REGULATING UNDERGROUND FUEL STORAGE TANKS (USTS), BENEFITS AND CHALLENGES

A. Maqsood Ahmad[1], O. Al-Attas[2], S. Mohiuddin[3] and M. Al-Suwaiyan[4]

1,3: Research Assistant, Civil Engineering Department, KFUPM.
2: Graduate Assistant, Civil Engineering Department, KFUPM.
4: Associate Professor, Civil Engineering Department, KFUPM.

E-mail: mianabid76@hotmail.com

ABSTRACT

In arid regions like Saudi Arabia where surface water is scarce, groundwater becomes the main source of freshwater. The recent growth in municipal, agricultural, and industrial sectors resulted in a huge increase in water demand, which is currently provided by the costly seawater desalination as well as by groundwater. Groundwater quality is an essential part related to this issue since this natural source loses its value significantly as its quality deteriorates. An important source of groundwater pollution is leaking Underground Storage Tanks (USTs), which are common in older gas station and fuel storage facilities. Assessment and remediation of groundwater contamination is a very costly, complex, and extremely difficult tasks due to the hidden nature of the subsurface environment and the big variations in the subsurface media. This paper examines the long-term potential threat to groundwater quality posed by (USTs). It also shows the difficulties associated with the clean up of such contamination stressing the importance of spill prevention measures. And finally it shows that there is a need for the quick development of required specifications and standards for (USTs) at various stages of construction and operation in order to minimize the potential for groundwater contamination and to reduce the high cost of aquifer remediation.

Keywords: *Groundwater Contamination, USTs, NAPLs, Aquifer Remediation.*

الملخص

في المناطق القاحلة مثل المملكة العربية السعودية حيث أنّ المياه السطحية نادرة، تصبح المياه الجوفيّة المصدر الرئيسي للماء العذب. إنّ النمو الأخير في القطاع الزراعي، البلدي، و الصناعي تسبّب في زيادة كبيرة في طلب الماء الذي يمدّ حاليا بتحلية ماء البحر (الغالية التكاليف) وأيضًا بالمياه الجوفيّة. نوعية المياه الجوفيّة جزء أساسيّ متّصل بهذه القضيّة حيث يفقد هذا المصدر الطّبيعيّ قيمته بدرجة كبيرة عندما تتدهور جودته. إن تسرّب الوقود في الخزانات تحت أرضية هو مصدر مهم لتلوث المياه الجوفيّة و الذي يعتبر شائعاً في محطّات البنزين القديمة و مرافق تخزين الوقود و يجب أن يؤخذ بعين الإعتبار أن التقييم ومعالجة تلوّث المياه الجوفيّة غالي، معقد، و صعب جدا بسبب الطبيعة الخفية للمواد المكونة للبيئة المتواجدة تحت سطح الأرض. إن هذه الورقة تفحص التهديد المحتمل-الطويل المدى- و الذي قد يؤثر في نوعية المياه الجوفيّة من قبل الخزانات تحت أرضية و تبين أيضاً الصعوبات التي إرتبطت بتنظيف مثل هذا التلوّث و تؤكّد على أهمية إجراءات منع إنسكاب هذه الملوثات. و أخيرًا تظهر ورقة العمل أن هناك حاجة ماسة للنّموّ السّريع لتحديد متطلّبات و مقاييس الخزانات تحت أرضية في مراحل البناء المتنوّعة و التشغيل لكي يحدّ من إمكانيّة تلوّث المياه الجوفيّة و لتقليل التّكلفة العالية لمعالجة الطبقة الجوفية.

1. GROUNDWATER

Water is the lifeblood of every living creature on earth. Approximately 70 percent of the earth's surface is covered with water. Groundwater is often thought of as an underground river or lake. Only in caves or within lava flows does groundwater occur this way. Instead, groundwater is usually held in porous soil or rock materials, much the same way water is held in a sponge. When rain falls to the ground, the water does not stop moving. Some of it flows along the surface in streams or lakes, plants use some of it, some evaporates and returns to the atmosphere, and some sinks into the ground. Groundwater is water that is found underground in cracks and spaces in soil, sand and rocks. The area where water fills these spaces is called the saturated zone. The top of this zone is called the water table. The water table may be only a foot below the ground's surface or it may be hundreds of feet down.

1.1 Importance Of Groundwater

In arid region like Saudi Arabia where surface water is scarce, groundwater becomes the main source of freshwater. The recent growth in municipal, agricultural and industrial sectors resulted in a huge increase in water demand, which is currently provided by the costly desalinated water as well as by groundwater. Groundwater represents a major portion of earth usable water resources. More than 98% of the world's water supply is groundwater far exceeding the volume of surface water. It often has high quality resulting in a very low treatment cost. Unlike the surface water reservoirs, which occupy large areas, frequently of prime agricultural land, the presence and utilization of groundwater need not conflict with other use of land under which it occurs. Deep beneath the ground it is unseen insulated from changes in temperature, and protected from evaporation.

1.2 Literature Review

The most relevant works regarding underground storage tanks began in 1960's and thereafter. Initial studies regarding the regulations of underground storage tanks (UST) did not reveal much. The following are the scan of most relevant works done regarding the underground storage tanks.

In 1987, Maresca et al. in their article discussed about the EPA evaluation program. The united states EPA evaluated the performance of 25 commercially available volumetric test methods for detecting small leaks in underground storage tanks containing Gasoline and the performance was established by means of an experimentally validated performance simulation.

In 1989, Eklund et al. published an article about the work of EPA regarding USTs. The U.S. Environmental protection agency EPA has been implementing an underground storage tank program and is doing research on external and internal leak detection devices for UST'S. The EPA monitoring systems laboratory (EMSL) in Las Vegas, NV has been participating in research on external leak detection devices.

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In 1991, Rogers and Richard discussed the new technologies and designs evolved in recent years as a result of regulations of underground storage tanks. The technologies include composite, jacketed, Double wall, vaulted and catholically protected steel tanks. They also discussed the purpose of design, construction recommended practices and applicable regulations.

In 1997, Rafferly and Ellen expressed the need for developing a number of systems for monitoring storage tanks. They also underlined the need for regulating the storage tanks by storing the petroleum based products in single walled tank but with protection against corrosion and equipped with leak protection.

In 1999, Marxsen and Craig's discussed about the cost of remediating UST that was found to exceed the benefits. The average tank upgrade has cost around $100,000, But the EPA estimates that the average clean up cost $125,000.Based on cost study it seems that the enormous effort of remediating USTs seems unjustifiable.

In 1999, Anzzolin et al. published an article about the major findings of the "National water quality inventory 1986 report to congress groundwater chapter" this report was produced by EPA in 1998. They found that the leading source of groundwater contamination in USA is underground storage tanks. They collected data for a total of 162 aquifers and other hydrological settings and found that most of the aquifers are contaminated.

In 1999, Canning and Kathie published an article in journal of pollution engineering to discuss an innovative system that is under development at new Mexico institute of Mining and Technology in Socorro to stop groundwater contamination that can result from underground storage tank (UST) spills. According to the institute, the system incorporates a 3D liner that prevents groundwater contamination from underground storage tank surface spills, leaks and faulty installations. It can also serve as a separator to remediate spills captured by liner.

Christensen et al. published an article about sensor rich robots, which function with respect to models of their environment, have significant potential to reduce the time and cost for the cleanup while increasing the operator safety. Sandia National laboratories are performing experimental investigations into the applications of intelligent Robert control technologies to the problem of removing the waste from groundwater. Intelligent system control is achieved through the integration of extensive geometric and kinematics world models with real time sensor based control. All operator instructions with the system are through fully animated, graphical representations, which validate all operator commands before execution to provide for safety operation.

In a study Huang et al. proposed an internal parameter fuzzy relation analysis (IPFRA) model for environmental risk assessment of petroleum-contaminated aquifers due to leakage from underground storage tanks. This model can effectively incorporate effects of different pollutants and different remediation techniques within a general framework. Also, it can directly reflect uncertainties presented as inexact intervals of a number of modeling inputs. Results of a case study indicate that reasonable solutions of risk assessment under different system conditions have been generated.

A monitoring system that has enhanced the ability of Naval Fleet industrial supply center, point Loma, California, to detect fuel leaks was described in a featured article. The system is called the soil Sentry Twelve X Aspired Monitoring system and is produced by Arizona Instrument, phoenix, Arizona. The system constantly monitors the concentrations of total organic hydrocarbons in the area around the fuel storage tanks, and it was upgraded so that it could differentiate between ambient levels expected and those associated with spillages.

In 2000, Charbeneau, Rindall J., Jones, suggested simple models for estimating recovery rates when using wells and vacuum enhanced systems. Algebraic equations that can be used to estimate recovery times can be developed through the use of non aqueous phase liquids (LNAPL) volume balance between LNAPL recovery rate and formation free product volume. Model parameter selection and validations were also presented.

In July 2000, Torrensand Kelvin D. considered ways of identifying cost savings in groundwater treatment. Although groundwater pump and treatment systems are meeting current remediation requirements, there are usually opportunities to reduce costs through reduced pumping or modification of existing treatment system operations. It is often possible to negotiate operational changes with regulatory agencies to produce cost savings without compromising the integrity of the remedy.

In January 2001, Gandhi and Ashish proposed the use of volatile corrosion inhibitors for protection of storage tank bottom. They also presented the technique of using VCI’s at the bottom of storage tanks to store oil and petroleum supplies. VCI’s may be used alone or in conjunction with traditional control method of cathodic protection.

2. GROUND WATER QUALITY

A Contaminant is defined by the safe Drinking water Act as “any physical, chemical, biological, or radiological substance or matter in water.” Freeze and cherry (1979) define as contaminants “all solutes introduced into the hydrologic environment as a result of man’s activities regardless of whether or not the concentrations reach levels that cause significant degradation of water quality.” For them “pollution is reserved for situations where contaminants concentrations attain levels that are considered to be objectionable.” Miller (1980) used a very similar definition: “Groundwater contamination is the degradation of the natural quality of groundwater as a result of man’s activities”.

Much current research is being devoted to defining just what "normal" groundwater quality is, or how it can best be defined. Groundwater which naturally contains objectionable amounts of dissolved substances can properly be considered contaminated, as well as polluted; however most regulatory functions focus on human activities which artificially introduce contaminants into groundwater.

2.1 Threat Posed By (USTs)

Underground Storage Tanks (USTs) can affect the quality of groundwater in different ways. Accidental spills, routine washing and rinsing of machinery and chemical storage tanks can release contaminants to soil and groundwater. The tank system includes the tank, underground-connected piping, underground ancillary equipment, and any containment system. The system consists of a tank (or a combination of tanks) and connected piping having at least 10 percent of their combined volume underground. The USTs in gas stations are filled with petroleum hydrocarbons. Most of the old stations use steel USTs. Unprotected steel USTs are most commonly damaged by corrosion. When corrosion occurs, a steel UST system and its underground surroundings act like a battery. Part of the UST can become negatively charged and another part positively charged. This reaction causes the steel tank to corrode, thus forming holes that result in leaks.

Overfills occur less frequently but usually result in larger-volume releases. Spills most often occur at the fill pipe opening when the delivery truck's hose is disconnected. Repeated releases of this nature can create environmental problems. According to The U.S. Environmental Protection Agency's (EPA) Blue Ribbon Panel appointed in 1999 to investigate problems with the nation's air and water quality, has determined that leaking (USTs) for gasoline remain the primary source of groundwater contamination. Although most of these systems have been upgraded or replaced over the past decade in response to EPA requirements, the panel estimates that about 20% of the storage tanks have not. In addition, leaks are occurring from upgraded USTs because of inadequate design, installation, maintenance, and/or operation of cathodic protection and other corrosion and leak-prevention systems.

The flow of petroleum hydrocarbons that include the components of gasoline (benzene, toluene, ethylbenzene, and xylene, together known as BTEX) and other fuels into the ground from leaking petroleum underground storage tanks can pose a severe environmental threat to the underground water supply. Some contaminants are released directly to groundwater while others are released to the soil. When released to the soil, contaminants will migrate through the soil and may contaminate the underlying groundwater. Some contaminants may dissolve in the groundwater as it percolates through the soil. Others may dissolve in the gases contained in soil pores and spread before dissolving in the groundwater. The fate of contaminants once released to the soil or groundwater is extremely difficult to predict.

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3. UNDERGORUND STORAGE TANKS

In 1984, Hazardous and Solid Waste Society of USA made an amendment to the Resource Conservation and Recovery Act (RCRA) added a new subtitle I, "Regulation of underground storage tanks". This subtitle requires EPA to develop a comprehensive program for regulating the Under Ground storage tanks.

According to EPA, the average cost of tank cleanup at site is about 70,000 US $. However if tanks removal and treatment of surrounding soils are required, these costs can total more than 8 million US $.

3.1 Underground Storage Tank Design

The EPA has classified underground storage tanks in two broad categories, based upon the tank application.

- Gas Stations.
- Industrial/Commercial Installations.

The configuration of thousands of underground storage tanks in the kingdom varies to suit several constraints, including the geography of the site, the type of material stored and the owner's operation. According to EPA each installation will probably have three basic components:

- One or more tanks
- Anti-flotation anchorage (in regions having high water table)
- Piping system
- Pumps
- Means for leveling gaging
- System for corrosion protection

Underground storage tanks in the gasoline stations are used for storing of the following products:

- Gasoline-leaded, unleaded, and premium grades.
- Diesel Oil.
- Waste Oil (many contain some gasoline).

Underground storage tanks vary in size, shape and materials of construction. Metal tanks are usually welded and have some kind of exterior coating for protection against corrosion. Tanks fabricated from fiberglass, epoxy, or other nonmetallic material which are common in newer installations, generally required no coating for corrosion resistance. Table 1 presents a summary of installation practices for fiberglass-reinforced plastic (FRP) and steel tanks, according to the standards of American Petroleum Institute.

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Table 1-1 Underground Storage Tanks Installation Practices

Item	FRP (Capacity<20,000gal)	FRP (Capacity>20,000gal)	Steel
Distance Between adjacent tanks	18	24	12
Distance Between tank and adjacent side wall	24	24	24
Thickness of compacted bedding	12	12	6
Top slab extension beyond tank	18	24	12
Maximum burial depth	84	84	1.5 tank diameter
Top slab thickness assuming 34,000Ib per axle load.			
Reinforced concrete plus compacted back fill	24	42	24
Asphalt concrete plus compacted backfill	36	48	26
Top slab thickness assuming no traffic			
Reinforced concrete plus compacted backfill	16	30	16
Anchor slab extension beyond tank (if required because of buoyancy)	18	24	18
Anchor slab thickness (if required because of buoyancy)	8	8	8

Minimum Recommended Dimension, inches

3.2 Leak Detection

A continuous tank monitoring and accurate leak detection system are essential. In addition, when a release is discovered, accurate leak characterization of the extent of release and the pathways of migration is critical to planning response action. The EPA (Environmental Protection Agency) has published a report which explains the techniques for detecting underground storage tank leaks and methods for making an initial assessment of the extent of the resulting product release to the Environment.

3.2.1 Tank Monitoring

According to EPA, Methods of detecting leaks in underground storage tanks fall into four general classes:

- Volumetric (quantitative) leak testing and leak rate measurement.
- Non volumetric (qualitative) leak testing.
- Inventory control.
- Monitoring of leak effects.

These methods can be used independently or in combination. Efforts are being made by EPA's Hazardous Waste Engineering Research Laboratory to evaluate the effectiveness of select control technology.

3.2.2 Corrective Action Response Process

The responses to releases from USTs depend on several different factors, largely site specific. Each incident is unique.

According to EPA the corrective action involves two phases:

- The first involves the initial corrective actions intended to limit the impact of a sudden or newly discovered release. When a leak in UST is discovered or occurs suddenly, initial corrective actions are directed toward collection and containment of the substance released. Initial efforts typically occur within a short time frame, are of brief duration, and involve limited resources. This often entails deployment of field personnel and equipment to the scene within hours of the occurrence to minimize the impact of the release.

- The second involves long-term, permanent corrective measures. After the initial response, the focus of assessment and investigation activities turns toward the need for permanent measures. The procedure for permanent corrective action should be decided by an appropriate regulatory agency. Figure 1 generic flow diagram showing the procedure for deciding what the corrective-action approach should be used.

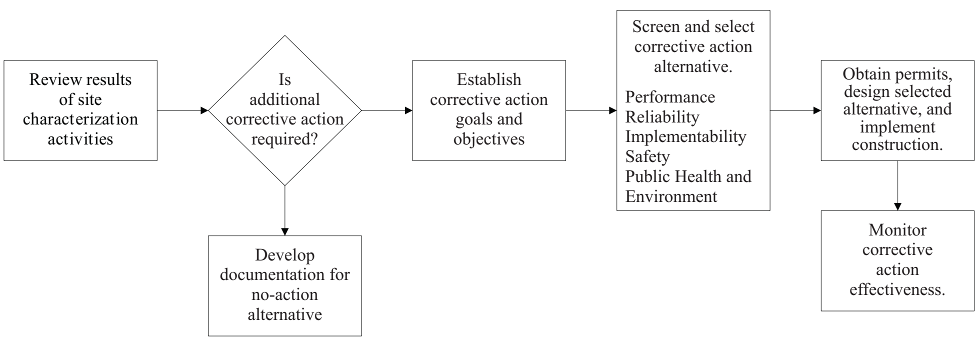

Figure 1 Typical corrective-action process (EPA)

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4. REMEDIATIONS TECHNIQUES

Remediation could be defined as the development and implementation of strategies to clean up the environment by removing the hazardous contamination.

4.1 Conventional Remediation Technologies

The Conventional technologies are based on a simple principle that if enough water is pumped from the site, the containments will eventually be flushed out and treated. These technologies are known as “pump-and-treat” systems. The conventional methods for cleaning up ground water and soil hazardous waste sites have met with limited success. The flushing process employed by pump-and-treat systems has limited effectiveness, especially for cleaning up un-dissolved sources of contamination beneath the water table.

4.2 Innovative Remediation Technologies

During the 1990s, as the limitations of conventional subsurface remediation technologies have become increasingly clear, innovative technologies have been increasingly common in the cleanup of contaminated soil and of leaking underground storage tanks containing petroleum products. Treatment methods are divided into those for soil remediation and for surface and groundwater remediation. Further categorization results in the consideration of biological, chemical and physical treatment techniques.

4.3 Remediation Of Soils

4.3.1 Biological Treatments

Biodegradation generally refers to the breakdown of organic compounds by living organisms eventually resulting in the formation of carbon dioxide and water or methane. Inorganic compounds are not biodegraded, but they can be bio-transformed, that is, transformed into compounds having more or less mobility or toxicity than their original form.

Hydrocarbon contaminants are removed from soils by bioremediation and volatilization. The potential of hydrocarbon biodegradation depends on the availability of desired microorganisms.

4.3.2 Chemical Treatments

The chemical treatment of the soil can be done by different techniques such as chemical Immobilization, Critical Fluid Extraction, and Oxidation.

The Chemical Immobilization technique can be carried out by introducing treatment chemicals into the ground by saturating the soil with the chemical solution. Insoluble chemicals can be introduced into the ground by spreading, filling, forced injection, suspension transport, or by placing it in a low permeability encapsulation barrier.

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The Critical Fluid Extraction technique is done by compressing the gas to fluid state under high pressure and moderate temperatures. The critical fluid extraction process begins with the addition of hazardous waste to a vessel containing a critical fluid. The organics move to the top of the vessel with the critical fluid and are pumped to a second vessel. There, the temperature and pressure are decreased causing the contaminants to volatilize from the critical fluid. The concentrated organics are then recovered and the critical fluid is recycled. Oxidation, in waste remediation, refers to the use of strong oxidants to destroy organic contaminants. Three technologies are utilizing oxidation as a treatment method: 1) chlorine dioxide and hydrogen peroxide additives, 2) photolysis, and 3) reductive dechlorination.

4.3.3 Physical Treatments

The physical treatment of contaminated soil can be done by different techniques such as Incineration, In-situ Grouting, Soil Washing, and Vapor Stripping.

Hazardous wastes can be volatilized and combusted in incinerators at temperatures that range from 870 to 12000^{o}C. Incineration at these temperatures can break the chemical bonds of organic compounds and other substances. Incineration reduces the risks posed by hazardous wastes because they efficiently destroy chemical contaminants, thereby reducing the toxicity and volume of substances at hazardous waste sites.

In-situ grouting of shallow landfills has been used to effectively control the inflow of surface water, thus reducing leach rates, into hazardous waste sites. Grouting, or the injection of matter to fill the voids, can be done with chemical grouts (such as sodium silicate or polyacrylamide), in solution form, or slurry grouts that are in particulate form.

Soil washing is used by removing coarse soil (known as physical washing) and then relies on a multiple stage chemical extraction process for washing contaminants from the fine (<2 mm) soil. Soil vapor stripping or extraction is applicable to the removal of volatile and semi-volatile organic compounds. The technology involves the positioning of a well through the contaminated region and the use of a vacuum to draw air down through the soil and up the well. Vapor stripping is essentially the reverse technology of air sparging. The air extracted from the well is routed through a demister to remove excess water and then a bank of filters to remove the volatile organics, after which it is vented to the atmosphere.

4.4 Remediation of Surface and Groundwater

4.4.1 Biological Treatments

Biodegradation is the disappearance of environmentally undesirable properties of a substance by the help of microorganisms. These are bacteria, fungi, and microfauna (e.g. protozoans, some worms, and some insects). Microorganisms degrade substances using specific and non-specific processes. Specific processes refer to a microbe targeting a single site of a molecule as the pivotal action in biodegradation. Non-specific processes are those with a chain of microbial events in the biodegradation of waste. Degradation pathways are determined quite often by environmental conditions such as pH, molecular oxygen and nutrient conditions. The biodegradation of a particular waste may require a series of different environmental conditions for a variety of microorganisms to cause a cascade of reactions.

4.4.2 Chemical Treatment

Removal by Sorption to Organo-Oxides is a chemical technique that is used for the remediation of surface and groundwater. Organo-oxide synthetic sorbents provide an organic phase able to bind nonionic organic substances. An organo-oxide synthetic sorbent forms when anionic surfactants adsorb onto oxides in an acidic environment. For this to happen the oxide must have a net positive charge. A pH less than the zero point of charge (the pH at which solid surface charges from all sources are zero) cause the oxide to take on positive charges.

4.4.3 Physical Treatments

Using either Air Sparging/Air Stripping or Incineration can carry out physical remediation. The technique of remediating the water in the ground is called air Sparging. Air Sparging actually refers to two different techniques, in-well aeration and air injection. The technique of remediating the groundwater above the ground is called pump and treat. Water is pumped out of the ground and treated by air stripping or granular activated carbon absorption or both. Air stripping relies on the sorption processes to transfer contaminants from the liquid to the gas phase. With this technology, the contaminated liquid is brought in contact with ambient air and the organic contaminants are transferred to the air.

Incineration techniques are used for treatment under extremely high temperature. There are incinerators for liquids, solids, and sludge. The feasibility of incineration depends on both the chemistry and the matrix of the waste.

5. BENEFITS AND CHALLENGES IN REGULATING USTs

The significance of groundwater contamination depends on our perspective. To those individuals who are directly affected, it is an imminent disaster. Once contaminated, groundwater remains in an unusable and hazardous condition for decades or even for centuries. Groundwater contamination will continue, but its impact can be reduced.

Once the groundwater is contaminated, remedial action is time consuming and expensive. Each incident must be handled as a separate problem. Although prompt action is essential to limit contamination and minimize remedial action, no strategies have been established for rapid response to contamination or pollution problems. The best way to minimize groundwater contamination is to prevent it. Therefore the regulation of UST to protect groundwater is especially important. To effectively regulate potential source of contamination i.e. (UST) we must understand the behavior of contaminants in subsurface. We can reduce groundwater contamination by thoroughly evaluating and monitoring the old UST's by responding quickly and effectively when a contamination problem is detected.

An important factor in subsurface migration of contaminants is pressure maintained in gas reservoir. Pressures in excess of natural reservoir pressure may cause upward migration from an imperfectly scaled reservoir. As a result maximum pressure in oil storage tanks should be maintained so that the pressure, which exists in reservoir naturally, cannot be exceeded. After the product is spilled or leaked, it tends to migrate downwards under the force of gravity. If water table is far enough below the ground it reaches the water table.

The storage and leakage of petroleum products has given rise to concern over potential groundwater contamination because.

- Products are stored in numerous small underground containers widely spread in Saudi Arabia.
- Many of these tanks are privately owned and it is difficult to enforce standards for storage of petroleum products.
- Many of the storage tanks are located in populated areas hence a leak may rapidly affect other people.

In most of the instances no well-established regulatory strategies have been developed. For rapid response to alleviate groundwater pollution problems and in many cases the regulatory agencies do not even have technical expertise available to them for advice and assistance. Furthermore how can anybody accurately predict what might happen at some future date at a groundwater contamination site since installations of wells, discharge rates may change the water level surface.

Individual groundwater sites polluted by UST's generally do not include extremely large areas. The problem of groundwater is certainly a disaster to those individuals who depend on groundwater as their source of supply and who awake some morning to find it contaminated. Moreover the regulatory agencies, industries and courts have paid but little attention to problems of individuals, tank owners who usually cannot bear the burden of high cost.

A regulatory agency may have an expertise to respond to emergency situations, but may seek consultation with outside resources to properly evaluate remedial action for long-term contamination problem.

Regulations can reduce but not totally eliminate groundwater contamination. Accidental spill from UST will continue Because of impossibility of monitoring storage facilities of oil industry and UST's, Petroleum products will continue to be significant source of groundwater contamination.

Prompt action can drastically reduce the extent of groundwater contamination as it is shown that 70-80% of all products recovered are recovered in first 72 hours. In assessing the cost of clean up hydrocarbon contaminants, it has become apparent that the costs depend more on site sensitivity than the volume of product. Small spills and leaks are more expensive than the larger ones.

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The measures required to control groundwater pollution from leakage of UST's are

- Controlling the spread of oil on ground surface and removing as much as possible from ground surface.
- Notifying appropriate agencies i.e. regulatory agencies etc.
- Trying to prevent the contaminated groundwater from reaching the potable water sources.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Within the last several years, underground storage system design and construction has experienced more significant changes than in the previous thirty years. Driven by a heighten environmental awareness of the problem of leaking USTs and increasing regulatory pressure especially in developed countries, new materials, innovative designs, and improved construction techniques have been developed to reduce the number and severity of leaks.

Leaks in USTs are most commonly the result of corrosion, improper installation, or a lack of system maintenance. The type of material that provides a high level of environmental protection and address the causes of leaks include cathodically protected steel and non-corrosive materials.

This study gives an insight of long-term potential threat to groundwater quality posed by underground storage tanks. The underground storage tanks can affect the quality of groundwater in different ways. Accidental spills routine washing and rinsing of machinery and chemical storage tanks can release contaminants to soil and groundwater. One of the major difficulties associated with cleanup of such contamination is the long term cleaning operation which is time consuming and costly. It is worth mentioning the solution of the problem is spill prevention.

6.2 Recommendations

The groundwater sources are lifeblood for an arid region. Especially for Saudi Arabia where recent growth in municipal, agricultural and industrial sectors resulted in a huge increase in the water demand, which is currently provided by the costly desalinated seawater as well as groundwater. The contamination of groundwater due to USTs is a big problem. It is recommended to develop specifications and standards for USTs at various stages of construction and operation in order to minimize the potential threat for groundwater contamination. A committee should be appointed which can work with the specific authorities to carry out this work. A program to analyze leaking gas stations storage tanks and other storage facilities through out the Kingdom should be started as soon as possible. In the start of the work the regulations imposed by Environmental Agency (EPA) in USA can be used as a guideline for work.

In developing a comprehensive system for detecting and monitoring leaks, it must be acknowledged that no one system will meet all the criteria of "fail-safe system" in a comprehensive and cost effective manner.

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