Leaking Underground Storage Tanks (USTs) as Point Sources of MTBE to Groundwater and Related MTBE-UST Compatibility Issues

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ABSTRACT

As part of a larger effort investigating the occurrence and impact of MTBE in California water supplies, this report addresses the probability of product releases from UST systems and also the compatibility of materials used in UST systems construction with MTBE. A review of the existing literature identified more than 15 studies in which UST leakage incidence and/or the compatibility of MTBE with UST systems was investigated. The studies investigated the effect of MTBE reformulated fuels on a) metals, b) fiberglass tanks and piping, c) elastomers and plastics. These studies indicate that no significant threat exists to UST systems from the concentrations of MTBE likely to be present in reformulated fuels. Neat (100%) MTBE has been shown to be incompatible with certain UST system components—specifically with some elastomeric sealing components. For materials other than certain fluorinated elastomers, however, effects seen at concentrations of up to 20% were not statistically different from those seen when MTBE concentration was 0%. Those fluorinated elastomers that showed noticeable swelling in MTBE-reformulated fuels were noted to be still functional, however, and in most cases the increased swell was less than 10%. Nonetheless, we believe there is sufficient lack of objective, independent and quantitative research on materials compatibility with MTBE to warrant further investigation. This is especially true in the areas of metallic corrosion, fiberglass permeability and elastomer performance.

To estimate the probability of an MTBE release to groundwater from UST systems, regression analysis was performed on leak data for six annual periods (1992 through 1997). This analysis showed annual baseline leakage probabilities ranging between 2.5% and 2.9% of USTs active between 1992 and 1997. The average value for the six analyses was 2.6% per year. A direct ratio of confirmed releases to active tanks per year was also calculated. This analysis returned values ranging from 3.0% to 3.5% per year; however it was noted that some unusually large ratios within some individual analyses tended to skew those distributions in an upward direction. The two forms of analysis were deemed consistent.

In order to assess projected UST leakage probability in light of new regulatory standards mandating improved storage facilities and practices, a California leaking tank information database was examined for cases in which systems qualifying as upgraded to the new standard appeared. The number of these qualifiers was then balanced against the number of systems in the general UST population known to be upgraded. Following this rationale, a figure of 0.07% per year was calculated for upgraded systems. This figure is probably lower than ultimately expected over UST lifetimes because the upgraded fraction of the UST population is relatively "young", and one of the major factors in leakage incidence is known to be system age. As this fraction of the UST population ages, the tendency to leak will increase, and the leakage probability will rise by a corresponding amount that cannot presently be quantified.

I. INTRODUCTION

With the recent advent of concerns over the fuel oxygenate additive MTBE, the condition of the nation's underground storage tank (UST) population has become a renewed concern of regulators and policy-makers across the country. As part of a larger effort toward understanding the risks posed by MTBE contamination, this report focuses on just two questions:

- Based on existing data, what probability can we assign to the likelihood that a given UST will leak in a given year?
- Is there any evidence to suggest that MTBE, as a component of the stored fuel product, enhances that likelihood?

In order to determine the projected probability of leakage of USTs, we must understand and accept the inherent limitations involved. The most notable of these limitations is the fact that many UST leaks go undetected until such time as the leaking tanks are removed. The ideal data set for analyzing this question would be a representative cross-section of the UST population that could be removed and inspected for leakage. Obviously, this prospect is not feasible. However, the EPA keeps records of USTs nationally (the Corrective Action Database, or CAD). Similarly, the State of California maintains a statewide database of UST information (the Leaking Under-ground Storage Tank Information System, or LUSTIS). These databases record such useful facts as numbers of active tanks, tanks closed, and releases confirmed per quarterly monitoring period (CAD), and numerous site-specific facts such as location, date, discovery method and leak source (LUSTIS). Another condition that must be understood regarding assessment of these data is that the demographics of the UST population is in the process of shifting towards newer, upgraded tanks. It is natural to assume that, with an upgraded and less leak-prone UST population, a lower incidence of leakage therein will be realized.

2. COMPATIBILITY

Compatibility is defined as "The ability of a material to retain its physical properties when exposed to another substance" (ICF Incorporated, 1997).

2.1 MTBE COMPATIBILITY WITH METAL TANKS AND PIPING

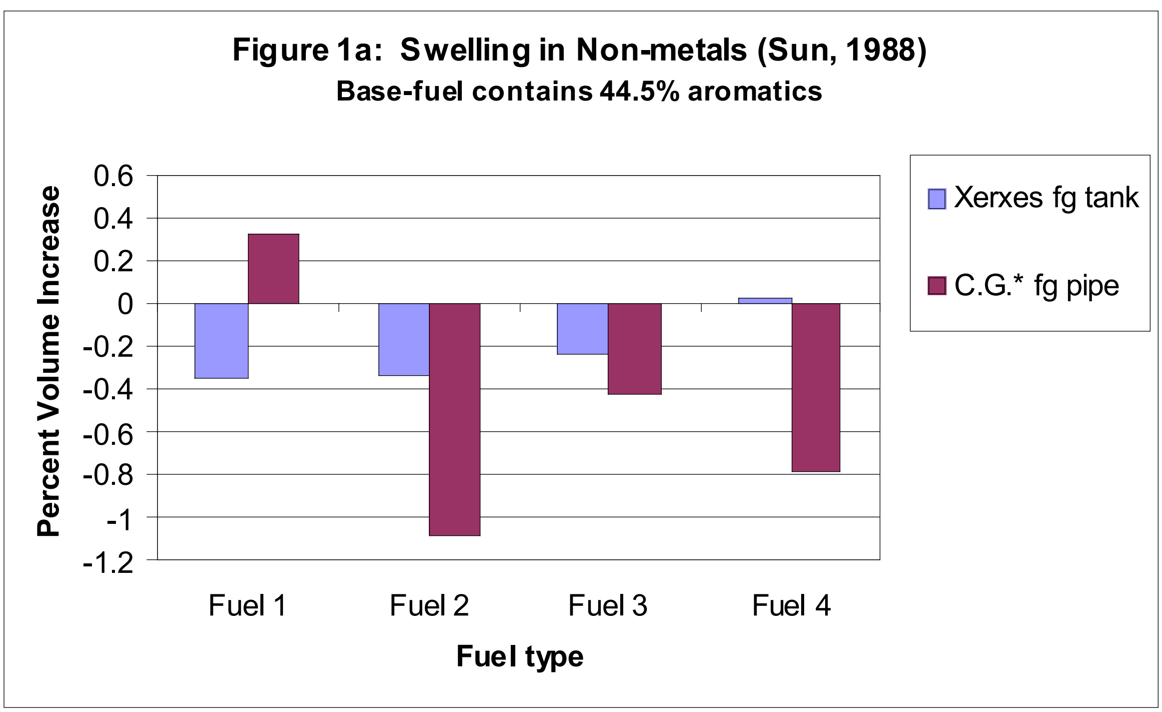
There have been concerns over whether the additional oxygen provided by MTBE could enhance oxidation and corrosion of metals in UST systems (Sun Refining, 1988). Metals such as plain carbon steel, galvanized steel, and cathodically protected steel are common materials used for USTs and associated piping (Davidson, 1997)). In their request to EPA for a waiver from the then-current 11% (vol/vol) MTBE restriction, Sun Refining & Marketing Co. in 1988 conducted tests on magnesium and terne plate coupons using four different gasoline/MTBE blends (Sun Refining, 1988). The blended fuels contained between 0 and 15% (vol/vol) MTBE. Tests were conducted for 7 months, and in all cases weight loss due to corrosion was deemed to be small (largest weight variations were a 0.31% gain and a 0.02% loss, both for magnesium in 1985 base fuel only). Results of previous tests were also reported in the same paper, during which seven other automotive metals were tested in three fuel blends containing 1970 base fuel and a) no MTBE, b) 15% MTBE only, and c) 15% MTBE plus antioxidant and multi-functional additive. During these tests, in only one case was weight loss judged to be greater in MTBE containing fuel than in non-MTBE containing fuel. In that instance, a 10/20 steel coupon had a weight loss of 2.95 mg after seven months in a) above, a weight loss of 10.75 mg after seven months in b) above, and a weight loss of 18.20 mg after seven months in c) above. Original weights of the samples were not given, however, for these earlier tests; nor were the losses given as percentages of the original weights.

In a separate study, Lang and Palmer conducted tests of MTBE, methanol, ethanol, and tertiary butyl alcohol (TBA) on various common automotive metals including brass, aluminum, zinc and mild steel (Lang and Palmer, 1989). Their report found that MTBE was the least aggressive of these oxygenates toward these metal samples, but did not quantify their findings; nor did they state whether the testing was based on measured weight loss, strength loss, or any other measurable quantity.

An American Petroleum Institute study of oxygenate compatibility with vapor recovery unit (VRU) systems found no difference in metals compatibility between MTBE and straight gasoline (API, 1990). Once again, however, no effort was made to quantify these results; and no evidence of any testing was shown.

2.2 MTBE Compatibility with Fiberglass Tanks and Piping

In 1988, Sun Refining submitted a waiver request to EPA in which they reported on compatibility between MTBE and fiberglass tank and piping materials (see figure 1a). Coupons of tank material (manufactured by Xerxes) showed "essentially no volume changes" after immersion in six test fuels ranging in MTBE content from 0 to 15% for a six-month period. Actual measures of volume change ranged from +0.26% to –0.74%. Sections of Ciba-Geigy fiberglass piping were immersion-tested for seven months in the same set of MTBE-blended fuels.



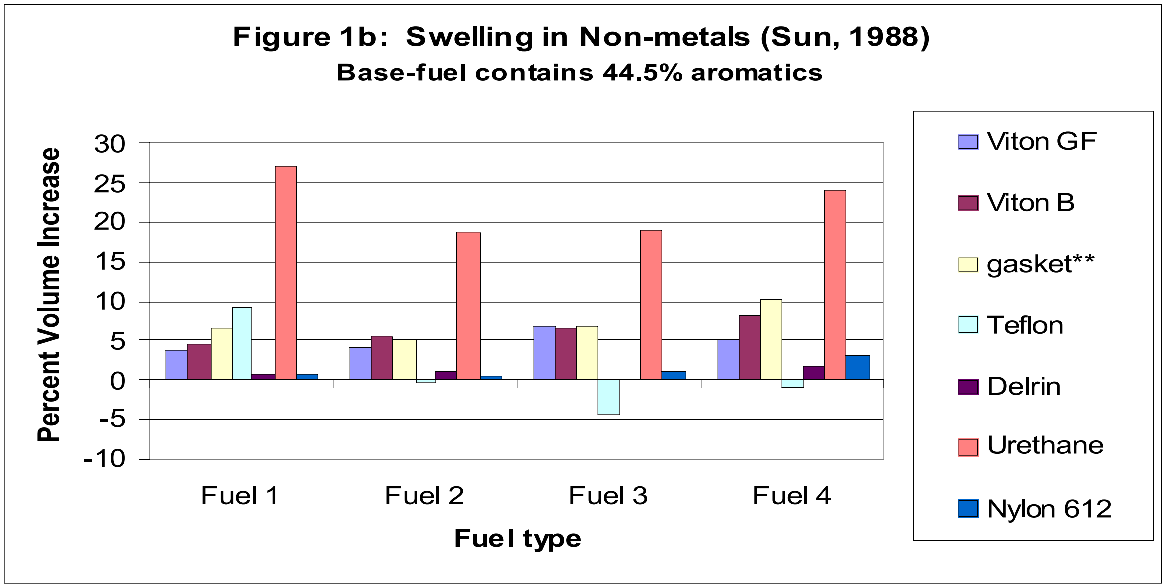


Figure 1b: Swelling in Non-metals (Sun, 1988)
Base-fuel contains 44.5% aromatics

Fuel 1: base fuel (bf)
Fuel 2: bf + 11% MTBE
Fuel 3: bf + 15% MTBE
Fuel 4: bf + 7.5% MTBE + 5% EtOH
* Ciba-Geigy fiberglass pipe
** Ford carburetor body gasket

Fluid Containment (formerly Owens-Corning) and Xerxes are major manufacturers of fiberglass USTs (Davidson, 1997). In 1995, Owens-Corning sent a letter to all of its tank customers in which they reported extensive testing of their products with fuels containing up to 20% MTBE (Owens-Corning, 1995). According to their tests, there was very little effect on the laminate used in their tanks. Furthermore, Owens-Corning stated that storage of ether-containing fuels would not void the manufacturer's warranty of their USTs made since 1964. This has been interpreted as essentially constituting a 30-year warranty of all Owens-Corning/Fluid Containment fiberglass USTs against internal corrosion stemming from storage of fuels containing up to 20% MTBE (Davidson, 1997). According to Alpine Environmental, Xerxes has provided a 30-year warranty of its USTs for storage of fuels containing up to 20% MTBE since 1988 (Davidson, 1997). It should be noted that in none of the literature reviewed was any permeability testing information found pertaining explicitly to MTBE-blended fuels and fiberglass tanks or piping.

2.3 MTBE COMPATIBILITY WITH ELASTOMERS, PLASTICS, AND HOSES

The effect of neat MTBE on elastomers is often seen as an increase in swelling and softening of these materials (API, 1990; Alexander, Ferber, Stahl, 1994). Alexander, Ferber and Stahl reported in 1994 on tests conducted on six common sealing elastomers to determine their relative resistance to increasing concentrations of MTBE (Alexander, Ferber, Stahl, 1994). They found that fluorinated elastomers (e.g. Viton®) were aggressively attacked by neat MTBE resulting in swelling between 70% and 130%. Their results, given in graphical form, indicate that the three Viton® formulations tested experienced the greatest degree of swelling at all concentrations. For concentrations below 20%, however, only one Viton® formulation swelled in excess of 10%, and all showed swell of less than 20%. The authors suggested that any of the formulations tested, including the Viton® formulations, would be suitable for use with commonly encountered (less than 20% vol/vol) MTBE-blended fuels.

Sun Refining conducted tests of six different fuel blends containing between 0 and 15% MTBE on elastomers and plastics (Sun, 1988). The seven-month tests consisted of soaking specimens in the test fuels at room temperature in sealed jars. Volumetric swell was recorded periodically and at the end of the test. Materials tested included: elastomeric carburetor parts, Viton® fluoro-elastomer, Teflon and Delrin samples, plastic fuel system parts, and Nylon 612. See Figure 1b. While Sun reported no large differences in swell between specimens soaked in 0% MTBE fuel and those soaked in 15% MTBE fuel, the Viton® samples did swell slightly more with 15% MTBE than in 0% MTBE fuel (between 2% and 10% increased swell in 15% MTBE fuel). It was noted, however, that the samples were still functional. The plastic fuel system parts experienced less swelling in 15% MTBE fuel than in 0% MTBE fuel "indicating a diluent effect with the MTBE" according to Sun.

The performance of fluorocarbon (FKM) elastomers in MTBE was studied by Aloisio in 1994 (Aloisio, 1994). He found that FKMs of 66, 68, 69, and 70% fluorine content exhibited >200%, 114%, 104%, and 72% swell, respectively, after 168 hours in neat MTBE at 23ºC (see Figure 2). Decreases in tensile strength, elongation at break point, and Shore A hardness were also observed for all FKMs during this test. The 66% fluorine FKM became too soft to test, and thus is not included in Figure 2. Lesser effects on strength, elongation, and hardness were reported when a lower concentration of MTBE (25%) was used on 66% and 70% fluorine FKMs; and these effects were compared to effects seen when no MTBE was present in the fuel (Figures 3a-c). The author states: "When MTBE is blended with fuels the overall polarity of the media is decreased, therefore FKMs can be used in [MTBE-blended fuels] so long as the concentration of MTBE does not exceed 20-30%." In a similar finding, Abu-Isa noted the effect of MTBE on FKMs (Abu-Isa, 1983). The author states: "One elastomer, namely the fluorocarbon elastomer, shows a sharp increase in swell with increased MTBE concentrations, especially in the concentration range of 25-100%."

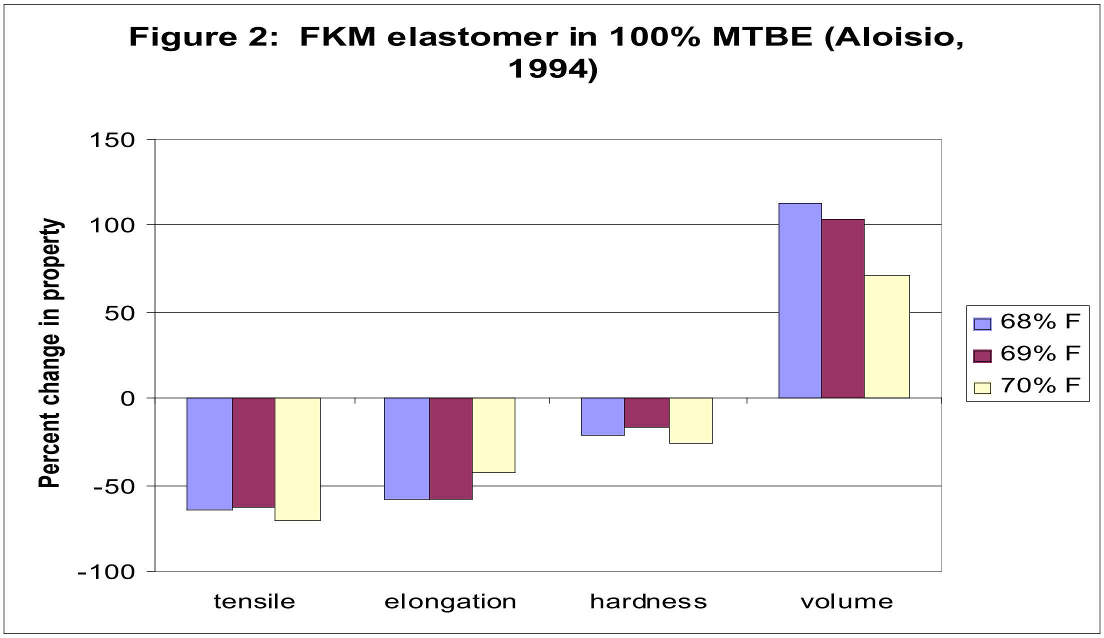


Figure 2: FKM elastomer in 100% MTBE (Aloisio, 1994)
Percent change in property
150
100
50
0
-50
-100
tensile
elongation
hardness
volume
68% F
69% F
70% F

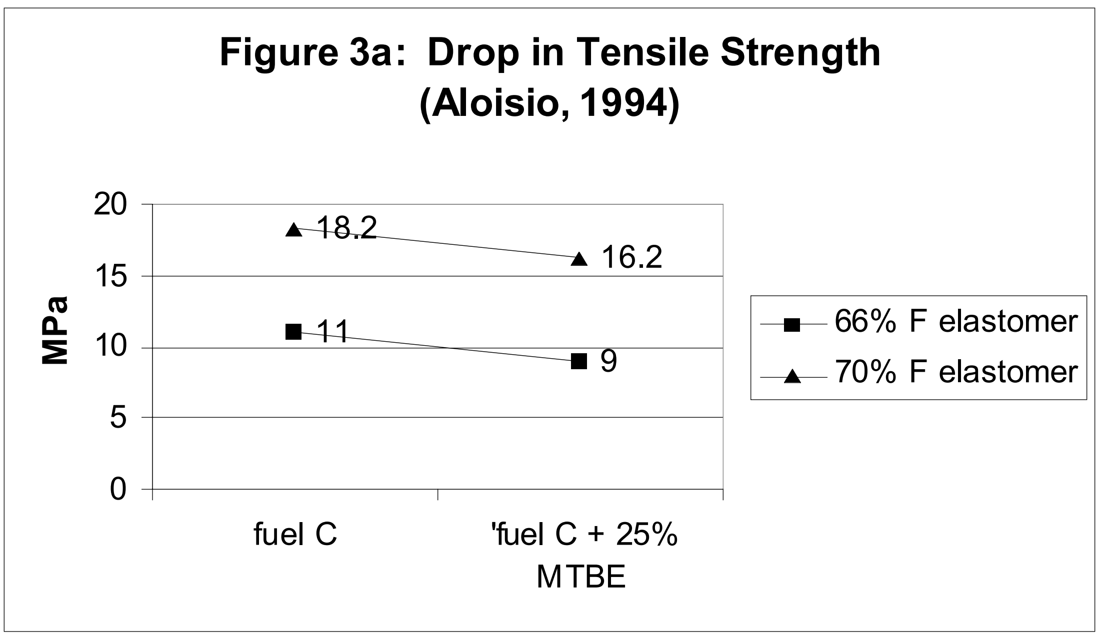
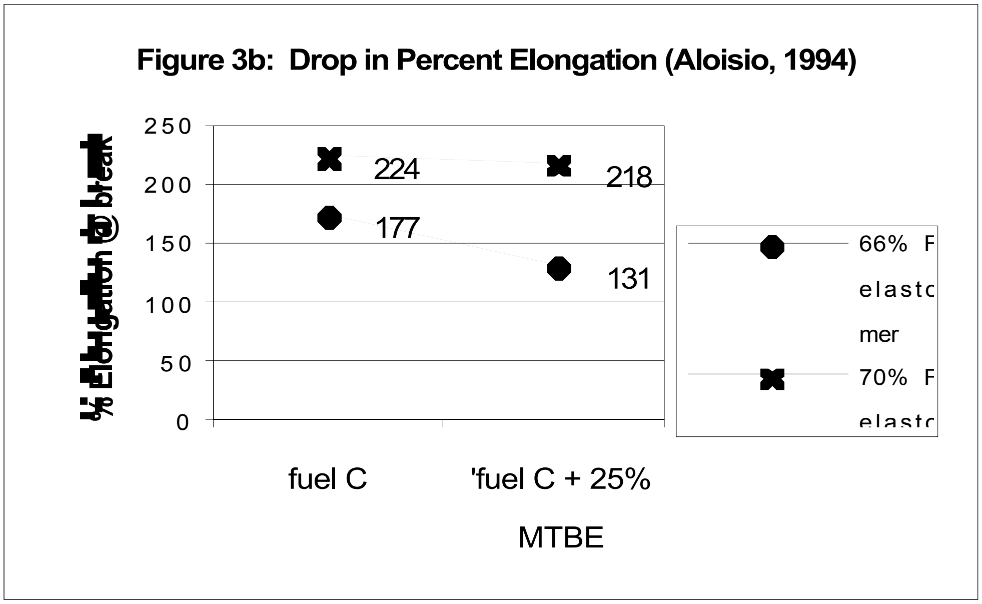
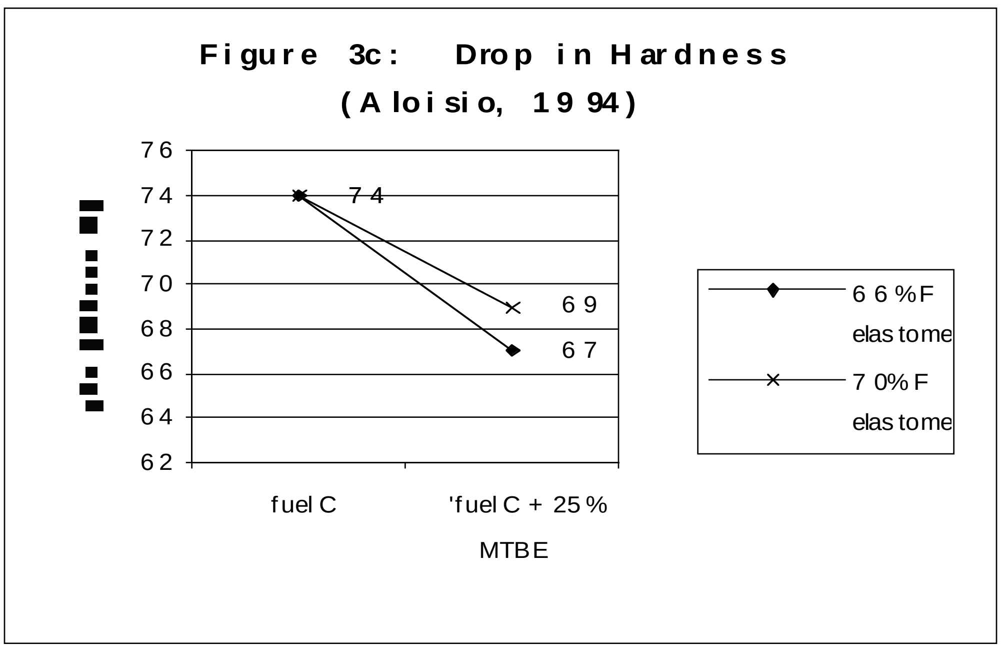
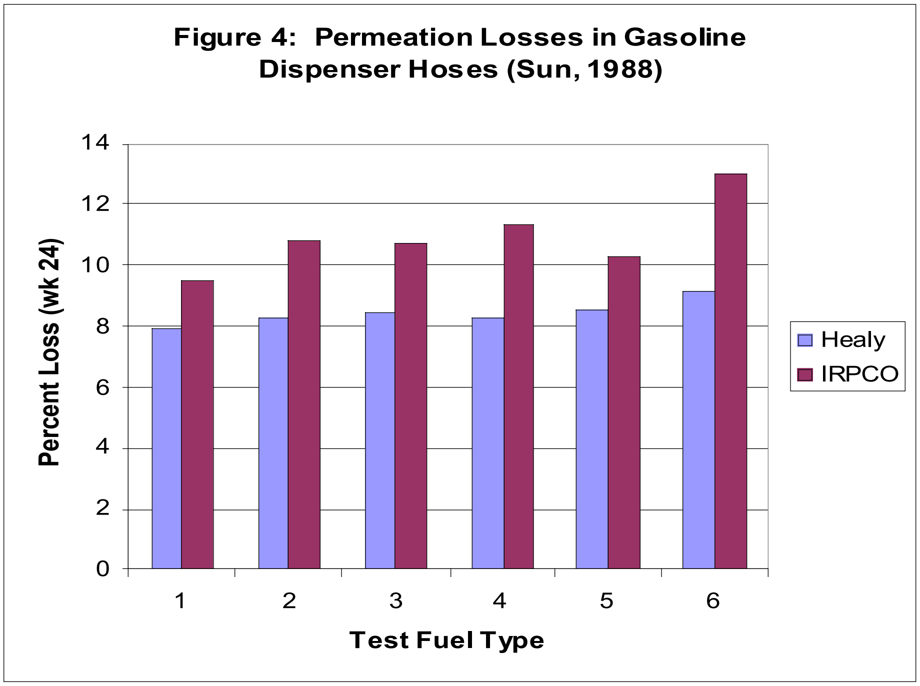


Figure 3a: Drop in Tensile Strength (Aloisio, 1994)
MPa
20
15
10
5
0
18.2
16.2
11
9
fuel C
'fuel C + 25% MTBE
66% F elastomer
70% F elastomer





Fuel line and dispenser hose evaporative permeability tests were conducted on several commonly used elastomeric hose materials (Sun Refining, 1988; figure 4). Sun reported "…no large differences [in weight loss] between the samples containing base fuel and samples with base fuel and 15% MTBE" over the 24 week study. Weight loss increased in the Healy hose from 8.0% to 8.5% in 15% MTBE fuel, and in IRPCO hose from 9.5% to 10.7% in 15% MTBE fuel.



Fuel 1: base fuel (bf)
Fuel 2: bf + 11% MTBE
Fuel 3: bf + 15% MTBE
Fuel 4: bf + 7.5% MTBE + 5% EtOH
Fuel 5: bf(2)*
Fuel 6: bf(2) + 15% MTBE
* Base fuel 2 contains 50% aromatics vs. 44.5% in standard base fuel

Greater evaporative losses were reported, however, from dispenser hoses containing fuel with 15% MTBE plus elevated levels of aromatics. Weight loss increased from 8.5% to 9.2% for Healy hose and from 10.7% to 13.1% for IRPCO hose, when the level of aromatic content was raised from 44.5% to 50% (in 15% MTBE fuel).

In 1997, the CaSWRCB issued a local guidance letter which included results of a survey of MTBE testing performed by or on behalf of seven flexible piping manufacturers (CaSWRCB, 1997). All seven piping systems were reported as having been tested by either the manufacturer or by Underwriter's Laboratories (UL). The survey concludes: "From an environmental standpoint, the performance of this technology to date has been excellent" indicating that the piping systems surveyed are safe for handling MTBE-containing fuels at the concentrations under which the test was run (UL 971).

3. UST LEAKAGE

3.1 DATA SOURCES AND USE

Quarterly and semi-annual reports were obtained from the EPA Corrective Action Database covering the period from the last quarter in 1991 through the last quarter in 1997. These reports (Data Set 1) contain data fields including the following: Active Tanks, Tank Closures, and Confirmed Releases. The Active Tanks field contains the number of active USTs at the time of each quarterly report; the Tank Closures field contains the cumulative number of UST closures for the state; and similarly, the Confirmed Releases field contains a cumulative number of known UST releases for the state. The CAD is an all-inclusive, nationwide database and provides the broadest possible base to draw from. Analysis of Data Set 1, therefore, should identify general trends in the greater UST population. It is, however, limited in that it provides little information beyond the three fields mentioned. Furthermore, large variations occur in these data from quarter to quarter, somewhat compromising the statistical rigor of the regression analyses conducted on them. See Data Limitations, Section 3.3.1.

A database obtained from the CaSWRCB contained results of a file review on known leaking tanks in California. Records dating back to 1996 were sampled from CaSWRCB's Leaking Underground Storage Tank Information System (LUSTIS) database. The information in these records was expanded upon to include additional site characteristics, such as the following: types of leak detection employed, most recent tests completed and results, age of tank, and type of materials used in construction. Data Set 2 is very useful in that it is specific to California and contains precise information of use to this investigation. Data Set 2 is limited, however, in that some of the reports in the expanded LUSTIS are incomplete. See Section 3.3.2.

Information in Data Set 1 was used for regression analysis as well as for a simple ratio analysis between active tanks and confirmed releases. Regression analysis revealed correlations between releases and a) total tanks in service and b) closures. Ratio analysis was used to determine a "ballpark" value of leak incidence for comparison with those values returned via regression analysis.

Data Set 2 was analyzed to identify factors that influence leak incidence (tank testing, age, material types, etc.), and determine to what degree upgrade practices are reducing the number of leaking systems.

3.2 DATA ANALYSIS AND RESULTS

3.2.1 DATA SET I

REGRESSION ANALYSIS

Clearly, there must exist some baseline probability of release in the active UST population, even under the most optimistic of scenarios. Releases due to poor installation of fittings, construction encroachment, or from frost heave in cold regions are examples of potential contributors to this baseline probability. Also, as we will show, most releases are discovered through closure activities. Thus, a correlation must exist between the two, and any attempt to investigate release incidence with these data must include closure statistics in the analysis. Regression analysis allows for the isolation of one parameter as another is varied, thereby enabling comparisons to be made and the relative impacts of the parameters to be explored.

A linear regression analysis was employed on the CAD field variables to investigate the relative dependence of Confirmed Releases (Releases) on Active Tanks and Tank Closures (Closures). As the figures contained in the Releases and Closures fields represent cumulative totals, differences over the analysis period, or "deltas", were first computed. These deltas were then normalized by dividing each by the average value of Active Tanks (which was not given as a cumulative number) for the period. Normalizing the variables was necessary due to the large variations occurring within the data set. For proper regression analysis, the relevant parameters should have similar variances. Normalization accomplishes this. The regression was then performed with Releases per Avg Active Tank as the dependent variable and Closures per Avg Active Tank as the independent variable:

y(Rls/Act)=x(Clsr/Act) + b(intercept). (Equation 1)

The intercept in the above equation can be viewed as the baseline probability of leakage in a year in the active UST population if no closures occurred.

This analysis was applied over the entire six-year period (Regression Method 1) and annually (Regression Method 2), and the results compared. For Regression Method 1, we chose the six-year period from 1992 to 1997, which was the largest time interval for which all the required data fields were present in the data set supplied. A total of 54 observations (states, territories, etc.) were included. Results of this analysis indicate that, nationwide, an average of 8.2% of the active tank population leaked over the course of the six-year period, for an average annual release incidence of 1.4% per year.

For Regression Method 2, analyses were conducted on the data as it varied annually. Each analysis thus represents a "snapshot" of the relationships between the respective variables for the particular year in question. Numbers of observations (states, territories, etc.) included in these analyses ranged between 44 and 53. These numbers vary due to certain inconsistencies seen in the data (see section 3.3 Data Limitations). Results of these analyses indicate nationwide annual averages for confirmed releases ranging between 2.5% and 2.9% of active tanks (see Figure 5).

Regression characteristics such as p-value and 95% confidence limits can be used to evaluate the statistical significance of individual parameters. In Regression Method 2, the intercept coefficient returned very small p-values (10^{-6} to .016), and exhibited upper and lower 95% confidence limits that did not enclose zero in every case. Thus it appears that, using the model given by Equation 1, the intercept seems to be significant in predicting releases. By contrast, p-values for closures per active tank were large (between .13 and .52), and 95% confidence limits did enclose zero for all six periods. This suggests that the contribution of this parameter (closures) in predicting release incidence is uncertain.

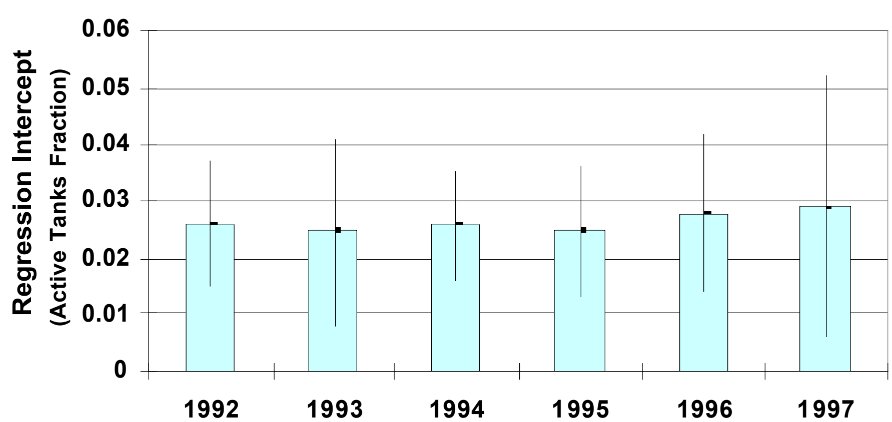
Interestingly, Regression Method 1 yielded somewhat different results. While p-value and confidence limit figures for the intercept were consistent with those for Regression Method 2, the x-variable (closures per active tank) p-value was relatively low (0.010) and upper and lower 95% confidence limits did not enclose zero. This result indicates that, over a six-year period, closures and active tanks are both significant parameters in predicting releases. This makes intuitive sense. Over a short span of years, as in this case, the average number of active tanks tends to remain more or less constant; while the number of closures steadily increases each year. The variability in closures remains essentially the same for the longer period as compared to the shorter one, but the longer period encompasses a larger number of closures and "evens out" the individual variations. In short, having more samples leads to improved statistical rigor.

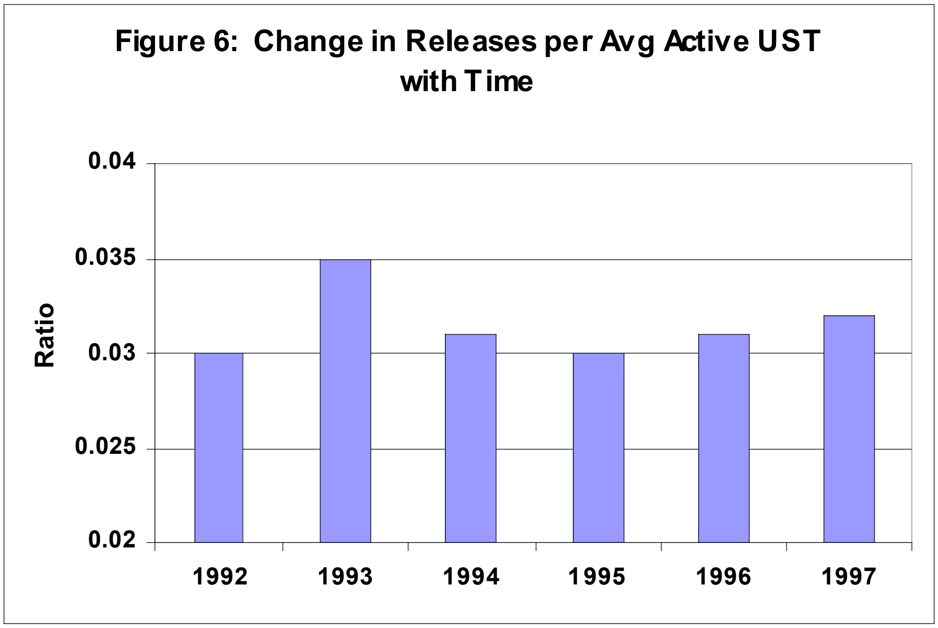
RATIO ANALYSIS

The second form of analysis performed on Data Set 1 was a simple ratio of Releases to Active Tanks. Ratios of Releases to Active Tanks were therefore computed for each state containing useful data. (As noted in the following section on Data Limitations, some of the data contain errant entries and were therefore omitted from analysis.) An average of these ratios was calculated across states on an annual basis and the combined average of all the annual average ratios was then calculated. Good agreement was seen amongst the individual annual averages,

Figure 5: Change in UST Regression Method 1 Intercept with Time

(w/95% confidence limits)





all being between 3.0% and 3.5% (Figure 6). The combined average was 3.2%. Standard deviations for these groups ranged from 2.0% to 4.0%, and in some cases were larger than the computed averages themselves. In these cases, a few unusually large ratio values skewed the distribution and thus biased the calculated averages in an upward direction.

3.2.2. DATA SET 2: RELEASE INCIDENCE FACTORS

Data Set 2 contains 1705 records of leaky USTs contained in an MS Access formatted database. Although the database contains 87 fields, the principal ones of interest to this project are the following:

Most recent tank test and result
Most recent piping test and result
Age of tank
Tank walls
Tank material
Type of upgrade (if any)
Source of release
Means of release discovery

Dates that these reports were filed range from 06/01/96 to 12/17/97. Reported dates of leak discovery range from 01/01/67 to 12/10/97.

3.2.2 A) TANK AND PIPING TEST RESULTS

For the 1705 reports surveyed, 496 (29.1%) showed results from the most recent tank test done, while 391 (22.9%) showed results from the most recent piping test done. Of the 496 tank tests reported on, 468 (94.6%) were passing, 11 (2.2%) were failing, and 17 (3.4%) were inconclusive. Of the 391 piping tests reported on, 373 (95.4%) were passing, 10 (2.6%) were failing, and 7 (1.8%) were inconclusive. See Figures 7 and 8.

3.2.2 B) TANK AGE

Similarly, out of the 1705 cases, 722 (42.3%) reported the age of the leaky UST. Of those 722, 10 (1.4%) were 0-5 years old, 42 (5.8%) were 6-10 years old, 101 (14.0%) were 11-15 years old, and 42 (5.8%) were of unknown age. The remaining 527 (73.0%) were older than 15 years. See Figure 9.

3.2.3 C) RELEASE SOURCE

There were 1272 records (74.6%) indicating the source of the release. Of these, 741 (58.0%) reported the source as unknown, 334 (26.0%) reported the tank as the source, 137 (10.8%) reported the piping as the source, and 60 (4.7%) reported a leak source other than tank, piping, or some unknown source (figure 10).

Figure 7: Tank Test Results
(Systems with Confirmed Releases Reported to LUSTIS)

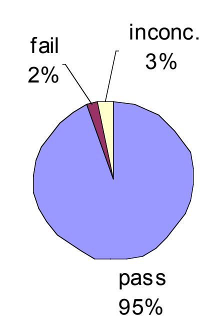
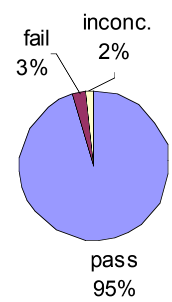


Figure 8: Piping Test Results
(Systems with Confirmed Releases Reported to LUSTIS)



3.2.2 D) RELEASE DISCOVERY

Figure 11 illustrates means by which releases were discovered. Of the 1705 reports, 1295 (76%) contained information on the method of leak discovery. In 866 cases (67.0%), leaks were discovered through tank closure activities. In 118 cases (9.1%), the leaks were discovered through subsurface monitoring. In 24 cases (2%) routine tank tests discovered the leaks, while 4 cases (0.3%) were discovered through inventory control measures. Five cases (0.4%) were

Figure 9: Tank Age

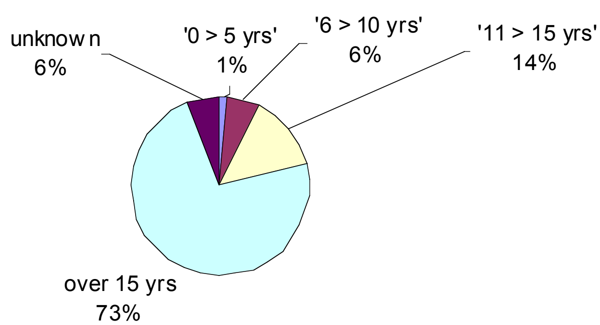
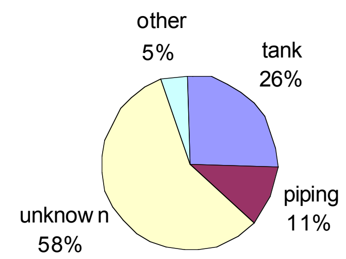


Figure 10: Release Source

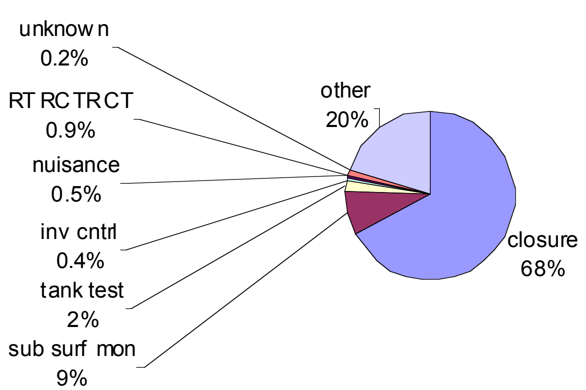


discovered as a result of a reported nuisance condition, 265 cases (20.5%) were discovered through other, unspecified means, and 2 discoveries (0.1%) were of unknown origin. 12 cases (0.9%) listed as one of the following inappropriate abbreviations: RT, RC, TR, or CT. These abbreviations are intended for use with the "how stopped" field, and refer to leakage mitigation techniques such as Remove Contents (RC), Repair Tank (RT), and Close Tank (CT). This sort of poor reporting practice is evidence of another limitation of these data.

3.2.3 DATA SET 2: PROJECTED LEAK INCIDENCE OF UPGRADED SYSTEMS

Information contained within Data Set 2 was used to project leak incidence in upgraded UST systems. We understand the limitations involved, however, in the use of these data for this purpose. Specifically, we know that most releases are discovered through closure activities; and, because the upgraded portion of the UST population is relatively "young", fewer upgraded systems have been closed. Therefore, we believe the existence of presently undiscovered leaky upgraded

Figure 11: Release Discovery Method



systems is plausible. The ability to investigate a representative portion of the upgraded UST population for leakage would offer an ideal means to assess its leak potential. This, however, is impractical. Nonetheless, even without further investigation of upgraded sites, we feel that a conservative estimate of release probability among upgraded systems is possible with these data.

As an initial cut, cases from the expanded LUSTIS wherein the tank was the source of the release were isolated, and the portion of these that appeared to be upgraded were counted. In order to be counted as upgraded, the tank had to be either clad, cathodically protected steel, double walled steel, or fiberglass. The fraction of this portion of the cases where tanks were the source of the release was also compared to the known fraction of the general UST population that has been upgraded to date. Similarly, the cases in which piping was the release source were examined to see what fraction of them appeared to have been upgraded. To qualify as upgraded, the piping needed to be fiberglass or double walled steel. It should be noted that even in instances where the examined component appeared to be of upgraded material, the system as a whole might not have been upgraded. Thus, this analysis offers only a rough idea of the effectiveness of upgraded materials in cases where the source of the release was known. It was found that a rough estimate of releases attributable to "upgraded" tanks via this method was approximately 19%. Similarly, a rough estimate of the number of releases attributable to "upgraded" piping was approximately 32%. While these numbers seem high, their size relative to one another seems appropriate. We would normally expect piping to be more leak-prone because of its more vulnerable (shallower) location, and because of the greater numbers of fittings involved, compared to the tank itself. The fraction of USTs that have been upgraded through June of 1998 (personal communication with source at CaSWRCB) is approximately 52%. Thus it appears that upgraded USTs are "under-represented" in the leaking UST population, even given the seemingly high percentages returned via this imprecise method of analysis. From this we can infer that upgraded systems are less likely to leak than are non-upgraded systems.

In order to gain a more quantitative result, Data Set 2 was analyzed in a different way. The entire data set, 1705 records, was searched to determine the number of those that appeared to be fully upgraded systems. In order to be counted (considered as fully upgraded), the record had to have a clad, double walled steel, cathodically protected steel, or fiberglass tank; double walled steel or fiberglass piping; full tank upgrades (spill, overflow, and striker plate); and have pipe containment. Thirty-six records containing the necessary characteristics were found representing the number of fully upgraded tanks reported to be leaking during the 18-month period. The total number of active tanks during the period was estimated by averaging the number of active USTs from June 1997, December 1997 and June 1998 (CAD and personal communication w/CaSWRCB). A total of 35,141 systems were therefore determined as having been upgraded statewide. The resulting percentage of leaking upgraded systems is 36 / 35,141 = 0.1% per 18 months, or 0.07% per year. Again, for reasons pointed out earlier in this section, we feel this to be a lower bound estimate.

3.3 DATA LIMITATIONS

Both data sets are inherently limited by the fact that they contain information on leaky tanks only. Ideally, a study such as this one would be able to remove and inspect a representative cross-section of the UST population for signs of leakage. Precise statistics could then be ascertained regarding factors that increase the likelihood of a release. As such an undertaking is not practical, one of the most feasible options is to use these data sets of leaky USTs to estimate the incidence of release and identify factors that influence the tendency toward leakage in the general UST population.

3.3.1 DATA SET I

The data exhibit certain inconsistencies that may limit the faith that can be placed in these analyses. In particular, numerous instances occur in which the change in either the Closure or the Releases field (referred to as the "delta" of Closures or Releases) of a record contained a negative quantity. For example, CAD data for New York in 1994 indicate a net decrease of 11,306 in the number of Closures (a cumulative number). This has no physical meaning. Closer inspection reveals that in 1st Q '94 closures increased by 1751 (3.4%), by 1518 (2.9%) in 2nd Q '94, and in 3rd Q '94 by 1169 (2.2%) all rather typical values of the data set as a whole. Then in 4th Q '94, NY shows a net decrease of 15,744 (28%). Data for 1995 indicates a return to more reasonable values of +8% for 1st Q '95, +3.5% for 2nd Q '95, +5.7% for 3rd Q '95. This example can only derive from a reporting error in the data. For the purposes of analysis, any such record was omitted from the analysis. Thus, varying numbers of entries (from 43 to 54) were used in the regression analyses. Furthermore, and perhaps of greater concern, the only reason that those errant entries were discovered was due to the fact that they contained negative quantities where a negative quantity made no sense. The question of whether or not other records might also contain false-valued entries that remain hidden by the fact that they are not negative should also be considered. This more subtle possibility requires a closer look at the data, but again, apparent inconsistencies can be found. According to the data for California, a sudden large increase in Closures of 55,115 (450%) occurred between 1st Q '94 and 2nd Q '94, accompanied by a drop in Active Tanks of 29,844 (23.0%). Cumulative Releases showed a nonsensical drop by 1 (see Figure 13). While an increase in Closures usually is accompanied by a decrease in Active Tanks (as in this case), variations on the order of 10% or less are more typical of the data in general. Though suspect, the questionable record was nonetheless included in the analysis and thus constitutes an example of the type of limitation inherent in these analyses.

Another serious limitation of these data is the large degree of variation they exhibit. This may in fact result from the aforementioned reporting inconsistencies. From a statistical standpoint, the large variance of the data set compromises the validity of the regression analyses performed on it.

The manner in which these apparent discrepancies in the data have been handled may also create interpretation problems. As mentioned, any errant records found were left out of the analysis in question. But the same record was then used for subsequent analyses, if it appeared normal (contained positive valued entries). The possibility exists that this procedure may be propagating errors within the analysis. For example, the record for MN was omitted from the analysis of 1992 based on a negative Closure value. Yet, in 1993 and in all subsequent data, MN showed no negative-valued deltas, and so was included in those analyses. The potential for error propagation must therefore be considered a limitation of these data as well.

3.3.2 Data Set 2

The principal limitation of this data set is that it is still incomplete, although poor reporting practices are also evident. In many instances, only a small amount of information is given for the area of interest. Analysis of tank test and piping test reports, for example, are based upon 30% and 23% fractions (respectively) of the survey sample (see Section 3.2.2a). Similarly, only 16% of the reports surveyed contain information on the type of tank upgrades in place (if any). The fact that only such a small fraction of the survey contains information on these subjects illustrates the lack of complete reporting typical of many of these records. Small sample sizes compromise the analysis, and thus any trends inferred for the UST population as a whole. Poor reporting practices, as seen in 3.2.2 d), have also been observed in these data; even though the number of such instances appears to be small. These instances could possibly stem from poorly trained or inexperienced personnel performing site inspections.

4. Conclusions

A review of the available literature indicates that no significant threat exists to UST materials from MTBE-containing fuels so long as the vol/vol concentration of MTBE is less than 20%. The most vulnerable materials in UST systems are elastomeric sealing components, some of which have exhibited significant amounts of swelling when in contact with 15% to 20% MTBE-containing fuels. Although deemed significant, the amount of swell associated with these concentrations did not adversely affect the ability of the material to perform its required function in short-term tests. However, no tests follow material properties over UST lifetimes (20 years or more). Fiberglass materials exhibit no significant volume changes when in contact with MTBE-containing fuels; and one manufacturer of fiberglass USTs reported very little effect on the laminate used in their tanks. Furthermore, at least one fiberglass tank manufacturer has warranted the use of their tanks for 30 years of usage with fuels containing up to 20% MTBE. Metallic UST components exhibit no significant changes in physical properties stemming from exposure to MTBE-containing fuels in the liquid phase. Even though the available literature appear to be consistent with one another in their findings, many of those findings were qualitative in nature, and in many cases, the studies were conducted by industry purveyors or materials suppliers. We believe there is sufficient lack of objective, independent and quantitative research on materials compatibility with MTBE to warrant further investigation. This is especially true in the areas of metallic corrosion, fiberglass permeability and elastomer performance.

Regression analysis of EPA data (CAD) on USTs nationwide indicates that, on average, about 2.6% of active USTs have a detectable release per year. This is consistent with a simple ratio analysis which results in a figure of 3.2% per year (releases per active tank).

Analysis of an expanded portion of California's Leaking Underground Storage Tank Information System (LUSTIS) showed that a lower bound estimate of release incidence among upgraded USTs could be placed at 0.07% per year. Both CAD and LUSTIS have limitations including data inconsistencies and incomplete reporting.

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