	1	U.S. EPA 1997a	
	BW	Body weight	kg	70	U.S. EPA 1997a	70	U.S. EPA 1997a	
	AT-C	Averaging Time (Cancer)	days	25,550	U.S. EPA 2000	25,550	U.S. EPA 2000	
	AT-NC	Averaging Time (Noncancer)	days	365	U.S. EPA 1989	365	U.S. EPA 1989	

Table A2a. Excess cancer and and noncancer risks for workers: One day exposure to lower contact concentrations

Pathways	Concentration of PCBs	Cancer Risk Estimates: Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$ [b]	Cancer Risk Estimates: Excess Cancer Risk	Reference Dose (mg/kg-day)	Hazard Quotient/ Index
Contact with Liquids					
Ingestion[a]	50.0 mg/L	2	2E-08	0.00002	0.03
Dermal[a]	50.0 mg/L	2	2E-08	0.00002	0.03
		Total Cancer Risk:	**4E-08**	**Total Hazard Index:**	0.1

[a] Exposure calculated assuming 1 day exposure.

[b] Cancer risk estimates used slope factor per EPA guidance on risk evaluation of all PCB mixtures in ingestion and dermal pathways.

Table Risk2b. Excess cancer and and noncancer risks for workers: One day exposure to higher contact concentrations

Pathways	Concentration of PCBs	Cancer Risk Estimates: Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$ [b]	Cancer Risk Estimates: Excess Cancer Risk	Reference Dose (mg/kg-day)	Hazard Quotient/ Index
Contact with Liquids					
Ingestion[a]	500.0 mg/L	2	2E-07	0.00002	0.3
Dermal[a]	500.0 mg/L	2	2E-07	0.00002	0.3
		Total Cancer Risk:	**3E-07**	**Total Hazard Index:**	0.6

[a] Exposure calculated assuming 1 day exposure per year.

[b] Cancer risk estimates used slope factor per EPA guidance on risk evaluation of all PCB mixtures in ingestion and dermal pathways.

Table Risk2c. Excess cancer and and noncancer risks for workers: Monthly single day exposures to lower contact concentrations

Pathways	Concentration of PCBs	Cancer Risk Estimates: Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$ [b]	Cancer Risk Estimates: Excess Cancer Risk	Reference Dose (mg/kg-day)	Hazard Quotient/ Index
Contact with Liquids					
Ingestion[a]	50.0 mg/L	2	2E-07	0.00002	0.36
Dermal[a]	50.0 mg/L	2	2E-07	0.00002	0.36
		Total Cancer Risk:	**4E-07**	**Total Hazard Index:**	0.7

[a] Exposure calculated assuming 12 day exposure.

[b] Cancer risk estimates used slope factor per EPA guidance on risk evaluation of all PCB mixtures in ingestion and dermal pathways.

Table Risk2d. Excess cancer and and noncancer risks for workers: Monthly single day exposures to higher contact concentrations

Pathways	Concentration of PCBs	Cancer Risk Estimates: Carcinogenic Slope Factor $(mg/kg\text{-}day)^{-1}$ [b]	Cancer Risk Estimates: Excess Cancer Risk	Reference Dose (mg/kg-day)	Hazard Quotient/ Index
Contact with Liquids					
Ingestion[a]	500.0 mg/L	2	2E-06	0.00002	3.6
Dermal[a]	500.0 mg/L	2	2E-06	0.00002	3.6
		Total Cancer Risk:	**4E-06**	**Total Hazard Index:**	7.1

[a] Exposure calculated assuming 12 day exposure per year.

[b] Cancer risk estimates used slope factor per EPA guidance on risk evaluation of all PCB mixtures in ingestion and dermal pathways.

Table A3. Construction worker injury and illness estimate by mile of pipeline constructed, based on 2008 data

Factor	Factor Description	Value	Source
A	Incidence Rate for Injuries and Illness/100 FTE-year	2.2	1
B	Incidence Rate for Injuries and Illness/FTE-year	2.20E-02	Calculated as Factor A divided by 100
C	Estimate of Number of FTE/ mile pipeline construction	12.9	2
D	Incidence of Injuries and Illness/ pipeline mile constructed	0.2831154	Calculated as Factor B x Factor C

	Miles of Pipeline Constructed				
	2.5	50	75	250	1,000
Incidence of Injuries and Illness/pipeline construction project	0.7	14	21	71	283

Sources: 1. Incidence rates of nonfatal occupational injuries and illnesses by industry and case types from Bureau of Labor Statistics (2008). Heavy and civil engineering construction, Oil and gas pipeline and related structures construction (NAICS Code 23712).

2. Confidential industry estimate for two example pipeline construction projects:

Example	Total Pipeline Miles	Total Hours Worked	Total 100 Full-Time Equivalents	Total Full-Time Equivalents	Total 100 Full-Time Equivalents/ Mile of Pipeline	Total Full-Time Equivalents/ Mile of Pipeline	Miles Constructed/ Full-Time Worker
Project 1	639	19,521,000	97.6	9760.5	0.153	15.3	0.0655
Project 2	507	10,609,600	53.0	5304.8	0.105	10.5	0.0956
		Average -->	75.3	7532.7	0.129	12.9	0.081

Note: Need to know duration of example pipeline projects to estimate FTE-year (assumed project duration of 1-year for calculations).

Table A4. Construction worker fatality estimate by pipeline mile constructed, based on 2008 data

Factor	Factor Description	Value	Source
A	Incidence of fatal injuries in 2008	22	1
B	Average FTE in 2008	107700	1
C	Incidence of fatal injuries/FTE -year	2.04E-04	Factor C = (Factor A/Factor B)
D	Estimate of # of FTE/ mile pipeline construction	12.87	2
E	Total # of Fatalities/ mile pipeline constructed	2.63E-03	Factor E = Factor C * Factor D

	Miles of Pipeline Constructed				
	2.5	50	75	250	1,000
Incidence of fatalities/ pipeline construction project	0.01	0.13	0.20	1	3

Sources: 1. Incidence of fatal occupational injuries by industry and case types from Bureau of Labor Statistics (2008). Heavy and civil engineering construction, Oil and gas pipeline and related structures construction (NAICS Code 23712).

2. Confidential industry estimate for two example pipeline construction projects:

Example	Total Pipeline Miles	Total Hours Worked	Total 100 Full-Time Equivalents	Total Full-Time Equivalents	Total 100 Full-Time Equivalents/ Mile of Pipeline	Total Full-Time Equivalents/ Mile of Pipeline
Project 1	639	19,521,000	97.6	9760.5	0.153	15.3
Project 2	507	10,609,600	53.0	5304.8	0.105	10.5
		Average -->	75.3	7532.7	0.129	12.9

Note: Need to know duration of example pipeline projects to estimate FTE-year (assumed project duration of 1-year for calculations).

Table A5. Natural gas transmission worker injury and illness estimate by mile of pipeline maintained, based on 2008 data

Factor	Factor Description	Value	Source			
A	Incidence Rate for Injuries and Illness/100 FTE -year	2.3	1			
B	Incidence Rate for Injuries and Illness/FTE -year	2.30E-02	Calculated as Factor A divided by 100			
C	Estimate of Number of FTE-year/mile pipeline maintained	0.020	2 for Example			
D	Incidence of Injuries and Illness/pipeline mile maintained	0.00046	Calculated as Factor B x Factor C			
		Miles of Pipeline maintained				
		10	50	250	500	5,000
	Incidence of Injuries and Illness/pipeline project	0.005	0.02	0.12	0.23	2.30

Sources: 1. Incidence rates of nonfatal occupational injuries and illnesses by industry and case types from Bureau of Labor Statistics (2008). Pipeline transportation, Pipeline Transportation of Natural Gas (NAICS Code 4862).

2. Estimate for example natural gas transmision company:

Example	Total Pipeline Miles/Year	Total Full-Time Equivalents	Estimate of Number of FTE-Year/Mile Pipeline Maintained
Example 1	500	10	0.020

Table A6. Natural gas transmission worker fatality estimate by pipeline mile maintained, based on 2008 dat6

Factor	Factor Description	Value	Source
A	Incidence of fatal injuries in 2008	4	1
B	Average FTE in 2008	25500	1
C	Incidence of fatal injuries/FTE -year	1.57E-04	Factor C = (Factor A/Factor B)
D	Estimate of # of FTE/ mile pipeline maintained	0.02	2 as example
E	Total # of Fatalities/ mile pipeline maintained	3.14E-06	Factor E = Factor C * Factor D

	Miles of Pipeline maintained				
	10	50	250	500	5,000
Incidence of fatalities/ pipeline maintained	0.000	0.000	0.001	0.002	0.016

Sources: 1. Incidence rates of nonfatal occupational injuries and illnesses by industry and case types from Bureau of Labor Statistics (2008).
Pipeline transportation, Pipeline Transportation of Natural Gas (NAICS Code 4862).

2. Estimate for example pipeline company:

Example	Total Pipeline Miles Maintained/ Year	Total Full-Time Equivalents	Estimate of Number of FTE-Year/ Mile Pipeline Maintained
Example 1	500	10	0.020

Table A7. Human health risk estimates by remediation scenario for a hypothetical natural gas transmission pipeline company with PCB-contaminated pipeline

		PCB Chemical Risk						Physical Risk	
Remediation Scenario	Scenario Description	Exposure Frequency (days/year)	Number Workers/ Mile	Number of Miles with PCBs	Estimated Cumulative Cancer Cases Due to PCB Exposure	Hazard Index	Estimated Noncancer PCB Illnesses	Cumulative Numbers of Injuries or Illness	Cumulative Numbers of Fatalities
Baseline Pipeline Operations[a]	Normal level of pipeline replacement assumed to be 1 percent per year. For a 5000 mile pipeline this equates to 50 miles of pipe/year. 5% of pipe could be PCB contaminated (i.e., 2.5 miles replaced of 250 miles total miles potentially PCB contaminated). Typical levels of maintenance worker exposure defined as contact with condensate 12 day/year, and exposure to air and surfaces in a compressor station of 12 day/year for 8 hours/day .				Cumulative number of cancer cases based on baseline conditions of PCB exposure		Qualitatively evaluated in light of hazard index (HI) presented (i.e., > than or < than 1)	Numbers of illness and injury based on 2.5 miles of PCB contaminated pipeline construction (i.e., replacement). We scaled the injury estimates by a factor of 1.5 because for replacement there would actually be twice as much pipeline handled and so the injury and illness risks should be scaled upward to account for this factor. Numbers of illness and injury based on 250 miles of PCB contaminated pipeline maintenance by pipeline workers.	Numbers of fatalities based on 2.5 miles of PCB contaminated pipeline replaced. We scaled the injury estimates by a factor of 1.5 because for replacement there would actually be twice as much pipeline handled and so the injury and illness risks should be scaled upward to account for this factor. Numbers of fatalities based on 250 miles of PCB contaminated pipeline maintenance by pipeline workers.
Construction Worker Risks[b]		2.5	0.016	2.5	2E-10	0.01	<1	1.1	0.01
Maintenance Operations Worker Risks		12	0.020	250	2E-06	0.8	<1	0.1	0.001
Total Overall Risk					2E-06			1	0.01
Increased Pipeline Replacement: Includes pipeline replacement to eliminate PCBs; placement of new pipeline, and increased replacement of gas compressor station components including scrubbers and concrete.	Increased levels of pipeline replacement (250 miles/year); Construction worker exposure defined as contact with contaminated surface 250 day/year, and exposure to air and surfaces in a compressor station of 250 day/years for 8 hours/day. No exposure to condensate assumed during construction, because it would be removed prior to construction activities. Maintenance of pipeline similar to baseline conditions.				Cumulative cancer cases based on increased exposure conditions to PCBs		Qualitatively evaluated in light of hazard index (HI) presented (i.e., > than or < than 1)	Numbers of illness and injury based on 250 miles of pipeline construction (i.e., replacement) and compressor station remediation. We scaled the injury estimates by a factor of 1.5 because for replacement there would actually be twice as much pipeline handled and so the injury and illness risks should be scaled upward to account for this factor. Maintenance operations similar to baseline.	Numbers of fatalities based on 250 miles of pipeline construction (i.e., replacement) and compressor station remediation. We scaled the injury estimates by a factor of 1.5 because for replacement there would actually be twice as much pipeline handled and so the injury and illness risks should be scaled upward to account for this factor. Maintenance operations similar to baseline.
Construction Worker Risks[b]		250	0.016	250	2E-06	0.8	<1	106	1
Maintenance Operations Worker Risks		12	0.020	250	2E-06	0.8	<1	0.1	0.001
Total Overall Risk					4E-06			106	1

Table A7. (cont.)

Remediation Scenario	Scenario Description	PCB Chemical Risk: Exposure Frequency (days/year)	Number Workers/ Mile	Number of Miles with PCBs	Estimated Cumulative Cancer Cases Due to PCB Exposure	Hazard Index	Estimated Noncancer PCB Illnesses	Physical Risk: Cumulative Numbers of Injuries or Illness	Cumulative Numbers of Fatalities
Increased In-Place Pipeline Remediation: Includes pipe cleaning only, no replacement of pipe. Increased cleaning of gas compressor station components including scrubbers and concrete and sealing of concrete.	Increased levels of pipeline cleaning (250 miles/year); increased levels of worker exposure defined as contact with condensate 250 day/year, and including exposure to air and surfaces in a compressor station of 250 day/year for 8 hours/day. No increase in pipeline replacement. Maintenance of pipeline similar to baseline conditions.				Cumulative cancer cases based on increased exposure conditions to PCBs		Qualitatively evaluated in light of hazard index (HI) presented (i.e., > than or < than 1)	Numbers of illness and injury based on 250 miles of pipeline cleaning only; Maintenance operations similar to baseline.	Numbers of fatalities based on 250 miles of pipeline cleaning only; Maintenance operations similar to baseline.
Construction Worker Risks[c]	Note: Concentrations scaled downward by 100 fold due to cleaning solvent dilution.	250	0.040	250	9E-07	0.2	<1	No task specific data available	No task specific data available
Maintenance Operations Worker Risks		12	0.020	250	2E-06	0.8	<1	0.1	0.001
Total Overall Risk					3E-06			--	--

Notes:	Unit Cancer Risk	Unit Noncancer Risk
One day risks for worker exposure to PCBs at 50 mg/L in liquid and 10 µg/100cm^2 on surfaces is:	4E-08	0.06
One day risk of exposure to PCBs on surfaces at 10 µg/100cm^2 is:	2E-09	0.003
One day risk of worker exposure to PCBs at 50 mg/L in liquid is:	4E-08	0.06

[a] Industry estimates of the number of miles of PCB contaminated pipeline in 1996 were used with more current estimates of total pipeline to derive an estimate of 5% PCB contaminated pipe for an example company (see Table A8). The 1% pipeline replacement estimate for existing pipe is an assumed value for illustration purposes only.

[b] Assumed 1 day of PCB exposure/mile pipeline constructed (includes cleaning) for a construction worker and that PCB concentrations are on average 50 mg/L in liquid or 10 µg/100cm^2 on surface. It was assumed based on professional judgment that it would take 0.016 persons/mile pipeline decontaminated (4 person crew/250 miles).

[c] Assumed 1 day of PCB exposure/mile pipeline cleaning for a construction worker and that PCB concentrations are on average diluted by 100 fold by solvent used for flushing (i.e., 0.50 mg/L in liquid or 0.10 µg/100cm^2 on surface). It was assumed based on professional judgment that it would take 0.04 persons/mile pipeline to clean (i.e., 10 person crew/250 miles) due to increased labor hours for this task compared to cleaning as part of pipeline removal.

Table A8. Summary of miles of PCB-contaminated pipeline by company and percent of total mileage

Company in 1996 Memo[a]	Miles of Pipeline 2005[b]	1996 Estimate of Miles of PCB Contaminated Pipeline (>50 ppm)[a]	Comments	Percentage of 2005 Mileage PCB Contaminated (>50ppm)
Midcon (Natural Gas Pipeline Co. Of America)	9,111	200		2.2
Tenneco	13,302	450	Refer to this area as limited PCB contaminated	3.4
Algonquin	1,103	Entire line in 1996 - mileage not specified		
CNG Transmission Corporation (Now Dominion)	3,142	800		25.5
Columbia Gas	10,354	600		5.8
Columbia Gulf	4,105	250		6.1
Texas Eastern	9,179	Mileage not specified, assumed segment is (see comment)	The entire Texas Eastern from LA to NJ was assumed to be PCB contaminated at greater than 500 ppm PCBs.	
Texas Gas	5,643	250		4.4
Transco	10,469	50		0.5
Median	9,111	250		4.4
Mean	7,379	371		6.8

[a] Calhoun, M. 1996. Memorandum to M. Marshall, Multimedia Enforcement Division, dated December 24, 1996, regarding approval of 9 revised natural gas pipeline PCB Compliance Monitoring Program (CMP) plans. Multimedia Enforcement Branch.

[b] EIA. 2006. Additions to capacity on the U.S. Natural Gas Pipeline Network: 2005. Energy Information Administration, Office of Oil and Gas. August 2006.