IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 2, February 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Quality of Household Water Storage Tanks: Case Study with Emphasis on Dammam Metropolitan Area In the Eastern Region

Fahad Abdullah Alharbi , Fahad Abdulmohsen Alshikh , Mohmammed Alshukri , Iehab Abdel-Ilah Mohamed Omar Aga and Isam Mohammed Abdel-Magid

Iehab Abdelilah Mohamed, lecturer, Environmental Engineering Department, College of Engineering, Imam Abdulrahman bin Faisal University,
Dr. Omer Osman Aga, associate professor, Vice Dean of Quality & Strategic Planning, College of Engineering, Imam Abdulrahman bin Faisal University
Prof. Dr. C.Eng. Isam Mohammed Abdel-Magid Ahmed, Chair Development & Training Unit of Postgraduate Deanship, Head Proofreading and revision department at the Centre of Scientific Publications and Dammam University, Professor of water resources and environmental engineering, Environmental Engineering Department, College of Engineering,
Imam Abdulrahman bin Faisal University,

Abstract:
KSA has a generally hot, dry climate and available fresh water is a valuable and vulnerable resource. Residence at the Eastern district in the Kingdom of Saudi Arabia, KSA receive their domestic supply from municipality mains. Due to brackish and salty nature of municipal supply, a large number of inhabitants use household water storage tanks to augment supplies, or provide an alternative and attain a continuous source of drinking water. The condition of this tank may have an impact on water quality (type of material, structural design failures, operation error, ill maintenance, ill reliable water source etc.). Tanks are of different shapes, sizes, material quality and manufacture.
The aim of this research work is to consolidate information and advice on household storage tanks material and content of water quality, describing issues and providing guidance on managing water collection, conservation and preservation in domestic tanks in a way that would maximize water quality as per adopted guidelines and standards.
Research work covered comprehensive literature review, classification of types and properties of household tanks, manufacturing processes and water content quality. Data collection through sampling, laboratory tests and survey of selected tanks. Data collection via predesigned questionnaires for reasonable sample, homeowners, personnel responsible and municipality. Response analysis through gathered information and data into analyzable formats through a well-chosen program that lead to appropriate conclusions.

Keywords: Water quality, roof storage tanks, household water.

I. BACKGROUND

Drinking water shortages and costs incurred within its abstraction, desalination and distribution within KSA, dictated the importance of household storage and keeping. Mostly, there is at least one water household storage tank in every house in the Eastern province. Such a system is of paramount importance for homes because it is related to everybody's' everyday life activities (drinking, cooking, showering, ablution, cleaning... etc.). There are many types of household storage facilities services that are used within the community. Used storage tanks differ in shape, characteristics, design, material manufacture, use, performance and cleaning patterns. This research work focused on types of tanks and water quality issues within them. Data collection followed a dual platform using questionnaires and sample analytical investigation techniques. (Alharbi, et al 2015)

The main goal of this research study is to test water quality level in KSA household storage tanks as it is related to regional standards, global guidelines and acceptable public hygiene concerns with special emphasis on areas within Dammam metropolitan fringes. This is besides exploring impacts on public health for KSA society, especially in the cities and district of Dammam and Al-Khobar. Research specific objectives of this work covered the following areas:

1) Determining the quality of household storage water.
2) Testing tank water quality (physicochemical and bacteriological characteristics) and its satisfaction to guidelines, standards for selected households.
3) Determining influence of water collection method on quality content.
4) Finding the best type of tank should everyone use
5) Identifying whether the water quality is suitable, for drinking, cooking and the use of human.
6) Surveying user's attitudes towards water quantity and quality.
7) Checking tank's hydraulic and structural condition and design requirements.
8) Testing periodic maintenance schedules, visual checks and quality analysis.
9) Outlining owner, water vendor and municipality responsibilities.

10) Producing minimum safety requirements and key performance indicators (KPI) for household storage tank.
11) Finding best solutions to maximize the quality of household storage water

This research work is of paramount importance for the following reasons:

- Finding actual water quality of household storage tanks and its adherence to set standards and guidelines governing drinking water quality.
- Identifying household tanks water sources and diurnal or time changes if any.
- Establishing a baseline survey as distributed to a selected sample of residents in specific areas. This would include sampling facilitates for different types of storage tanks within households, roads and capacity tanks with emphasis on knowledge of water quality influencing factors.
- Finding appropriate ways and means to maintain and improve water quality supplied to homes and residential establishments.

Research hypothesis assumes that by taking samples from household water storage tanks, quality issues will be outlined. This information will be utilized for improving quality of water in household tanks in KSA districts. If there is any water contamination, pollution, or problem in the tank, it can be avoided by many ways to be outlined in this study.

Researchers were motivated to carry out this piece of work through the following alarming points and urging reasons:

- Their observation to existence of different types and shapes of household storage tanks in the market.
- Deteriorated conditions of certain tanks.
- Complaints of some inhabitants to water quality taste, odor and clarity.
- Lack of appropriate maintenance to tanks by locals, companies or firms.
- Lack of adherence to bylaws and directives of municipality for design, construction, installation and maintenance of tanks.
- Ignorance of people towards safety considerations and public health issues while storing, handling and using this precious water resource.

The methodology adopted in this research work followed a field study and data collection pattern supported by comparative investigations and validated by practical case studies. Classification of sources and characterization of properties of household storage water necessitates data collection through a survey of selected household storage water samples. Analysis of data would be conducted by random samples taken from different houses, places and locations. Data collection would be through a questionnaires and testing of quality of water samples and materials of tank. This is yet to be compared with national, regional and global standards and regulations.
Expected research outputs and outcomes are anticipated to focus on the following:

- User ideas regarding improvement in household storage, use and maintenance.
- Addressing challenges associated with water quality as related to public health.
- Establish suitable KPIs for household tank design, installation, construction and monitoring.
- Ease in tank design & maintenance.
- User-friendly maintenance method and guideline.

Development of Saudi household storage tank code of practice.

I. LITERATURE REVIEW

The current study is motivated by the need to provide quality water in households by assessing the materials and content of household water storage systems. Plenty of clean and safe water is important for domestic use and has become a vital constituent of Household Water Treatment and Safe Storage (HWTS) program. As a result, WHO globally advocates HWTS in the provision and storage of clean water that is free of contamination in personal and public storage systems in regions that lack piped water (Al-Zarah 2014). A number of studies have evaluated the source of household water contamination in relation to the material used to construct the storage containers (Schafer et al. 2012; Al-Zarah 2014). The current study assesses the effect of material, user behaviors and water quality on household tanks. The work reviews the literature on the effect of the materials construct of household water storage tanks and the relevance of proper maintenance on water quality. The age of the storage tank, design and its cleaning frequency has an effect on physical, chemical and microbial content of drinking water. Tank material affects the physical, microbial and chemical content of household water. Household water storage tanks and other vessels that take different shapes and forms is common in all areas with or without piped water. They are generally a source of physical, chemical and microbial contamination if frequently not inspected and monitored which may pose a hazard to both animal and human health (Al-Ghanim et al. 2014; Quick et al. 1996).

Poor construction and lack of sanitation continue to compromise the quality of water. The important aspects to consider in the provision of safe water for domestic use mainly revolve around the provision of proper sanitary infrastructure. The containers in which water is stored for home use are vulnerable to contamination and may be a source of heavy metals contamination, including lead or radioactive substances, which may pose a great risk to the consumer. Microbial contamination is common when water is stored in containers that are not covered. Water stored for extended periods of time with fluctuations in temperature, presence of dust, and human contaminants may be a source of infectious diseases (Gundry et al. 2003). Fecal contamination is common from collection sources and during storage. Microbial pathogens may proliferate and become a source of persistent waterborne infections, such as cholera, typhoid, and hepatitis. In some instances, water can be collected from quality supply systems that are treated, but when it is not hygienically stored, it could become contaminated in the process (Gundry et al. 2003; Quick et al. 1996).

The rise in microorganisms in a storage tank may occur in biofilms due to sedimentation, especially when there are minimal disturbances of water. All kinds of tank material can form biofilms. Corroded cast iron tanks contain rough surfaces which act as a substratum of biofilm formation that facilitates microbial growth. On the other hand, plastics are less prone to biofilm formation due to the smooth surfaces, hence are more preferred than metallic material. For maintenance, frequent cleaning of the storage tanks and complete emptying allows for the disruption of biofilms. Fungal growth and Coliforms are common inhabitants on the biofilms, especially where there is lack or minimal chlorine levels and warm temperatures above 15^oC. Biofilm formation is eliminated through proper tank maintenance and use of enough disinfectants. The concentration of the nutrients in storage facilities has to be controlled through filtration processes and use of disinfectants. Underground water has minimal nutrients hence is not invaded by microbial growth as compared to surface water (Alegre et al. 2010).

The chemical quality depends on material of tank and may deteriorate its water quality. Corrosion from cast iron material causes water discoloration. Corrosion may also cause accumulation of substances that may increase resistance and affect the hydraulic capacity of flowing water. It can also reduce the quality of tanks by causing perforations that may cause water leakages and potential contamination. Corrosion products vary depending on the oxidation rate, the pH and iron ions concentration in water. Higher temperature, low alkalinity, lower calcium and low pH enhance corrosive processes. (Alegre et al., 2010). Oxygen depletion in the tank can form reduced iron and less stable oxidized forms, such as green rust, ferric hydroxides and pyrrhotin. For maintenance, hydraulic conditions by increasing the velocity of water are crucial which helps to avoid stagnation, increases shear forces and allows for plenty flow of oxygen in the tank. This detaches the corrosion products (Alegre et al., 2010). Salinity of groundwater is another problem, which compromises the quality of drinking water. Additionally, chemicals may leach from PVC supply pipes that could cause chemical contamination of piped water supplied to households. Contamination from galvanized iron plumbing leach hazardous chemicals such as iron, chromium, lead, copper, cadmium and zinc into drinking water compared to the houses with PVC plumbing. These levels of chemicals are beyond the set standards and therefore, consumers should ensure that they receive safe and quality drinking water (Al-Zarah 2014).

Technological advances have gone a long way in diversifying and simplifying the water treatment methods, especially in large-scale water supply systems. Ancient methods which are still in use in some regions, that were used to improve the quality of drinking water included sedimentation, use of heat, filtering, sunlight exposure, use of chemicals such as lime, alum, charcoal, clay and plant extracts. Sedimentation involves lowering the turbidity of water by reducing the suspended contaminants and settling the clear water. The process can be enhanced by using coagulants. Filtration further lessens turbidity and sift microorganisms from water through straining or adsorption. Nowadays, chlorination and the use of other disinfectants is common due to its practicality, effectiveness and affordability. In the developed countries, large household water supply systems use various advanced techniques to treat water, such as filtration, adsorption, chlorination, ultraviolet radiation and use of ion exchange resins where water is extensively disinfected to minimize any risk of microbial contamination (Al-Zarah 2014).

The integrity of water reservoirs is a main factor in ensuring the quality of water (Al-Ghanim al. 2014). Hydraulic interruption may prompt the sediments to stir-up, which could compromise the water quality. After maintenance of tank or pipe leakages hydrocarbons present in cast iron layered with tar, may be released after flushing. In addition, plumbing content such as paints, solvents and lubricants may compromise the water quality, causing unpleasant odors and taste of water (Alegre et al., 2010). Plastic vessels used in many households are more preferred due to their convenience in cleaning and they are much friendlier to household water chemical treatment such as chlorine. For heat treatment, plastic containers are, however, not recommended since they cannot withstand the heat. Metallic containers are, thus, preferred in such uses. Therefore, the properties of storage and collection cans are of paramount importance with regard to usage, safety, and convenience. In urban areas, household storage tanks range from 500 to 1, 400 liters in the less developed parts of the world so as to ensure continuous water supply (Schafer et al. 2012).

Water is stored in various forms of vessels that are of different sizes. These vessels may vary in the developed and less developed countries, and may even be culturally significant such as earthen pots, gourds, animal hides or others from woven materials. In current times, water storage vessels are mainly made of plastic, such as buckets, tanks, basins and jerry cans, while others are metallic, made of aluminum, iron or steel. The portability and capacity of these vessels are of primary importance to home users, some of whom need to carry the cans for long distances especially in the developing countries where piped water is less prevalent. Another factor that is equally important is the durability of these vessels. Plastic and metallic containers are more preferred, since they are long lasting as opposed to the traditional earthen pots and gourds. Presence of handles and covers is also crucial for portability and prevention of spillages and contamination. The convenience at which water is drawn into the container also matters during collection. In most cases, the water collection and storage cans range between ten and twenty five liters in average capacity, flat-bottomed, light and with screw caps (Quick et al. 1996).

The type and quality of materials, making the storage tanks affect the quality of water. Fiberglass is recommended for water storage due to its safety and ability to tolerate high temperatures, thus maintaining cool water. Storage tanks made of galvanized sheets may corrode and pose further health hazards by leaching metals into household water (Alegre et al., 2010). Cement material like concrete can also deteriorate and the cement released into the drinking water. The calcium hydroxide from cement raises the pH, which also compromise the water quality. Storage water reservoirs should also not be painted due to the leach of heavy metals in drinking water while materials such as asbestos are hazardous due to their oncogenic properties (Alegre et al., 2010). Besides, reinforcement of storage reservoirs with cement may cause the leaching of calcium carbonate, which may make the water to become alkaline. However, the leaching of lime may depend on the age of the reservoir and the period of time it has stored water (Al-Ghanim al. 2014). Polyethylene tanks, on the other hand, are more susceptible to *E. coli* contamination and high temperature as compared to tanks made from cement and fiberglass (Schafer et al. 2012). Plastic tanks may also facilitate growth of bacteria, which may adhere on the surface of the containers.

The temperature of water has an effect on the growth of pathogens, which may have survived chlorine treatment. Water temperatures higher than 15^{o}C enables the growth of bacteria, especially of *E-coli* forms, whose concentration is reportedly higher and increases by 18 times when the temperature rise from 5 to over 20 ^{o}C in chlorinated water (Schafer et al. 2012). The age of the water tank and the water temperature, retention times of over seven days along with reduced chlorine levels may cause the microbial contamination. High temperatures and decrease in residue chlorine in storage water corresponds to high bacterial contamination from *E. coli* and Coliforms between the source supply and point-of-use (Schafer et al. 2012). The material made for constructing the tank dictates the water temperatures while lack of regular cleansing allows for sedimentation, which compromises the quality of the incoming water. Fiberglass and fiber cement storage tanks allow for lower temperatures and should be designed to allow for complete emptying before the tank is freshly refilled (Schafer et al. 2012).

The shape of the storage tank is equally important in that some shapes and designs may not allow for totally emptying, thus retaining sediments that may be ideal for microbial growth (Schafer et al. 2012). The storage tanks should be elevated so as to ensure a continuous flow of pressurized water. However, elevated tanks set for automatic refilling when a certain capacity is attained may not be totally emptied, hence incoming water may possibly become contaminated by the retained amount (Schafer et al. 2012). Chlorine residue present in the larger storage tanks may be insufficient and prone to coliforms contamination. The chlorine may also volatilize over longer storage times in larger containers as opposed to smaller ones whose chlorine residue is more thus less contamination (Graham and VanDerslice 2007; Quick et al. 1996).

Sedimentation, microbial and corrosion processes from distribution network and storage containers may compromise the quality of household water. Biofilm formation can occur after the organic content decomposes in the storage tanks, which, may further be complicate by the tank materials and may harbor fertile grounds for microbial growth (Alegre et al. 2010).

In arid and semi-arid regions, there remains a big challenge in the provision and delivery of safe water to households. In KSA communities face the problem of physical, microbial, and chemical contamination of water provided in the cities such as Al-ahsa and Alkharj province where the sanitary conditions of storage water tanks are poor and below the internationally set standards for heavy metal concentration, microbial and physical contamination. Regular maintenance of storage tanks, testing and treatment of household water as well as public places is, therefore, recommended along with creating public awareness on how to maintain clean and safe storage water for domestic use (Al-Zarah 2014; Al-Ghanim et al. 2014). Covering water storage tanks reduces physical as well as microbial contamination from external contaminants such as birds, rodents and dust from the environment and avoids sedimentation that encourages bacterial and algal growth due to sunlight exposure that could alter the color, taste and smell of water as well as cause oxygen depletion in the water (Al-Zarah 2014).

The integrity of the storage facilities has to be maintained through different ways. Physical integrity considers the facility as a physical barrier that curbs contamination from external sources. The facilities have to be maintained to safeguard it from external contaminants such as reducing the corrosion by enhancing efficient flushing and frequent cleaning of the tanks. Compromising the physical barrier contaminates the water contained inside, hence proper installations, rehabilitation and repair has to be done to ensure the physical integrity of the storage tanks. Hydraulic integrity, whereby the pressure of the flow of water is ensured is important. Inadequate or low pressure may cause dysfunctions of valves or pumps. Enough water pressure decreases the formation of biofilms, which encourage bacterial and fungal growth (Alegre et al. 2010).

The age of the water as well as the frequency of emptying and refilling affect sedimentation. Frequent cleaning and increasing the water pressure, ensures the hydraulic integrity of storage systems. The frequency of cleaning the reservoirs has an impact on water quality. A high turbidity in the water may encourage microbial growth and may complicate disinfection. Lack of regular cleaning and maintenance of old water supply pipes, the total dissolved solids quantities may pileup. Cleaning the water tank regularly helps to reduce the extent of bacterial contamination from *E. coli* and also reduces turbidity (Schafer et al. 2012). Long retention periods as well as higher water temperatures are attributed to the reduction of the disinfectant levels as well as release of ammonia due to degradation of chloramines, which reduces chlorine level below limits (Al-Ghanim al. 2014).

II. MATERIAL AND METHODS FOR CASE STUDY IN THE STUDY AREA

Research study area is set and carried out at the Eastern region in Dammam, Dhahran and Khobar district as outlined in figure (1). Area was selected due to a number of influential reasons that incorporated: complaints gathered from inhabitants towards water within homes, ease and possibility of gathering required samples, diversity of types of home storage tanks, nearness of testing laboratories especially for bacteriological analysis and potentiality of finding needed data and information.

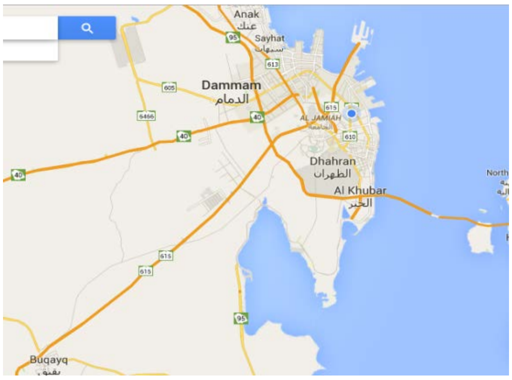

Figure (1) Study Area (Google maps 2014)

Data and information are collected and gathered through questionnaires and by water samples from designated project study zone. Storage household tanks have been selected across relevant localities to represent the study area and affecting quality parameters. The following steps were adopted in sampling and data collection:

- Identification of study zone and households for drawing relevant samples**.**
- Identification of water sources and resources supplying demand to household storage tanks for sampling.
- Selecting sampling technique and size.
- Preparation of samplers in accord with Standard methods for examination of water and wastewater (2012) procedures.
- Identification of laboratory investigations and analysis deemed necessary and vital to serve research goals and objectives.
- Locating local regional and international relevant guidelines and standard

In this research three types of analysis were carried out (chemical, physical and bacteriological) as outlined in table (1).

1) **Table (1): Type of Research Laboratory Analysis.**

Type	**Parameter**	**Unit**
Chemical	Free residual chlorine	ppm
	Residual chlorine	ppm
	Hardness	mol/L
	Alkalinity	mEq/L
	BOD	mg/L
	Dissolved oxygen	mg/L
	Cd	mg/L
	Zn	mg/L
	Pb	mg/L
	As	mg/L
	NO_3^{-1}	mg/L
	SO_4^{-2}	mg/L
Physical	TDS	mg/L
	TSS	mg/L
	TS	Mg/L
	pH	pH units
	Conductivity	mmho/cm
Bacteriological	Total Coliform	MPN Index/100ml
	Faecal coliform	MPN Index/100ml
	E. coli	MPN Index/100ml

The devices that were used in this research work included, but not limited to, ion chromatograph (IC), atomic absorption device and many other laboratory equipment and instruments. Ion chromatographs are able to measure concentrations of major anions, such as fluoride, chloride, nitrate, nitrite, and sulfate, as well as major cations such as lithium, sodium, ammonium, potassium, calcium, and magnesium in the parts-per-billion (ppb) range (Haswell 1991). Concentrations of organic acids can also be measured through ion chromatography. The basic principle of the ion chromatography device that is used in this study is a form of liquid chromatography that measures concentrations of ionic species by separating them based on their interaction with a resin. Ionic species separate differently depending on species type and size. Sample solutions passes through a pressurized chromatographic column where ions are absorbed by column constituents. As an ion extraction liquid, known as eluent, runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentrations in the sample. Chromatography includes some typical applications of ion.

Method of water testing by the IC has been done in accord with EPA Method 300.0 for inorganic anions. A small volume of sample, typically 50-100 □L, is introd and measured, using a system that is comprised of a guard column, separator column, suppressor device, and a conductivity detector. Initially, the test method covers the determination of common inorganic anions in drinking water, surface water, mixed domestic and industrial wastewaters, groundwater, reagent waters, solids (after extraction), leachates (when no acetic acid is used). Secondly, the test method covers the determination of bromate, chlorate, and chlorite in drinking and reagent waters. Ion chromatography is used for water chemistry analysis to measure concentrations of fluoride, chloride, nitrate, nitrite, phosphate, and sulfate in the parts-per-million (ppm) range.

Total solids (TS) are the total of all solids in a water sample. They include the total suspended solids and total dissolved solids. Total Suspended Solids (TSS) are the amount of filterable solids in a water sample. Samples are filtered through a glass fiber filter. The filters are dried and weighed to determine the amount of total suspended solids in mg/l of sample. Total Dissolved Solids (TDS) are those solids that pass through a filter with a pore size of 2.0 micron or smaller. They are said to be non-filterable. After filtration the filtrate (liquid) is dried and the remaining residue is weighed and calculated as mg/l of Total Dissolved Solids**.** Measurement of TS, TDS and TSS. The measurement of solids is by means of the gravimetric procedure. The various forms of solids are determined by weighing after the appropriate handling procedures. The total solids concentration of a sample can be found directly by weighing the sample before and after drying at 103oC. However the remaining forms, TDS and TSS require filtration of the sample. For liquid samples, all these solids levels are reported in mg/L.

A water sample can be collected in any glass or plastic container. Enough sample water is collected so that one can submerge the tip of the probe. The probe is then rinsed with sample water before placing it in the sample. No preparation is needed. Reused sample containers (and all glassware used in this procedure) must be thoroughly cleaned before the first run and after each sampling run. Total Solids determination procedure (as per standard methods) incorporates the following steps:

2) A clear dry glass beaker (which was kept at 103^0C in an oven for 1 hour) of 150ml.capacity is taken and appropriate identification mark is put on it. Weight of beaker is noted.
3) 100ml. (measured by a measuring cylinder) of the thoroughly mixed sample is poured in the beaker.
4) Beaker is placed in an oven maintained at 103^0 C for 24hours. After 24hours, beaker is cooled and weighted. weight of solids in the beaker is found out by subtracting weight of clean beaker determined in step (1)
5) total solids (TS) is calculated as: Total solids, TS (mg/l) = mg of solids in the beaker x1000 / (volume of sample)

In determining dissolved solids:
(1)Same as above for determination of TS referred to in step 1 of total solids.
(2)Take a 100 ml. of sample and filter it through a double layered filter paper and collect the filtrate in a beaker.
(3)Then repeat the same procedure as in steps (3) and (4) of the total solids determination and Determine the dissolved solids contents as follows:
Total Dissolved Solids, TDS (mg/l) = mg of solids in the beaker x1000 (volume of sample

Total Suspended Solids, TSS (mg/l)= TS (mg/l) –TDS (mg/l)

Biochemical Oxygen Demand (BOD) refers to the amount of oxygen that would be consumed if all the organics in water were oxidized (or mineralized) by bacteria and protozoa. The BOD test is used to determine the relative oxygen demands for stabilizing municipal and industrial wastewater, and polluted waters (e.g. rivers, lakes, etc.). The test has its widest applications in measuring the waste loadings to treatment plants and in evaluating the BOD removal efficiency of treatment plants. The test measures the molecular oxygen utilized during the specified incubation period for the biochemical degradation of organic material (carbonaceous demand). It may also measure the amount of oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is inhibited. In sampling and storage the following points need to be paid attention to:

- Samples for BOD analysis may degrade significantly during storage between collection and analysis.
- If analysis can be done within 2 h of collection cold storage is unnecessary.
- If analysis is not started within 2 h of sample collection keep sample at or below 4^0C from the time of collection. Begin analysis within 6 h of collection; when this is not possible, e.g. the sampling site is far from the laboratory store at or below 4^0C and *report length and temperature of storage with the results.*
- In no case start the analysis more than 24 h later than the time of collection.

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample. The HI 98703 meets and exceeds the requirements of the USEPA Method 180.1 for wastewater and Standard Method 2130 B for drinking water. The instrument has an EPA compliance reading mode which rounds readings to meet EPA reporting requirements. Users will appreciate the accuracy and sensitivity of this instrument, particularly at very low turbidity levels. This instrument incorporates complete GLP (Good Laboratory Practice) functions that allow traceability of the calibration conditions. The last calibration points, time and date can be checked at the touch of a button. With its logging function, up to 200 measurements along with its tagged locations can be stored in internal memory and consulted at any time. Data can be later transferred to a PC via RS232 or USB interface and HANNA HI 92000 software (optional). Turbidity is usually determined as soon as possible after the sample is taken. Gently agitate all samples before examination to ensure a representative measurement. Sample preservation is not practical; begin analysis promptly. Refrigerate or cool to 4°C, to minimize microbiological decomposition of solids, if storage is required. For best results, measure turbidity immediately without altering the original sample conditions such as temper

III. RESULTS AND DISCUSSIONS

Table (2) shows locations from where samples were withdrawn in the selected study area at Al-Khobar, Dhahran and Dammam metropolitan area (see figures 2 and 3). Water source to fill storage tank for each household or locality is indicated in the table. It is observed that many households have more than one storage tank. Certain tanks were reserved for drinking purposes where water is purchased from particular water vendors and firms. It is noticed that water source varies with vendor and method of water delivery and transportation. Majority of households prefer having dual storage systems (underground and elevated) tanks to affirm continuous water supply within household internal plumbing system and avoid any potential water shortage or frequent and unexpected changes in demand.

Table (2) Samples Locations.

sample	location	source
1	North Ar raka district (Al-Khobar)	commercial
2		
3	Al-Thoqba district (Al-Khobar)	municipal
4		
5	Al-Fakhrya district (Dammam)	municipal
6		
7	Area 71 (Dammam)	commercial
8		
9	Area 37 (Dammam)	municipal
10		
11	Area 91(Dammam)	commercial
12		
13	Al-Hada district (Al-Khobar)	municipal
14		
15	Golden belt district (Al-Khobar)	municipal
16		
17	green belt district (Al-Khobar)	municipal
18		
19	Al-Nada district (Dammam)	commercial
20		
21	south Doha (Al-Khobar)	municipal
22		
23	Al-jisr district (Al-Khobar)	municipal
24		
25	Suburb of King Fahd district (Dammam)	municipal
26		
27	Al-Kwzama district (Al-Khobar)	municipal
28		
29	al zohor district (Dammam)	municipal
30		
31	Al-Fisalya district (Dammam)	municipal
32		
33	Petromen district (Dammam)	municipal
34		

Table (3) sample results

SAMPLE ID / PARAMETER	UNIT	PME	WHO	EPA	1	2	3	4	5	6	7	8	9	10	11	12
Conductivity	(µS/cm)	2500		2500	364	149.9	1837	1784	2.39	1524	393	349	244	277	1273	478
pH		6.5-8.5	6.5-8.5	6.5-9.5	7.36	7.47	7.95	7.73	7.41	7.68	8.5	8	8	7.5	7.75	7.15
Turbidity	(NTU)		0.3-1	5	0.29	2.12	4.25	0.51	0.71	2.71	0.22	0.33	0.29	0.18	0.4	1.71
BOD	Mg/l	N/A	N/A	N/A	6	10	12	10	16	8	50	2	2	2	2	2
Nickel, Ni	Mg/l	0.02	N/A	0.02	0.001	0.0005	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.01	0.01	0.009
Chromium, Cr	Mg/l	0.05	0.1	0.05	0.0003	0.0001	0.002	0.002	0.0036	0.002	0.0007	0.0007	0.0005	0.0006	0.002	0.0009
Cobalt, Co	Mg/l	N/A		N/A	0.00007	0.00002	0.0003	0.0003	0.0004	0.0003	0.0001	0.0001	0.0001	0.00009	0.0003	0.0001
Cupper, Cu	Mg/l	2	1	2	0.0005	0.0005	0.002	0.004	0.005	0.003	0.005	0.006	0.01	0.008	0.01	0.008
Zinc, Zn	Mg/l	3	3	5	3.8	0.09	0.02	0.02	0.01	0.03	0.02	0.02	0.01	0.02	3.07	0.05
Arsenic, As	Mg/l	0.01	0.01	0.05	0.0002	0.0002	0.001	0.001	0.002	0.002	0.0004	0.0004	0.0003	0.0003	0.001	0.0006
Cadmium, Cd	Mg/l	0.003	0.005	0.005	0.00001	0.00004	0.00004	0.0005	0.00001	0.0001	0.00001	0.00002	0.0001	0	0.0001	0.0002
Lead, Pb	Mg/l	0.01	0.00015	0.05	0.00004	0.0001	0.00006	0.0001	0.00009	0.0001	0.0001	0.00007	0.00006	0.00003	0.0001	0.0001
Fluoride, F-	Mg/l				0	0	0.77	0.75	0.79	0.712	0	0	0	0	0.66	0
Chloride, Cl-	Mg/l	250	250	250	100.24	38.58	590.6	568.6	881.7	619.1	94.3	99.76	79.75	78.99	467.3	135.8
Nitrate, NO3-	Mg/l	50	10	50	2.12	2.17	6.51	6.66	7.35	4.508	0	1.16	0	0	3.95	1.34
Phosphate, PO4+3	Mg/l	N/A	N/A	N/A	0	0	0	0	0	0	0	0	0	0	0	0
Sulfate, SO4--	Mg/l	500	250	250	1.47	1.37	223.5	223.2	244.9	191.2	25.73	27.44	11.44	10.95	151.2	40.09
Total Coliform	(MPN Index/100 ml)	≤5%	≤5%	0	<1.1	<1.1	<1.1	<1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform	(MPN Index/100 ml)				<1.1	<1.1	<1.1	<1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E.coli	(MPN Index/100 ml)	0		0	<1.1	<1.1	<1.1	<1.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total suspended solids, TSS	Mg/l				36	45.2	53.6	45.2	56.8	20.8	N/A	N/A	N/A	N/A	N/A	N/A
Total dissolved solids, TDS	Mg/l		500	1000	18	25.2	24.8	26.8	23.2	11.6	N/A	N/A	N/A	N/A	N/A	N/A
Total solids, TS	Mg/l				54.8	70.4	78.4	72	80	32.4	N/A	N/A	N/A	N/A	N/A	N/A

Table (4) sample results

SAMPLE ID / PARAMETER	UNIT	PME	WHO	EPA	13	14	15	16	17	18	19	20	21	22	23	24
Conductivity	(μS/cm)	2500		2500	134.5	125.8	121.2	357	133	196.6	398	432	315	160.9	3.93	3.98
pH		6.5-8.5	6.5-8.5	6.5-9.5	6.75	6.8	6.3	6.4	7.4	7.35	7.2	7.1	7.25	7.35	7.9	7.47
Turbidity	(NTU)		0.3-1	5	0.65	0.42	0.45	0.409	0.31	0.38	0.99	0.99	1.13	1.45	0.49	0.48
BOD	Mg/l	N/A	N/A	N/A	4	2	2	2	2	2	2	0	2	4	4	2
Ni	Mg/l	0.02	N/A	0.02	0.0008	0.0006	0.0006	0.0009	0.00008	0.0002	0.0008	0.0007	0.0005	0.03	0.003	0.003
Cr	Mg/l	0.05	0.1	0.05	0.0005	0.0004	0.0005	0.0006	0.0003	0.0006	0.001	0.001	0.0007	0.004	0.004	0.004
Co	Mg/l	N/A		N/A	0.0001	0.0001	0.00005	0.0002	0	0.00002	0.00001	0.00009	0.00006	0.000009	0.0006	0.0006
Cu	Mg/l	2	1	2	0.01	0.01	0.007	0.004	0.001	0.001	0.006	0.004	0.003	0.01	0.006	0.006
Zn	Mg/l	3	3	5	0.03	0.03	0.02	0.09	0.003	0.01	0.05	0.05	0.4	0.9	0.008	0.01
As	Mg/l	0.01	0.01	0.05	0.0001	0.0001	0.0001	0.0006	0.00008	0.0002	0.0005	0.0002	0.0002	0.0001	0.004	0.004
Cd	Mg/l	0.003	0.005	0.005	0.00002	0.00003	0.00002	0.00004	0.000004	0.000008	0.00004	0.00003	0.00001	0.00002	0.00001	0.00002
Pb	Mg/l	0.01	0.00015	0.05	0.001	0.002	0.0006	0.0007	0.0001	0.0001	0.0002	0.0001	0.0001	3.1	0.01	0.005
Fluoride	Mg/l				0	0	0	0.61	1.26	1.04	0.493	0	0	0	1.18	1.376
Chloride	Mg/l	250	250	250	25.06	22.82	19.74	100.5	2.12	29.65	110.4	111.4	90.28	25.68	1810	1835
Nitrate	Mg/l	50	10	50	0	0	0	1.56	0	0.92	2.06	2.11	2.11	2.19	11.8	12.06
Phosphate	Mg/l	N/A	N/A	N/A	0	0	0	0	0	0	0	0	0	0	0	0
Sulfate	Mg/l	500	250	250	2.01	1.9	6.04	33.6	68.19	60.9	39.62	40.02	25.75	1.68	510	517.2
Total Coliform	(MPN Index/100 ml)	≤5%	≤5%	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform	(MPN Index/100 ml)				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E-Coli	(MPN Index/100 ml)	0		0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TSS	Mg/l				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDS	Mg/l		500	1000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TS	Mg/l				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 4 Issue 2, February 2017
ISSN (Online) 2348 – 7968 | Impact Factor (2016) – 5.264
www.ijiset.com

Table (5) sample results

SAMPLE ID PARAMETER	UNIT	PME	WHO	EPA	25	26	27	28	29	30	31	32	33	34
Conductivity	(µS/cm)	2500		2500	3.9	4	3.84	3.89	1252	1193	1098	1204	1144	1198
pH		6.5-8.5	6.5-8.5	6.5-9.5	6.7	7.2	6.8	6.8	6.4	6.71	7.2	7.3	7.3	6.64
Turbidity	(NTU)		0.3-1	5	0.63	0.6	0.85	0.62	0.62	0.74	0.66	0.65	0.58	0.5
BOD	Mg/l	N/A	N/A	N/A	4	4	4	2	2	0	4	2	0	2
Ni	Mg/l	0.02	N/A	0.02	0.003	0.003	0.003	0.003	0.01	0.01	0.01	0.01	0.01	0.01
Cr	Mg/l	0.05	0.1	0.05	0.004	0.005	0.005	0.005	0.001	0.001	0.001	0.001	0.001	0.001
Co	Mg/l	N/A		N/A	0.0005	0.0007	0.0005	0.0007	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002
Cu	Mg/l	2	1	2	0.005	0.006	0.006	0.007	0.04	0.07	0.06	0.01	0.01	0.01
Zn	Mg/l	3	3	5	0.004	0.005	0.006	0.005	0.007	0.006	0.02	0.05	0.03	0.03
As	Mg/l	0.01	0.01	0.05	0.004	0.004	0.004	0.004	0.001	0.001	0.001	0.001	0.001	0.001
Cd	Mg/l	0.003	0.005	0.005	0.00001	0.00002	0.00002	0.00002	0.00001	0.00001	0.00002	0.00002	0.00002	0.00002
Pb	Mg/l	0.01	0.00015	0.05	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Fluoride	Mg/l				1.22	1.21	1.24	1.21	0.63	0.61	0.64	0.63	0.63	0.63
Chloride	Mg/l	250	250	250	1883	1862	1881	1876	385.1	380	382.8	371.4	373.9	385.8
Nitrate	Mg/l	50	10	50	12.195	12.11	12.21	12.18	2.88	2.96	2.92	2.85	2.83	2.92
Phosphate	Mg/l	N/A	N/A	N/A	0	0	0	0	0	0	0	0	0	0
Sulfate	Mg/l	500	250	250	528.4	524.94	528.2	527.7	166.5	166.7	165.5	162.3	161.9	168.6
Total Coliform	(MPN Index/100 ml)	≤5%	≤5%	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fecal Coliform	(MPN Index/100 ml)				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E. coli	(MPN Index/100 ml)	0		0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TSS	Mg/l				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TDS	Mg/l		500	1000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TS	Mg/l				N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Figure (2) illustrates a plot showing the concentration of anions in ppm for fluoride, chloride, nitrate, phosphate and sulfate as determined by IC device.

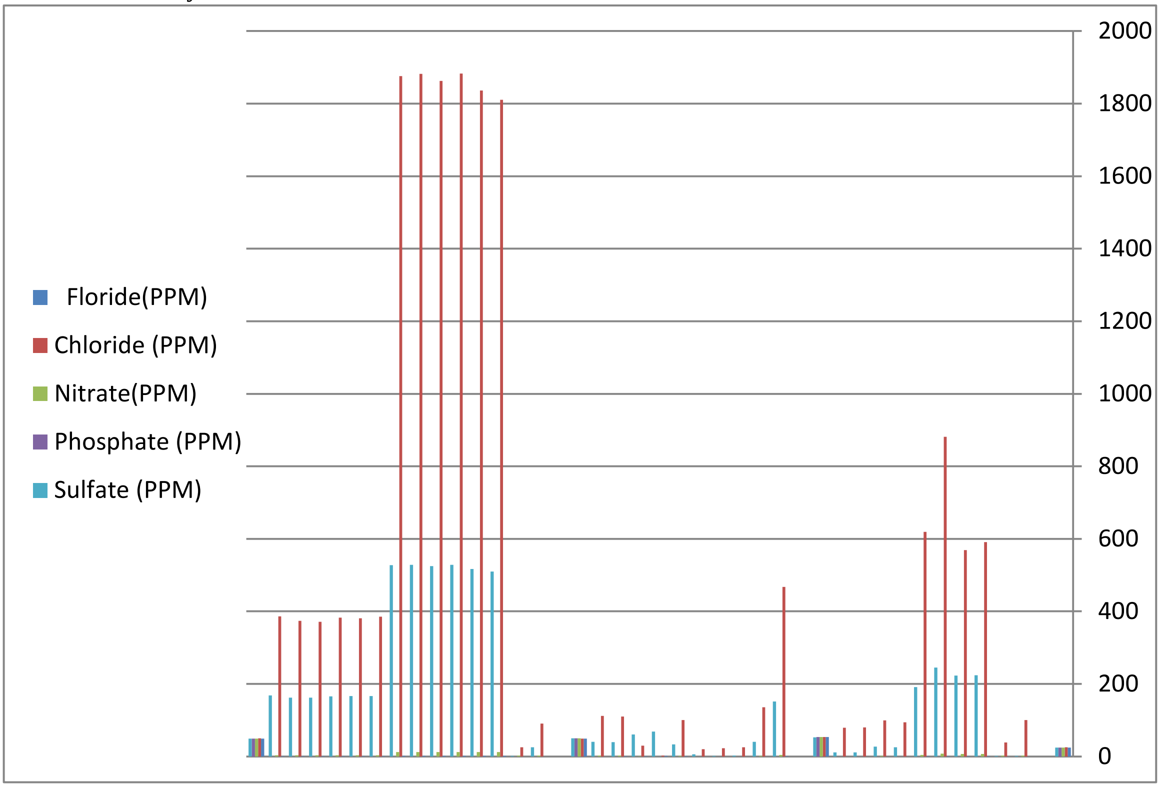

Figure (2) Concentration of anions.

Figure (3) shows the variation of conductivity for the 34 samples tested as per each sample ID

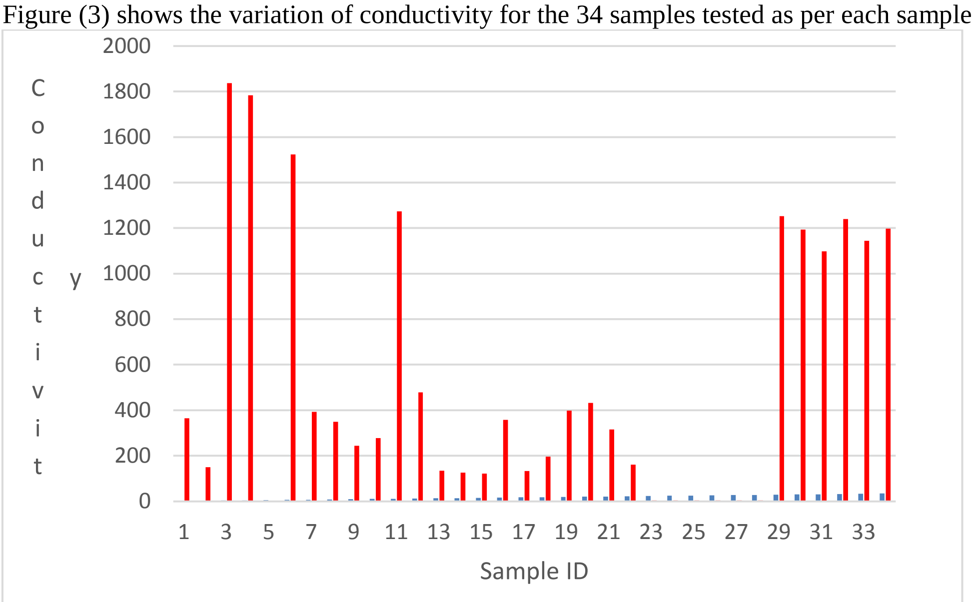

Figure (3) Conductivity versus Sample ID

Turbidity variation for each of tested samples is shown along Figure (4).

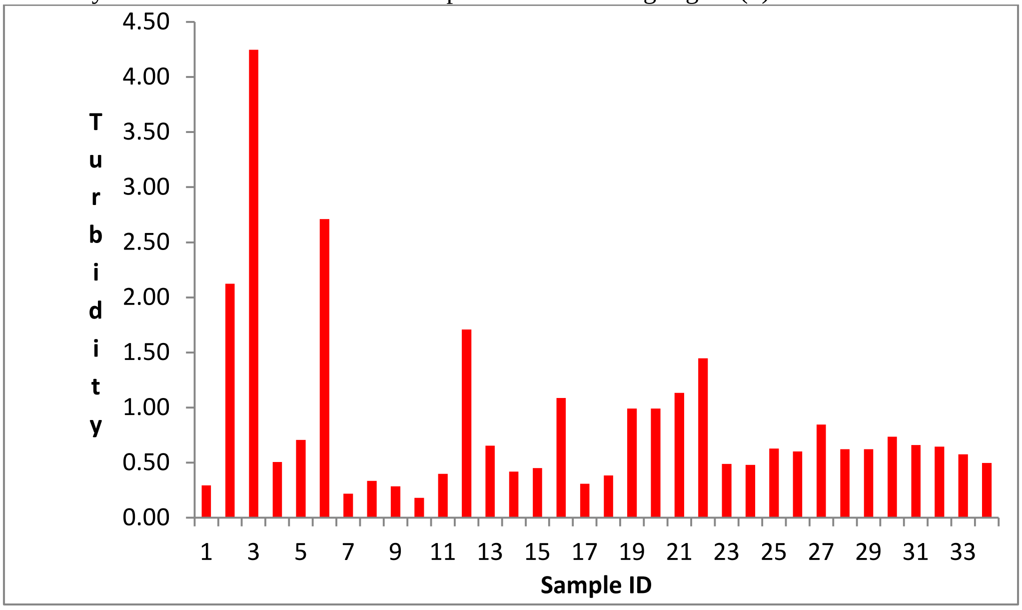

Figure (4) Turbidity versus Sample ID

Tables (2-5) present results obtained when analyzing 34 samples from several districts from several sources for anions and metals particularly: fluoride (F-) , chloride (Cl^-), nitrate (NO_3^-), phosphate (PO_4^{+3},), sulfate (SO_4^{-2}), chromium (Cr), copper (Cu), cadmium (Cd) nickel (Ni), lead (Pb), zinc (Zn), cobalt) Co), and arsenic (As) in storage tanks (tap water) using a high performance liquid Chromatography technique. Likewise, physical & chemical properties were conducted with reference to: BOD, pH, conductivity, turbidity and temperature.

Among the 34 samples tested, laboratory results showed that much higher amounts of sulfate and chloride are only observed in six samples. High levels of chloride were detected in seventeen samples in samples: (3, 4, 5, 6, 11, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 34 and 35). Comparing the concentration of sulfate and chloride to the primary/secondary EPA standards, majority of results are double the primary maximum contaminant (PMCL) Levels. Nitrate is about two ppm above the Maximum Contamination level for six of the samples. Fluoride was not very common throughout tested samples. The minimal levels of inorganic anions found were phosphate throughout all samples. Three inorganic anions (chloride, sulfate, and nitrate) were in violation of EPA standards for drinking water (see figure 2). The initial assumption was that the highest percent of contamination found would coincide with the condition of storage tank as well as the pipes lifetime. A situation that merits further investigation and practical research.

Results of the analysis suggest that the storage tanks water are violating the EPA Standards in term of chloride and sulfate. More testing and regulations by Saudi municipality and concerned authority has to be applied for the construction material of storage tank as well as plumbing pipes to avoid critical issues in the future. More investigations and concerns ought to govern storage tank material characteristics, instillation date, and inspection of tank, sample collection time and location. Water samples need to be collected from water sources, vendors and different locations of significance to have a positive and strong evidence that storage tank is the responsible source of sulfate and chloride contamination.)

This research work revealed that the majority of samples with high levels of chlorides and sulfates are water derived from the municipality. Usually, this water relatively is of high degree of salinity. The questionnaires that is distributed to household users showed that home owners are not supervising regular and periodic tank check and maintenance. Likewise, the researchers observed that water awareness as related to plumbing, water distribution and connecting pipes from municipal source is lacking.

When performing bacteriological and microbiological laboratory analysis samples were delivered to the Bacteriological Laboratory at the Environmental Engineering Department premises within 24 hours. This is to avoid and contamination. Tests indicated that water bacteriological properties are within the safe and acceptable range and limits of the EPA, WHO and PME standards and guidelines.

Laboratory testing results are in harmony with questionnaire results as related to high values of chlorides and sulfates. This is the main complains of household owners and users towards water received from the municipality. These areas are not provided with drinkable water of acceptable quality to consumers.

IV. CONCLUSION AND RECOMMENDATION

The following conclusions emerged from this research work:

- Laboratory investigations for selected samples from study area showed that there is no significant detrimental public health impacts expect for few locations where high levels of chlorides were detected.
- Laboratory investigations and rresults indicated conformity of tested samples to standards and guidelines for all checked physical, chemical, microbiological and bacteriological parameters.
- Environmentally-friendly alternatives for supplying potable & palatable water within homes are advocated for implementation at study zone (integrated household water management, water conservation, rain & water harvesting & wastewater reclamation and reuse).
- Key indicators are proposed to raise community awareness towards stored water (tank maintenance procedures, tank selection criterion, lessening wastage, use of inelegant taps, changing drinking behaviour, etc.).
- Regular maintenance of storage tanks, testing and treatment of household water is, therefore, recommended along with creating public awareness on how to maintain clean and safe storage water for domestic use.

REFERENCES

[1] Alharbi, F.A., Alshikh, F.A. and Alshukri, M. (2015) Quality of household water storage tanks: Case study with emphasis on Dammam metropolitan are in the Eastern Region, B.Sc. final year design project, Dept. of Environmental Engineering, College of Engng., University of Dammam, June (Unpublished report).

[2] Al-Ghanim, K. A., Abd El-Salam, M. M. and Mahboob, S. (2014), Assessment of Water Quality for Some Roof Tanks in Alkharj Governorate, KSA, Pakistan J. Zool, 46.4, pp. 1003-1012.

[3] Alegre, H., Pitchers, R., Jan Vreeburg, S. S., Bruaset, S. and Røstum, J., (2010), Water quality-driven operation and maintenance of drinking water networks, Best Management Practice, TECHNEAU report 5.2.7.

[4] Al-Zarah, A., I., (2014) Evaluation of Household Drinking Water Quality in Al-Ahsa City, Saudi Arabia." Research Journal of Environmental Sciences 8.2.

[5] American Water Works Assn. (2012), Standard Methods for the Examination of Water and Wastewater, APHA, Washington, DC., 22 Edi.

[6] Derick R. Douglas, Raaidah Saari-Nordhaus, Philippe Despres, and James M. Anderson, Jr., (2002),New Suppressor Technology Improves Trace Level Anion Analysis with Carbonate/Bicarbonate Mobile Phases', J. of Chromatogr. A, 956 47.

[7] EPA USA (2012) Edition of the Drinking Water Standards and Health Advisories, EPA 822-S-12-001, Office of Water, U.S. Environmental Protection Agency, Washington, DC

[8] Graham, J., and VanDerslice J. (2007), The effectiveness of large household water storage tanks for protecting the quality of drinking water. Journal of water and health 5.2, pp. 307-313.

[9] Gundry, S., Conroy, R., and Wright, J., (2013), A systematic review of the health outcomes related to household water quality in developing countries. J Water Health 2, pp. 1-13.

[10] Haswell, S. J., (1991). Atomic Absorption Spectrometry; Theory, Design and Applications. Elsevier, Amsterdam

[11] Quick, R. E., et al. (2006), Narrow-mouthed water storage vessels and in situ chlorination in a Bolivian community: a simple method to improve drinking water quality. American journal of tropical medicine and hygiene 54.5, pp. 511-516.

[12] Schafer, C. A., and Mihelcic, J. R., (2012) "Effect of storage tank material and maintenance on household water quality." Journal: American Water Works Association, pp. 104.

[13] WHO (2011) Guidelines for Drinking-water Quality, 4th edition, http://www.who.int.

[14] Zamilco,(2015),http://www.zamilco.com/en/products/water-tanks?gclid=cj0keqjw1pwrbrduv-rhstix6kwbeiqa5v9zobu6pjoftzapzhdkb4z3lugyaorr82d5wece_-z-kuuaarcd8p8haq