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ENVIRONMENTAL IMPLICATIONS OF TANJARO WASTE DISPOSAL SITE IN THE CITY OF SULAIMANI

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

قُلْ إِنَّ صَلَاتِي وَنُسُكِي وَمَحْيَايَ وَمَمَاتِي لِلَّهِ رَبِّ ٱلْعَٰلَمِينَ ١٦٢

سُورَةُ الأَنْعَام

Say: My worship and my sacrifice and my living

and my dying are for Allah Lord of the worlds(162)

Al-An'am

Dedication

To

My late mother

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Khasraw

SUMMARY

This study was performed in Tanjaro, an operational waste disposal site (landfill) located on 180 donnems (= $45000m^2$) of land, 10 km south of the city of Sulaimani in Tanjaro area. It receives waste from the city with a population of (699950) inhabitants as estimated in 2009. Sulaimani Governorate generates a daily amount of 1000 tons of solid waste. Data for this study were collected on seasonal and monthly basis including water samples from Tanjaro River, leachate from the dumping site, well water adjacent to Tanjaro Landfill site and soil samples. For laboratory analysis, samples were collected directly from different locations for physico-chemical and biological analysis. For air ambient quality both gas-analyzer and filter-gas were used inside the study area to collect samples and record data while microbiological contamination involved various laboratory tests. Each sample was analysed for the major cations (Ca^{2+}, Na^+, K^+, and Mg^{2+}) , anions (NO^{2-}, NO_3^-, Cl^-, and PO_4^{-3}) in addition to some heavy metals including (Hg, Pb, Cu, Zn, Cr, Cd, Mn and Al..

Results showed that the average mean concentration values for Hydrogen ion (pH) ranged 7.8, 7.9, 8.1 and 8.2 in Tanjaro River standing, running conditions, leachate and well water samples respectively. The collected samples in the study area showed moderate to strong alkaline.

Electrical Conductivity (EC) values varied from 876.4, 781.9, 24117.8 and 1125 µs/cm for standing, running Tanjaro River, leachate and well water samples respectively. Higher values of EC were observed in Tanjaro landfill leachate which indicate a high concentration of dissolved solids and salts of the leachate produced in Tanjaro landfill site. EC values were high in the majority of Tanjaro river samples where they are reflecting the effect of effluent sources from residential and agricultural area where large amount of drainage water and sewage from different sources enter into Tanjaro River.

The total hardness was recorded in the range of 224.7, 233.8, 281.2 and 90.2 mgL^{-1} as CaCO3. Tanjaro River was regarded as hard water, while leachate samples were regarded as very hard. The maximum value of total hardness was obtained at well water adjacent to Tanjaro landfill site. Water samples from well water considered as moderately soft water. Results indicated that the mean concentration values of BOD (mgL^{-1}) ranged 3.7, 2.4, 0.35 and 1.1 mgL^{-1} respectively. The minimum concentration value was recorded in leachate 0.03 mgL^{-1} while the highest concentration value 13.9 mgL^{-1} was recorded in

Tanjaro River's standing condition while drinking water for well water was categorized as clean to fairly clean water. The average mean concentration values of Dissolved Oxygen (DO) ranged 4.43, 4.16, 0.59 and 2.65 mgL^{-1} respectively. The maximum concentration values during the studied period coincident with low value of Turbidity while (DO) increases gradually to the direction of Darbandikhan reservoir due to the reareation and sefl-purification. Conversion of sulfate to Hydrogen Sulfide, which is highly obnoxious in leachate, causes a "rotten egg" smell due to the lack of DO (0.6 mgL^{-1})

Sewage from Sulaimani City, active gravel and sand open cast mining and washing down of landfill components are the main causes for high Turbidity, Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) in the study area. The maximum mean Turbidity was recorded in Tanjaro river's running condition was 703.6 Nephlometric Turbidity Unit (NTU), and the minimum average mean concentration value of TSS recorded in leachate was 5350.5 mgL^{-1} it was due to the nature of the municipality pollutants which are composed of different sorts of wastes. Concentration values of TDS were high for most of the Tanjaro river locations with the average mean values of 827.8 and 1540 mgL^{-1} for standing and running condition respectively while for leachate was 31080 mgL^{-1} , this higher average mean value of leachate is due to uncontrolled condition for this site as an open dump area.

The average mean concentration values of Sodium (Na) were 53.6, 84.5, 5144.3 and 120.92 mgL^{-1} while for Potassium (K) 29.4, 20.73, 1861.5 and 1.18 mgL^{-1} and for Magnesium (Mg) 22.6, 20.77, 354.2 and 17.3 mgL^{-1} in Tanjaro river standing, running leachate and well water respectively. The values were higher than permissible levels recommended by different standards. Excess of Na, K, Mg concentrations in groundwater may be due to the effect of Tanjaro landfill site and action of detergents. While for Tanjaro River it is due to discharging of sewage effluents directly to river from Sulaimani city, washing down of pollutants from landfill and human activities. Nevertheless, the results show that the mean concentration values of Potassium in most well waters were within the permissible limits for drinking.

The average mean concentration values of Cl, SO_4, PO_4, and NO_2 were 35.4, 24.48, 3459.4 and 17.42 mgL^{-1} for Chloride, while 77.8, 56.8, 459.3 and 83.8 mgL^{-1} for Sulfate, 8.8, 8.2, 27 and 0.2 mgL^{-1} for Phosphate , 0.2, 0.16, 0.72 and 0.04 mgL^{-1} for Nitrite, in Tanjaro river standing, running ,leachate and well waters respectively. Concentration of PO_4 in well water was higher than permissible limits. High Sulfate concentration was due to industrial wastes exists in landfill site which is regarded as a point source of Sulfate. Wells water show Nitrite concentration values within the acceptable limits.

The average mean concentration values of heavy metals Hg, Pb, Cu, Zn,Cr, Cd,Mn and Fe were 0.59, 0.34, 12.1,and 0.29 mgL^{-1} for Hg, while for Pb 0.42, 0.35, 0.46 and 0.28 mgL^{-1} and for Cu 0.06, 0.06, 0.15 and 0.06 mgL^{-1} and for Zn 0.05, 0.04, 0.75 and 0.21 mgL^{-1} for Cr 0.16, 0.22, 0.7, and 0.24 mgL^{-1} for Cd 0.08, 0.08, 0.12 and 0.05 mgL^{-1} for Mn 0.15, 0.17, 4.75 and 0.01 mgL^{-1} and for Fe 0.05, 0.06, 2.4 and 0.12 mgL^{-1} in Tanjaro river standing and running, leachate and well water respectively.

The results revealed that the dump site leachate samples recorded high concentration of heavy metals (except Mn, Zn and Fe) which exceeded the permissible recommended values due to composition of solid waste that has been dumped daily which contains different variety of industrial products, municipal, hazardous and medical wastes. While mean concentration values of heavy metals in Tanjaro river showed lower values. Most of the studied samples from the river showed pollution by heavy metals (except Zn, Cu, Al and Fe) which exceeded permissible recommended values due to impact of sewage waste water from Sulaimani city, location of landfill site adjacent to river, and anthropogenic activities. Levels of heavy metals were relatively high in well water adjacent to landfill site. Nearly all well water samples were exceeding the permissible recommended values for drinking purpose except Fe, Mn and Al.

Bacteriological characteristics showed that the mean value of total bacterial count was 21.8×10^9 ,344.6×10^9 and 4.36×10^9 CFU/ ml (Colony Forming Units), while for total coliform 1217,2400 and 816.5 and for faecal coliform was found to be too many numbers to count for running ,standing condition in Tanjaro river and landfill leachate respectively. Higher bacterial count and the existence of the thermotolerant faecal coliform in all samples gave higher faecal pollution according to standards. Results also showed higher coliform mean number and total bacterial count for Tanjaro River as compared to Tanjaro landfill leachate.

Results from Ambient Air Quality represented the level of $RPM_{10,}$ SPM, SO_2, NO_x, CO and HC, were higher than the concentration objectives given by the World Bank Ambient air quality norms.

Evidence of health problem had been seen in the level of complains of inhabitants in the vicinity of the site and the increase in cancer cases in Sulaimani governorate according to Hewa Oncology Hospital indicate the harmful consequences of Tanjaro landfill site.

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List of Abbreviations

A.H.O	American Heart Organization
AMIS	Air management Information System
APHA	American Public Health Association
AQI	Air Quality Index
AQM	Air Quality Management
BOD	Biochemical Oxygen Demand
BPEO	Best Practical Environment Option
CEE	Central and East European Countries
CFC	Chloroform Carbonate
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency (US)
EP	Environment Protection
EPR	Environment Performance Report
GAW	Global Atmospheric Watch
GF/C	Glass Fiber Circles
GHG	Greenhouse Gases.
HCFCs	Hydro Chlorofluorocarbons
HSE	Health, Safety, and Environment
IVI	Important Value Index
KRI	Kurdistan Region of Iraq
KRG	Kurdistan Region Government
LF	Landfill
LFL	Landfill Leachate
LFG	Landfill Gas
MCLG	Maximum Contaminated Level Goal
MSWM	Municipal Solid Waste Management
MSW	Municipal Solid Waste
M.A.S.L.	Meter Above Sea Level
MOE	Ministry of Environment
MPN	Most Probable Number
MSC	Meteorological Service of Canada

MSW	Municipal Soil Waste
ND	Not Detected
NTU	Nephlometric Turbidity Unit
OECD	Organization for Economic Cooperation and Development
OHSMS	Occupational Health & Safety Management System
PFCS	Per Fluorocarbons
PPM	Part per million
PVC	Polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
RPM_{10}	Respirable Particulate Matter of 10 Micron Dimension
SD	Standard Deviation
SEPA	Scotland Environmental Protection Agency
SHF	Sulfur Hexafluoride
SPM	Suspended Particulate Matter
TDS	Total Dissolved Salts
TSP	Total Suspended Particulate Matter
TSS	Total Suspended Solids
UNFCCC	United Nations Framework Convention on Climate Change
U	Unavailable
VOC	Volatile Organic Compound
WB	World Bank

CHAPTER ONE: Introduction and Literature Review

INTRODUCTION

Pollution has become one of the most serious concerns which threaten human lives and the confining bio-system. As human beings, we pollute the environment through many ways. One of the major pollutants is the produced waste; everyday millions of tons of trash get dumped into the earth landfills. Therefore, as population growth continues to increase in the future waste management will play a big role to maintain an ecological balance in our environment.

The environmental impacts of waste management have far more reaching consequences than we think. In addition to its impact on soil, water and air quality, waste management practices has impact on energy consumption, in 2003 the United States generated just over 236 million tons of Municipal Solid Waste (MSW), EPA (2007) while in 2006 the United States generated about 251 million tons of MSW and recycled 82 million tons, individual waste generation rate is equal to 2kg per person per day, from this amount of 750g was recycled. In 2006 the United States recycled 82 million tons of Municipal Solid Waste (MSW) saved the energy equivalent of more than 10 billion gallons of gasoline EPA (2007). In Scotland the Municipal Solid Waste (MSW) production is approximately 0.66 tons per capita per year = 1.8kg per capita per day in 2002-2003 SEPA (2003). There has been a substantial fall in the amount of approximately 14 million tons of MSW in 1997 to approximately 8.5 million tons in 2007. These changes are due to the reduction of the quantity of biodegradable MSW being landfilled and it had been decreased from a peak of 19 million tons in 1990 to 1.7 million ton in 2005 (SEPA 2003).

The rapid increase in the volume, type of solid waste and hazards waste generated in Kurdistan region in the recent years especially in Sulaimani governorate is mainly due to the economic growth, urbanization, migration of farmers from villages to the cities and displaced people, from different parts of Iraq due to unstable political conditions to, Kurdistan region including Sulaimani Governorate, as the result of increasing number of industrial projects and enlargement of urbanized sections of Sulaimani city, level of solid and liquid waste has increased substantially. This flux of waste is not treated or disposed in the norms that can prevent pollution. In Sulaimania Governorate, owing to the lack of awareness, all types of waste, especially solid waste including hazardous waste are often mixed with domestic wastes and disposed in an uncontrolled manner without any form of site management; these practices among others contaminate soil, water and air, and poses health risks to the people living close to the dumping area. In Kurdistan most of these dumping sites are natural morphological or drainage depression chosen, without due consideration or assessment, on the outskirts of the major towns and cities. These dumping grounds have become part of the existing urban areas due to population and urban expansion. In addition to the problems imposed by such proximity, these site have no protective membrane to control developing and migration of harmful chemical, bacteriological materials and are open to weather elements. Tanjaro Landfill site is regarded as a major environmental risk that has raised concern and impacted the region most adversely. The site is chosen to represent a point source in Sulaimani is to be studied in details as an adverse intrusion on the environment in the region. Tanjaro Landfill is basically a large open area (180 donems = 45000 m²) of land where garbage is placed and left to incinerate and then placed to decompose, this type of dumping area can be harmful for people living close to the landfill location and those who live miles away. Landfill or sanitary landfill as is called in US, is actually a scientific foundation that can be either a very large depression or a structure above the ground that has a liner, venting and a pumping system. The liner and the pumping system are the most important aspects of the landfill because these two items prevent contaminated leachate from entering the soil, while the venting allows the release of gases to be used or neutralized property.

The purpose of this study can be summarised as follows:

- This study for the first time reports the effect of open dump area (Tanjaro Landfill) on the environment condition of Kurdistan Region especially Sulaimani Governorate.
- This study explains a number of aspects the KRG (Kurdistan Region Government) can do to protect inhabitant's health, soil, air and water from the negative impact of landfills
- This study gives information about different types of solid waste which may contaminate soil, water and air due to the process of landfilling which includes collection, transportation, incineration, decomposing and dumping to eliminate the effects of pollution,
- The purpose of this study is to alert the KRG (Ministry of Environment), local people, as well as people living at the proximately of landfills to the risks of contamination by air, water (surface water, groundwater and wells water) and soil. This details of types of risks and what measure KRG can employ to protect people, atmosphere, water and soil from contamination.

- Since waste production cannot be avoided, the aim of this study is to regulate the disposal, management of municipal solid waste and recovery in a manner that reduces the risks to human health and the environment.
- The aim is to make steady progress towards reducing biodegradable municipal solid waste going in to landfill through the process of segregation at source (Houses, Hospitals, Factories….etc.) , and recycling.
- To determine the causes of pollution of Tanjaro River, water wells, air and soil.
- To ensure that the water of wells close to Tanjaro landfill are suitable for human consumption and other life activities.
- To investigate the presence of harmful micro-organisms.
- To identify potential sources of contamination within the landfill area.
- To examine the extent and degree of migration of toxic metals (heavy metals), towards groundwater, through proper geotechnical and geophysical matters.
- Air quality is essential to human health, the aim of this study is to regulate a significant number of industrial sites that have the potential to adversely affect air quality and ensure that emissions from these sites and from Tanjaro landfill are removed, minimized or made harmless through strict imposing industrial regulations.
- To introduce a protocol of designing, construction, management and operation in accordance to international recommended standards to be implemented for the city of Sulaimani and the rest of Kurdistan region in Iraq.
- Finally, a comparison will be made between the results of this study with the recommended standard levels permissible for irrigation, drinking and other living activities.

Literature Review

1.1: Pollution

Environment Protection Act (EPA 1986) defined pollution as the addition of materials or energy to an existing environmental system to the extent that undesirable changes are produced directly or indirectly in the system, it is created by individuals, communities and by industries that collect and dispose of pollutants improperly.

World Health Organization WHO (1998) "Stated that Pollution is the introduction of contaminants into an environment that causes instability, disorder, harm or discomfort to the physical systems or living organisms. Pollution can take the form of chemical substances or energy such as noise, heat or light energy. Sometimes the term Pollution is extended to include any substance when it occurs at such unnaturally high concentration within a system that endangers the stability of that system. While a pollutant is a material or a type of energy which its introduction into environmental system leads to pollution."

1.1.1: History of Pollution:

During 17 and 18 centuries there were no significant causes for pollution of environment due to human activities, because:

- Cities were small and none exceeded one million.
- World population was low.
- Village and small cities were self sufficient for almost everything including
  - Drinking water.
  - Use of water for agricultural activities.
  - Consumption of food and its limited diversity.
  - Accommodation style.
- Life requirements were simple and easy:

Not using cars by everyone in most cases bicycles (motor cycle) were used as means of transportation. Year after year, the number of inhabitants increased, and there was development in industry, agriculture and commerce.

The simple "primitive" way of life has restrained and limited the impact of pollution. Modern world has replaced and changed all that with the introduction of heavy industry and the gradual change in our consuming behavior. The growth in our life style has led to explosion in population which in turn has led to further pollution as follows:

- Life style of modern world was changed in every aspect.
- Our requirements were increased (e.g. consumption of water, electricity, oil).
- Our daily life habits was changed (e.g. food system, eating, drinking, etc…)
- Our mode of transportation (train, metro, aircraft, cars… etc.) All the above mentioned items cause pollution of environment. At the beginning of 20th century, people and governments start thinking about how to reduce the effect of pollution on environment. Pollution became a priority for everyone because pollution is directly and indirectly affects the life of every individual organism, human, animal and plants consequently the following changes were undertaken:

- City planning

- Proper sewage line system was established.
- Proper water plumbing system was established.
- Drainage system was established.

- Changing food style.

- Less consumption of food
- Using water in a scientific way.
- Waste food disposal into the garbage.

- Construction of disposal sites in a scientific way to reduce any harm on human health and that may not cause any kind of pollution on environment.

1.1.2: Forms of Pollution:

According to an environmental performance report (2001) the major forms of pollution are:

1- Atmospheric pollution:

American Heart Organization (A.H.O 2008) defined air pollution as the release of chemicals and particulates into the atmosphere. Common gases which cause air pollution include carbon monoxide, sulfur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides produced by industry and motor vehicles. Particulate matter characterized by size PM_{10} to $PM2_{2.5}$ is produced from natural sources such as volcanoes, or as residual oil fly ash from power plants. Diesel particles are another class of airborne particulate matter.

2- Water pollution:

Is caused by the release of waste products and contaminants by surface run off into river drainage systems, leaching into groundwater, liquid spills, waste water discharges, and eutrophication and littering.

3- Soil deterioration:

It occurs when chemicals are released by spill or underground leakage. Among the most significant soil contaminants are hydrocarbons, heavy metals, herbicides, pesticides and chlorinated hydrocarbons.

4- Radioactive pollution:

Nuclear power generation and nuclear weapons research manufacture and deployment regards as the main sources of radioactive pollution.

5- Noise pollution:

This encompasses roadway noise, aircraft noise, industrial noise as well as high-intensity sonar.

6- Light pollution:

This can refer to the presence of overhead power lines, motorway billboard.

7-Thermal pollution:

It is a temperature change in natural water bodies caused by human influence, such as use of water as coolant in a power plant.

1.1.3: Sources of pollution

Motor vehicle emissions are one of the leading causes of air pollution. Environmental performance report (2001) reported that China, United States, Russia, Mexico, and Japan are the world leaders in air pollution emissions, however, Canada is the number two country ranked per capita, principal stationary pollution sources include chemical plants, coal-fired power plants, oil refineries, petrochemical plants, nuclear waste disposal activity, incinerators, large livestock farms (dairy cattle, pigs, poultry, etc), Polyvinyl chloride (PVC) factories, metals production factories, plastics factories and other heavy industries.

Some of the most common soil contaminants are chlorinated hydrocarbons, heavy metals such as chromium, cadmium found in rechargeable batteries and lead found in lead paint, aviation fuel still used in some countries. Lead and copper release from old pluming water system, municipal landfills are the source of many chemical substances entering the soil environment (and often groundwater), emanating from the wide variety of refuse accepted, especially substances illegally discarded; there are also some unusual releases of polychlorinated dibenzodioxins commonly called dioxins for simplicity.

Pollution can also be the consequence of a natural disaster. For example, hurricanes often involve water contamination from sewage, and some other sources of pollution such as nuclear power plants or oil tankers, can produce widespread and potentially hazardous release when accidents occur. Volcanic Eruption, Earthquake, isonomy, etc are sources of natural causes of pollution.

1.2: Solid Waste:

Solid waste is defined as any material that is discarded because it has served its purpose and is no longer useful. It is unavoidable in any society, but now we produce more waste than ever before Miller (1999). Around the world, modern civilization has been stuffing its refuse into an abandoned mine, canyons and even dumping it in the oceans. Some of it is being incinerated, releasing poisonous gases into the air. Most of the material that is incinerated falls within the class "solid waste". Unfortunately this class of waste is very difficult to deal with because handling of solid waste materials is difficult and can expose workers to risk and blending is slow and incomplete. Miller (1999) reported that the United States is responsible for creating 33% of the world's MSW and USA producing 2 to 3 times more garbage than other countries. Most of solid wastes coming from mining, oil, natural gas, agriculture, Sewage and plants that produce the things that we need in our everyday life. However the remaining waste comes from (municipal solid waste called garbage) which comes from our homes and business in and around our neighborhood. Improper disposal of municipal waste can create unsanitary conditions and these conditions in turn can lead to pollution of the environment and outbreak of vector- borne diseases (that is disease spread by rodents and insects).

1.2.1: Composition of Solid waste:

The composition of waste contained within a landfill is influenced by the affluence of the catchments area, season, age, etc. Waste composition alters with time as biodegradation takes place and the organic content of the waste degrades into inert waste. This reaction occurs alongside other chemical reactions to alter the composition of the waste.

Niessen et al (1970 and 1972) examined the refuse composition data from a cross the United States showed great variability, reflecting local practices regarding the wastes accepted at landfills or incinerators, seasonal effects (e.g. on yard waste quantities), economic level of the citizens, incorporation of commercial or industrial waste, etc. Walter (2002) generally categorized municipal refuse as shown in Table (1.1)

Table (1.1): primary constituents of categories of Mixed Municipal Refuse

Category	Description
Glass	Bottles
Metal	Cans, wire, and foil
Paper	Various types, some with fillers
Plastics	Polyvinyl chloride, polyethylene, etc, as found in packing, house Wears, furniture, toys and no woven synthetic fabrics.
Leather, rubber	Shoes, tires, toys, etc.
Textiles	Cellulose, protein, nonwoven synthetics,
Wood	Wooden packaging, furniture, logs, twigs
Food wastes	Garbage
Miscellaneous	Inorganic ash, stones, dust
Yard wastes	Grass, brush, shrub trimmings

Source: From (Walter 2002).

Green et al., (1997) listed the composition of the domestic waste was established through investigation of published data to find a typical composition of household waste. The typical composition reached as shown in Table (1.2).

Abdullah (2005) listed the composition of solid wastes for Dohuk city and its peripheries in Table (1.3). From the same study, garbage produced for Duhok city and its peripheries per day per capita = 0.94 kg. Torabian et al., (2004) reported that city of Tehran with approximate population of 10 million people is producing daily amount of 6000 tones of solid waste which is equivalent to 0.6 kg of solid waste per capita per day.

Table (1.2): Typical composition of the domestic waste.

Category	percentage
Paper	30
Putrescibles	25
Metal	08
Glass	08
Textile	03
Rubber/leather wood	03
Plastics	08
Fines	10
Miscellaneous	05

Source: From (Green et al. 1997)

Table (1.3): Composition of municipal solid waste for Dohuk city and its peripheries period 6-7 and 9 Oct. 2004.

	*General waste (kg)	plastics (kg)	Cartoon and paper (kg)	Rugs (kg)	Glass (kg)	Metals (kg)	Total weight (kg)
Total	6820	1111	565	317	114	200	9127
%	67.9	11.1	5.6	3.1	1.1	1.9	90.7

Source: From (Abdullah 2005)

** General waste (food waste, fruits, vegetable, sweepings from houses….etc.*

Table (1.4): Average general refuse composition (1960-1995)

Component	Year				
	1960 *	1970 *	1980 *	1990 *	1995 *
Paper& paperboard	34.1	36.7	36.6	35.4	38.5
Yard wastes	22.8	19.1	18.2	17.0	14.1
Food waste	13.9	10.5	8.5	10.2	10.2
Glass	7.5	10.5	9.9	6.4	6.1
Metal	12.4	11.4	10.2	8.0	7.5
Wood	3.4	3.1	4.7	6.0	5.0
Textiles	1.9	1.5	1.7	2.9	3.4
Leather & rubber	2.2	2.5	2.8	2.9	2.9
Plastics	0.4	2.5	4.4	8.4	8.8
Other	1.5	2.2	3.0	2.9	3.4
Estimated rate (kg/person/day)	1.21	1.47	1.65	2.05	2.00

*Source: From (EPA 1998) ,*weight percent %*

EPA (1998) listed the average general composition of municipal solid waste in the United States from 1960 -1995 as shown in Table (1.4) the estimated per capita waste generation rate patterns over period from 1960 through 1995 which is equal to 1.21, 1.47, 1.65, 2.05, and 2 kg per capita per day respectively. The increase in production of solid waste per capita per day is due to the change in life style, economic condition for capita becomes better and life requirements become more. A review of Table (1.4) shows the dramatic increase in the plastics content of the waste stream. EPA (1990) estimated 177.7 million metric tons of municipal solid wastes were generated in the United States. This is equivalent to 1.95 kg per person per day Finstein (1992).

After material recovery for recycling and posting, discards were 1.64 kg per person per day. Virtually all of these discards were incinerated or landfilled.

Steuteville (1996) estimated 297 million tones of Municipal Soil Waste (MSW) were generated, with 27% recycled, 10% incinerated and 63% landfilled in the United States.

Glenn (1990) reported that the amount of MSW produced is higher than the figures reported by (EPA) which based estimates on per capita rates and the use of estimated disposal by states did not include biosolids (also known as sewage sludge), yard trimmings, and recycling projects. Scotland Environment Association Protection SEAP (2003-2004) in Scotland the Municipal Solid wastes production of approximately 0.66 tones per head of population/ year, which is equal to 1.83 kg per capita per day. One can expect seasonal variation in the composition and quality of wastes. Seasonal and annual average compositions shown in Table (1.5) were derived from an analysis over 30 data sets from municipalities throughout the United States during 1970 listed by (Nieseen et al., 1972).

Table (1.5): Estimated average municipal refuse composition, during 1970

Category	*Summer Wt %	Fall Wt %	Winter Wt %	Spring Wt %
Paper	31.0	39.9	42.4	36.5
Yard wastes	27.1	6.2	0.4	14.4
Food wastes	17.7	22.7	24.1	20.8
Glass	7.5	9.6	10.2	8.8
Metal	7.0	9.1	9.7	8.2
Wood	2.6	3.4	3.6	3.1
Textiles	1.8	2.5	2.7	2.2
Leather, rubber	1.1	1.4	1.5	1.2
Plastics	1.1	1.2	1.4	1.1
Miscellaneous	3.1	4.0	4.2	3.7
Total	100	100	100	100

*Source: From (Nieseen et al. 1972), * Weight percent*

The result for Table (1.5) shows seasonal variation in the composition and quantity of waste, it also shows the percent weight of solid waste production per capita per day is the highest in winter and the lowest in summer except for yard waste.

1.2.2: Types of Solid Waste:

As outlined by United Nation Environment Protection (UNEP), (2008) the types of solid waste, incorporating household (Domestic), commercial, construction and other wastes which have been identified or suitable for LF disposal. These include:

Inert Wastes:

Wastes that do not undergo any significant physical, chemical or biological transformation are regarded as inert wastes.

Directive Waste:

This type of wastes will undergo biodegradation within the LF environment to varying degree depending on their physical and chemical composition. (Biodegradable material is material that can be broken down by living organisms into simpler chemicals that can be consumed by living organisms, synthetic materials created in Lab, they are no biodegradable, Plastic is a common synthetic material. Microorganisms have ways to break down things in nature but not man made things. Plastics may last for hundreds of years before they are able to start the process of being broken down.

Hazard Waste:

Is regarded as any waste that by virtue of its composition carries the risk of death, injury or impairment of health to human beings or animals. The pollution of wastes could have an unacceptable environmental impact if improperly handled, treated or disposed of.

There are a number of waste categories according to various definitions and criteria there are waste types that affect distinct media (air, water and soil). At the present stage, the strategy focuses on solid waste and hazardous waste. Specific waste streams such as nuclear waste, mining waste, munitions waste, space waste are outside the scope of the present study. According to UNEP (2008) types of waste are:

1.2.2.1: Household (Domestic) Waste:

Waste or refuse that arises from private houses, synonymous with household waste. This consists of both non-hazardous wastes such as organic waste, textile, paper, food, grass clippings and hazards such as batteries, paint containers and oil mixtures.

1.2.2.2: Industrial waste:

Comes from processes or manufacturing and services, this consists of

- Non-hazardous waste.
- Hazardous waste.
- Sludge from wastewater treatment plants.
- Historical hazardous waste, of which production has ceased such as polychlorinated biphenyls and ozone-depleting substance waste.

- End-of-life equipment, discarded products and appliances such as electronics and electrical appliance (and their peripheral and spares).
- Motor vehicles.

Some of these discarded products and appliances may end up in municipal waste.

1.2.2.3: Commercial waste:

Environmental protection agency EPA in (1990) reported that commercial waste comes from premises used mainly for the purposes of a trade, business, entertainment, construction; demolition waste from construction activities or renovation of buildings, this type of waste can be subdivided into:

- Commercial waste.
- Construction waste.

1.2.2.4: Hospital Waste:

Health-care and waste from laboratories, hospitals, clinics and nursing facilities and offices, plate (2.2). Hospitals generate huge amount of wastewater per day. These effluents are loaded with pathogenic microorganisms, pharmaceutical partially metabolized, radioactive elements and other toxic chemical substances. These dosages of pollutants can provoke the pollution of the natural environment by entailing a biological imbalance. According to the United Nation Environment Protection Agency UNEPA (2008) two other types of wastes were added as follows:

1.2.2.5: Agriculture waste:

This includes crop residues, manure and chemical wastes such as pesticides, including persistent organic pollutants.

1.2.2.6: Marine related waste:

Such as marine litter, products dumped at sea, land-based wastes discarded the marine environment, waste from dismantled ship recycling.

1.2.3: Impact of Waste:

The increased amount of wastes and the contaminant rise is the hazards that poses threats that affects global and local environments, natural resources, public health, local economics and living conditions. Various diseases, including cancers, result from exposure to hazardous emissions, mainly from open burning and substandard incineration of wastes. Communities living near dumps are suffering from the associated littering, odour, insects, and vermin. Human scavengers incur even greater health risks EPA (2008). Wastes accumulated over decades and leachate from unmanaged landfills and wastes dumps have contaminated groundwater and soil worldwide. Waste dumping into rivers, lakes and seas has caused damage that threatens the agriculture water supplies and live hoods that depend on these aquatic systems. Waste chokes sewage and irrigation system, leading in turn to damage to infrastructure and the local economy EPA (2008).

Substandard Landfills and waste dumps emit methane, among other gases which is a major greenhouse gas of concern for climate change. Methane has also been the cause of repeated accidents involving fires, explosions and collapses at landfills and dumps (Global waste management 2004).

1.2.4: Volume of Waste:

Global waste management market report (2004) estimated that the total amount of municipal solid waste generated worldwide reached 1.84 billion tones in 2004, 7% increase on the 2003 total. The amount of industrial wastes generated worldwide is difficult to estimate. Oced (2004) reported that the volume of non hazardous industrial waste ranges from 1.1 to 1.8 billion tons in Australia, Brazil, Canada, China, European Union, Japan, Mexico, Thailand, Republic of Korea and United States of America. Oced (2004) defined the term "special Waste", which is refer to waste streams that present particular problems and need special policies and regulation for their management these include hazardous wastes, E-wastes and end-of-life motor vehicles. The amount of hazardous waste in selected countries Canada, China, India, European Union, Japan, Mexico, Republic of Korea, South Africa, Thailand and United States is estimated at approximately 150 Million tons. Waste from agriculture residues and rural areas include both biomass agricultural residues and hazardous wastes such as pesticides. The European Union estimates that its 27 member states annually produce a total of 700 million tons of agricultural waste. E-waste generation is steadily increasing owing to large-scale use of electronics. E-waste is one of the fastest growing segments of the waste stream. Brunner (2007) estimated that 315 million personal computers became obsolete in 2004 and 130 million mobile phones were disposed of in 2005.

1.2.5: Density of Waste:

As demonstrated by Dislefano (1993) the density of waste in landfill varies widely because of:

-Amount of daily cover.

-The total depth of waste.

-Large degree of decomposition.

-The depth from which sample is taken.

-Waste density in landfill may change with time as significant mass may be lost by the formation of landfill gas and leachate.

-The calculation of density will be further affected by the settlement that has occurred between placing the waste and the date of taking sample for calculation.

However, Dislefano (1993) reported that densities range from lows of 0.4 tone/ m^3 recorded in United States. It has been recorded the value of densities range from 0.65- 1 ton/ m^3 in UK. On the other hand Harrison (1985) concluded that excessively high waste densities may inhibit biodegradation by restricting leachate and landfill gas movement and may cause perched water table within the site. Whereas Young (1994) suggested the density of about 0.8 ton/m^3 is the optimum for the biodegradation processes in mixed household waste. If this is the case, then excessive use of steel wheeled compactors should be avoided if there is a need for rapid biodegradation.

1.3: Landfill:

Since the ancient times, organic wastes and other refuses have been deposited in open damps and allowed to decompose in the open air. However, the nuisance associated with such dumplings' include odours, air-borne litter, waste paper, plastics, the occurrence of rats, mice and flies as well as the generation of gaseous emissions and leachates by rainwater filtering through the tipped waste. Therefore, the disposal of solid waste become a very serious problem for all countries because of a dense population, a large economy and advanced industry and a high level of consumption and lack of natural resources. Various types of waste have been generated in large quantities and many of them are not being used but are rather disposed of in the limited disposal sites available which will be exhausted in the future reported by (DoE 1994).

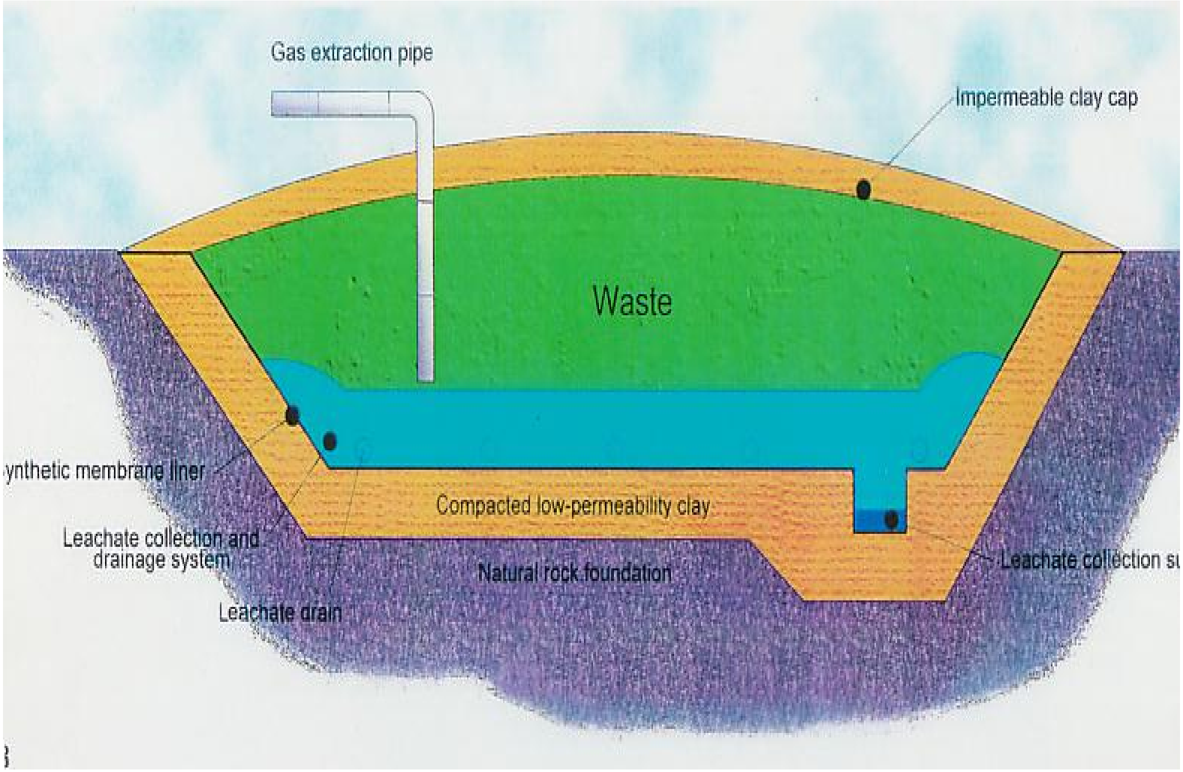


Figure (1.1) Sanitary landfill diagram.

Over the years the concept of sanitary landfill or engineering landfill was born, which is the process by which solid waste is dumped in a space which is fully covered by liner Fig (1.1). A secure landfills in carefully engineered depression in the ground into which wastes are put. The aim is to avoid any hydraulic connection between the waste and the surrounding environment particularly groundwater, all landfills should have regard to the requirements for environmental protection in order to ensure that they do not cause pollution of the environment or harm to human health or become seriously detrimental to the amenities of the locality in accordance with current legislation and the aim of sustainable development. Phillips and Freestone (1997) reported landfill is the most widely used system in the United Kingdom (U.K), with some 3500 sites in use; this is due in part to geological conditions and a significant number of voids or holes available in close proximity to centers of high population.

In the U.K, waste disposal by landfilling remains an integral part of approach to waste management. DoE (1994) reported approximately 70% of controlled wastes in U.K are currently disposed of to landfill sites, and recognized that landfill will remain the Best Practical Environmental Option (BPEO) for certain types of waste for the foreseeable future. The main objective of (BPEO) is to return the products of stabilization of a landfill to the environment in a controlled manner, at a rate which the environment can accept without harm. According to Meju (2000) ways in which this can be achieved include:

- Selection of inert wastes for landfill disposal.
- Pre-treatment to a quality which will not cause unacceptable harm.
- Management of bioreactive wastes in such away that the system degrades to approach a stable, non-polluting state. So it has been concluded that in spite of landfill regards as the (BPEO), the environmental impact of landfill sites is of major concern in developed countries due to their increasing development adjacent to urban area.

1.3.1: Environmental Impact Assessment (EIA):

For planning any project (dam construction, landfill, building…etc.), the EIA should be taken as an important issue to consider before, during and for the future because every project has an active live of (10, 20, 30 etc. years) for every new situation there should be an immediate solution otherwise disaster may strike in the area; for instance when landfill is constructed in an area the following points should be taken under consideration:

- Social impact:

  Constructing of landfill in an area perhaps causes evacuation of inhabitants due to the negative effect of landfill.

- Technical engineering implication:

  Landfill is regarded as an important and large project which may include recycling process project close to the area, landfill gas management, collection of leachate and management project which consequently induce change in natural condition of the area.

- The health risk of the potential effect of direct inhalation of landfill gases, released from landfill which are volatile organic compound (V.O.C) such as methane, as well as CO_2.
- As open dump method is practiced for waste disposal, runoff water passes through disposal wastes carries harmful substances, pollutants, hazard and materials, to the nearby streams, rivers, ponds, well water used for drinking and other life activities.

- Bad odour covering large area.
- Scattering big quantities of dusts, carbon particles and smokes covering large area.
- Expect increase vermin, dogs and insects in the area.

1.3.2: Site Selection for Landfilling:

Historically fifty years ago there were no systems set properly for the protection of environment from pollution. There were not any specific designated areas to be identified as a site (Land) for dumping solids. There were no plastic bags identified for the collection of disposals. There were no discriminations between commercial and toxic wastes as it is known nowadays.

One of the ways to eliminate the effect of pollution on environment is collecting different forms of solid wastes and disposes in an area known as landfill. Lanfilling is the process which provides way of safe disposing of solid wastes in a controlled manner which is the cheapest waste treatment method. These landfills are regard as the BPEO for certain types of waste. Most of these landfills are illegal, therefore illegal dumping areas should be replaced by sanitary landfills Fig (1.1) which are sophisticated in design and regulated in every aspect.

The following points should be taken in consideration for selecting the site location for disposing solid waste:

a- It should not be particularly valuable.
b- It should not be located close to permanent residences schools, hospital….etc)
c- It should not be located close to residential areas (House, markets, buildings…etc)
d- It should not be located close to the deep well used for drinking purposes.
e- It should not be located in flood plain areas. (To prevent seasonal pollution)
f- It should not be located close to historical, national park areas.
g- It should not be located close to an area where mines are expected.
h- It should be located above ground water table (GWT).
i- The type and volume of solid wastes which is collected every day by municipality should be known; according to this information the size of cell for dumping of solid waste will be estimated.
j- Which design for landfill construction is preferable in specific area for example (single big cell design, small single cells design together or individuals)

k- The active life of these selected cells (landfills) should be estimated for example (5, 10, 15, 20, and 30 etc…) years.

l- Before dumping of disposals, checking if there are any recycling processes.

m- The selected area for landfilling should not be located within drainage pattern (an area which is a natural pathway for run off due to slope effect). In case if preventing natural pathway escape of run off water after heavy rainfall causing entrapping of run off water in a certain area which finally cause the runoff water to be polluted, then due to infiltration process the polluted water moves downward and mix with ground water and water in the well.

n- The site to be selected for landfilling should be selected carefully and must be prepared in such way to minimize the impact of landfilling process on the environment as well as on public health.

o- The site bottom and the side slope of landfill are linked to make sure that there will be no cause for contamination of ground (soil), ground water, water in well, etc…).

For better protection of the environment close to landfill area, proper drainage, drinking water, and gas extraction system should be established. Proper liner material and liner system should be designed for leachate collection and treatment process without possessing any harm on the environment and human health.

1.3.3: Landfill leachate:

One of the most important problems when disposing of waste in landfills is an integral part of waste management strategies around the world. Freeze et al., (1979) reported that maintaining a landfill is managing the leachate that is generated when rain water percolates through the landfill and dissolves the organic and inorganic substances of the solid waste produces leachates which can move towards the ground water. Kimmel, et al., (1980) reported that production of leachate as a by- product of organic and inorganic. decomposition in landfills poses a serious threat if released to the environment Andreottola, et al., (1992) describe leachate pollution as the result of a mass transfer process between the waste and leaching water that has infiltrated into the waste layers. Physical, chemical and microbial processes transfer pollutants from the waste material to the infiltrating water resulting in a contaminated liquid containing high concentrations of organic and inorganic contaminants. If the leachate is released into the underlying aquifer, it forms a complex contaminant plume that fundamentally alters the chemical properties of the aquifer (Nicholson et. al. 1983, Bjerg, et. al., 1995, Jankowski 1992, Cozzarelli et al., 1999, Christensen et al., 2000). The amount, quantity and movement of such leachate have been studied by many researchers to observe the potential pollution from landfills, (Nicholson, et al., 1983, and Christensen, et al., 1994). A contamination plume is formed as a result of leaching into the ground water system and it has been described in various case studies, (Baedeckker, et al., 1979). The other problem is that in developing countries for instance Kurdistan region of Iraq, industrial solid waste, commercial solid waste, medical waste and domestic wastes are not separated and therefore organic, inorganic, and hazardous minerals content of leachate are extremely increasing and the COD in leachate will be more.

Torbian, et al.,(2004) reported that the COD in Tehran leachate is more than 60000 mgL^{-1}, the quantity and quality of Tehran leachate is changing seasonally in winter where the value of COD of Tehran leachate is low but during summer the level of COD will be more which makes the leachate treatment process harder.

1.3.3.1: Factors influence the production and composition of leachate:

Climate:

Climate is one of the major factor which influence the production and composition of leachate, when the climate is prone to higher levels of precipitation there will be more water entering the landfill and therefore more leachate generated.

Site topography:

Another factor is the site topography of the landfill which influences the runoff patterns and again the water balance within the site.

Stage of degradation:

The composition of leachate depends on the stage of the degradation and the type of the waste within the landfill. Leachate generated during the early stages of anaerobic degradation are characterized by high concentration of BOD, volatile fatty acids, high pH, high BOD to COD ratio and high levels of ammonia nitrogen and organic nitrogen. Ammonia is largely generated as a result of the degradation of proteinaceous materials.

Soil texture:

Soil texture at the site also influences the amount of water percolating into the landfill and escaping through the bottom. Soils with coarse texture possess high value of permeability means high hydraulic conductivity which helps leachate to reach ground water more quickly.

Vegetation cover:

Vegetation covers plays an integral part in leachate production control, thereby improving evaporation from the surface, and reduce percolation through the cover material. A site with poor vegetation cover may also experience erosion which cuts gullies through the cover soil, allowing precipitation to flow directly into the landfilled waste.

Waste:

Although leachate is primarily generated by percolation of water through solid waste layer in landfill, it can also be generated from water released from high moisture content waste.

1.3.3.2: Predicting leachate production rates:

Predicting the amount of leachate is a critical design parameter when designing a landfill. The amount of leachate generated will impact operating costs for leachate collection and treatment. The treatment plant must be sized to handle the peak period of leachate flow. The quantity of leachate generated will also be a factor in determining the leachate system which is installed at the base of the landfill. Model predictions of leachate production rate generally centre on a water balance analysis which is given by the following equation, according to Eden (1991):

$Q = I - E - aw$ ------------------------------ (1)

Q = Free leachate generated (m^3/year).

I = Total liquid input including liquid waste (m^3/year).

E = Actual evaporation losses (m/ year).

a = Absorptive capacity of the waste (m^3/tonne).

w = Weight of waste deposited (tones/ year).

Essentially, this balances liquid inputs against liquid outputs.

1.3.3.3: Landfill leachate management:

A landfill needs an efficient leachate collection and removal system to enable leachate to be removed from the site for disposal or recirculation. A good leachate management system is the prime requirement for accelerating stabilization.

(Parr 1989 and Knox et al., 1993) reported that the primary objectives of a leachate management system can be summarized as follows:

- Remove leachate contained within the site by the liner system for treatment and disposal according to the site's objectives.
- Control and usually minimize leachate heads within the site.
- Avoid damage to the liner system.
- As landfills decompose an aerobically over many years, the putrefy wastes they contain have the potential to generate highly polluting leachates. To avoid severe environmental impacts, proper control and disposal of these leachates is essential.
- In general the objective of leachate treatment at landfill sites should be to attain the required standards for discharge, whether to sewer, water course, land or tidal water. A variety of physio- chemical and biological techniques are available for the on –site treatment of leachate prior to discharge.
- Suspended solids must be removed from the leachate prior to treatment to prevent blockage of the filters.
- Leachate is pre- treated by addition of acid to reduce the pH value and to convert volatile ammonia into soluble ammonium salts.
- Oxidation of leachate by addition of oxidizing agent and pH adjustment may be used for the removal of sulphides, sulphite, formaldehyde, cyanide and phenolices. The principle use of this type of treatment is in situations where odors caused by sulphides are a particular problem.
- Organic material may also be removed by oxidizing agents such as ozone. Ozone has been used in wastewater treatment plants to control odour, improve suspended solids, and removal oxides pesticides.
- DoE (1990), has investigated the treatment of a high strength landfill leachate using a treatment sequence comprising an automatic aerobic lagoon plant, followed by a reed bed treatment system established in gravel media. Preliminary results indicate that the system can provide very effective reliable removal of suspended solids, COD and BOD.

1.3.4: Landfill Gas:

Solid waste deposited in the landfill produces gas when it decomposes; so generated gas is called landfill gas. The generation of landfill gas is a by-product of the digestion by micro-organisms of putrescrible matter present in waste deposited in landfill sites. The gas is predominantly methane together with carbon dioxide and trace concentrations of other vapours and gases Bingemen et al., (1987). The rate of gas production is influenced by the interaction of several environmental factors:

Composition of the deposited waste:

Waste high in organic matter such as food waste, garding trimmings and paper will decompose rapidly, whereas inorganic materials such as demolition and construction rubble will relatively unaffected by the decomposition process, sewage sludge mixed with the waste can enhance gas generation, Barlaz et al, (1997).

Daily cover:

Daily cover enhances the anaerobic condition, which enhance generation of methane gas, Bingemen et al, (1987).

Decomposition rate:

According to Eklund et al., (1998), the decomposition rate depends on, moisture content of disposal wastes, compaction degree of disposal wastes, volume and density of disposal wastes and condition of landfilling site (open dump process, sanitary landfilling).

1.3.4.1: Landfill gas components:

Oonk, et al., (1995) listed the major components of landfill gas; methane and carbon dioxide are "green house gases" and over hundreds of trace gaseous compounds.
A typical landfill gas analysis is shown in Table (1.6).

Christensen, et al., (1996) concluded landfill gas mainly consists of methane (CH_4) 55% and carbon dioxide (CO_2) 45%, landfill gas usually also includes source oxygen (O_2) and nitrogen (N_2) from the air introduced during collection procedures. Landfill gas is usually saturated with water vapor and contains trace amounts of mostly volatile hydrocarbons and some other gases. Whalen, et al., (1990) reported that both methane and carbon dioxide are green house gases; methane is estimated to be about 20-30 times more damaging to the environment than carbon dioxide. Large numbers minor constituents have been identified in household waste landfill gas at low concentrations, some of these compounds are responsible for unpleasant odours and some of them may represent a health hazard. Whalen, et al., (1990) estimated that odor from landfill gas differ from those from leachate since the smell of the latter is predominantly due to carboxylic acids which are only present at low concentration in landfill gas.

Table (1.6): typical analysis of raw landfill gas:

Component	Content
Methane (CH_4)	40-60%
Carbon Dioxide (CO_2)	20-40%
Nitrogen (N_2)	2-20%
Oxygen (O_2)	<1%
Hydrogen Sulphide (H_2S)	40-100 ppm
Heavier Hydrocarbons	<1%
Complex organics	100-200 ppm

Source: from (Oonk, et al., 1995).

1.3.4.2: International aspects of landfill gas:

Methane produced by the decomposition of organic waste in landfills and open dumps, is a significant contributor to global methane emissions. Christensen,(1996) confirmed that landfill may account for 8-20% of global anthropogenic (human influenced) methane emissions of 360 million ton per year. Table (1.7) shows the contribution of major anthropogenic methane source to global emissions.

The scientific community and many governments agree that various gases (landfill gas) in the atmosphere are causing warming of the earth's surface, which is having a destabilizing effect on global climate. These gases absorb and send infrared radiation back to the earth, causing the "greenhouse effect." The climate change could raise global sea levels, and increase the intensity of severs weather conditions and frequency of heat waves and droughts. Christensen, et al., (1996) estimated that increases in the concentration of methane in the atmosphere are roughly parallel to the world population growth. Over the last two centuries, since the industrial revolution, methane's concentration in the atmosphere has more than doubled. Journal of composting and recycling (2000) reported that methane has 21 times (by mass) the global warming potential of carbon dioxide over a 100- year time frame.

Table (1.7): Contribution of major methane sources to Global Anthropologenic emissions.

Sources	(Million tones/Yr.)	(%)
Coal mining, natural gas and petroleum industry	100	28
Enteric fermentation	80	23
Waste disposal (landfills, sewage, animal waste)	72	21
Rice paddies	60	17
Biomass Burning	40	11

Source: from: Christensen, et al, .1996.

1.3.4.3: Degradation of waste in landfills gas:

Mays et al., (1973) reported that the processes of degradation of waste in landfills involve not only biological process, but also interrelated physical and chemical processes. Paul (1998) concluded that the heat generated from the exothermic degradation reaction can raise the temperature of the waste up to 70-90 C^0, however compacting waste achieves lower temperature due to lower availability of oxygen. Water and CO_2 are the main products, with CO_2 released as gas or absorbed into water to form carbonic acid, which gives acidity of the leachate.

Methane may also form from the direct micro-organism conversion of hydrogen and carbon dioxide to form methane and water. There are two classes of micro-organisms which are active in the methanogenic stage, the mesophilic bacteria, which are active in the temperature range 30-35 C^0 and the thermophillic bacteria, which are active in the range 45-65 $C^{0\cdot}$ Paul (1998) suggested that landfill gas can be generated during the methanogenic stage over a temperature range of 35-65 C^0, with an optimum temperature range of gas generation between 30 and 45 C^0.

However, the main reaction and products during landfill gas generation after waste emplacement are reported by Paul (1998) as follows:

$4H_2 + CO_2 \rightarrow CH_2 + 2H_2O$ --- (2)

$CH_3COOH \rightarrow CH_4 + CO_2$

$HCOOH + 3H_2 \rightarrow CH_4 + 2H_2O$

(*Formic acid*)

$CH_3OH + 3H_2 \rightarrow CH_2 + H_2O$

(Methanol)

1.3.4.4: The potential Hazards of landfill gas:

The migration and emission of landfill gas potentially lead to different effects in the surrounding. The various effects which have influences on different scales can be distinguished as local, regional and global effects. When methane is mixed with between 5 and 15 vol % air, methane forms an explosive mixture, the methane, air mixtures burns and hence, poses a potential fire hazard. Gendebien et al. (1992) reported that landfill fires can be a source of chlorinated dibenzofurans and dioxins.

Christensen, et al., (1996) concluded that the main reason for damage to vegetation from landfill gas is asphyxia by removal of oxygen in the root zone. High concentration of $CO_2 > 20\%$ are also toxic to plants and some trace compounds, hydrogen sulphite halo-organic compound…etc) are toxic to plants as well. When the landfill gas depletes oxygen in the root zone of plants, it may converts iron and manganese to soluble reduced forms and produce high levels of iron and manganese in the vegetation. John et al., (1985) reported that high level of iron and manganese in plants may not cause visual symptoms but excess iron is very toxic to sheep and cattle.

Landfill gas migrating in the surrounding unsaturated zone is exposed to infiltrating water. Some of the components in the gas are highly water-soluble. Gendebin, et al., (1992) studied that solubility of CO_2 is 230 mgL^{-1} but only 30 mgL^{-1} for methane. Many of the trace organic in landfill gas are also highly water-soluble, and can be leached out by infiltrating water, thereby contaminating the underlying ground water.

The most current problem of the landfill gas is its unpleasant odour; Gendebien et al., (1992) estimated that odour can cause mental and physiological stress on human.

1.3.4.5: Landfill gas management:

The objectives of landfill gas management (LFG) systems are reported by Whalen, et al., (1990):

- Management of LFG provides a double greenhouse benefit because it does not only prevent emissions from entering the atmosphere, its utilization replaces fossil fuels another contributor to greenhouse gases of air pollutants such as sulphur dioxide, a major contributor to acid rain.
- Landfill gases contain, methane which is explosive, and also contain trace volatile hydrocarbons and other gases that may impact the atmosphere and groundwater if not controlled.

- Prevent unacceptable risk to human health.
- Both methane and carbon dioxide are green house gases. Methane is estimated to be about 20-30 times more damaging than CO_2. Therefore conversion of methane to CO_2 is less damaging to the environment than allowing the LFG mixture to be discharged to the atmosphere unchanged. The combustion of LFG either in flares or as part of an energy recovery process converts methane to CO_2.
- The best way for reducing LFG emission is by preventing organic materials from being landfilled but in reality still there are organic fraction of the waste is being dumped.
- Dumping of waste in a small area will be very easy to control for gas extraction system.
- Proper vegetation may also reduce the leakage of LFG.
- Proper gas extraction system will reduce the emission of LFG significantly.
- Gendebien et al., (1992) listed grass species capable of growing in landfill conditions as given in Table (1.8).

1.3.5 Ambient air quality:

Under the clean Air Act, (EPA 1990) establishes National Ambient Air Quality Standards (NAAQS) to protect public health and environment. EPA (1990) reported that Office of Air Quality Planning and Standards (OAQPS) have set National Ambient Air quality standard for six principal pollutants which are called "criteria" Pollutants these includes, carbon monoxide (CO), Lead (Pb), nitrogen dioxide(NO_2), particulate matter (also known as particle pollution) or (PM) and sulfur dioxide(SO_2).

Public Service Enterprise Group (PSEG) reported that carbon dioxide (CO_2), sulfur dioxides (SO_2) and nitrogen oxides (NO_x) are all by products of solid waste disposal. They also constitute Green House Gases (GHG) the main contributors to climate change, PSEG committed to reducing its impact on climate change, PSEG is equally focused on waste prevention, and waste reduction and recycling since waste generation and treatment are contributors to GHG production.

Table (1.8). List of grass species capable of growing in landfill conditions[1]

Common name	Scientific name
Red top	(Agrostis alba, L.)
Timothy	(Phleum pratense, L.)
Italian raygrass or rye grass	(Lolium multiflorum, Lam.)
Perennial raygrass	(Lolium perenne, L.)
Orchardgrass, cocksfoot	(Dactylis glomerata, L.)
Tall flescue	(Festuca elatior, L.)
Red flescue	(Fescuta rubra, L.)
Meadow grass	(Poa pratensis, L.)
Crownvetch	(Coronilla varia, L.)
Birdsfoot trefoil	(Lotus corniculatus, L.)
Alfalfa	(Medicago sativa, L.)
Lupin	(Lupinus)
White clover	(Trifolium repens, L.)

[1] Plant species resistant to landfill gas, Landfill gas from environment to energy

Sources: (Gendebien, et al., 1992).

Carbon Monoxide: (CO)

Carbon Monoxide is a colorless, odorless and tasteless gas once emitted into the atmosphere is slowly oxidized into CO_2, Freed et al., (2004). Tobacco smoking is also a major source of carbon monoxide, industrial sources including, coke ovens, incinerators and heating system. American Thoracic Society, (2000) reported that when CO in halted it pass through the lungs and enters the blood, it binds to hemoglobin and disrupts the supply of oxygen to the tissues. Consequent reduced oxygen availability can lead to a wide range of health effects related to blood levels of carboxyhemoglobin individuals at most risk from the effects of CO include those with cardiovascular or chronic respiratory problems, the elderly pregnant women and young children.

Sulphur dioxide:(SO_2)

Sulphur dioxide (SO_2) is found by the oxidation of sulphur at normal temperature and pressure. It dissolves in water to give an acid solution, which oxidizes to sulphuric acid (Ashbaugh et al., 1985). Traditionally sulphur dioxide pollution has been associated with the burning of coal in the domestic, commercial and industrial sectors. However clear fuels have replaced coal in the domestic sectors and in many industrial applications. Power generation in urban areas has predominantly moved to large and efficient plants situated at rural sites. The consequence of this changing pattern has been an overall decrease in sulphur dioxide emissions.

Oxides of Nitrogen: (NO_x):

The two oxides of nitrogen (NO, NO_2) are for local air quality purpose collectively known as NO_x. Typically 90 to 95% of NO_x at the time of emission from an industrial combustion source is in form of NO, once formed, nitrogen dioxide taken place in chemical reactions in the atmosphere (is a gas produced by the reaction of nitrogen and oxygen in combustion processes) that convert it to nitric acid and nitrates, both of which can be removed by rain.

1.3.5.1 The pollutants:

United States Environment Protection Agency EPA(2008) reported that hazardous air pollutants, also known as toxic air pollutants or air toxics are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects or adverse environmental and ecological effects. Examples of toxic air pollutants include benzene, which is found in gasoline, perchlore ethylene, which is estimated from dry cleaning facilities and methylene chloride which is used as a solvent and paint stripper by a number of industries. Most air toxics originate from human- made source, including mobile sources e.g. (cars, trucks, buses,…etc) and stationary sources e.g. (factories, refineries, power plants) as well as indoor sources e.g.(building materials and activities such as cleaning).

1.3.5.2. Particulate Matter (PM):

United States Environment Protection Agency EPA (2006) reported that (PM) is also known as particle pollution or (PM) is a complex mixture of extremely small particles and liquid droplets particle. Pollution is made up of a number of compounds, including acids (such as nitrates and sulfates), organic chemicals, metals and soil or dust particles.
Giri, et al., (2007) estimated that Particulates in an urban setting are emitted chiefly by human activities. The principal sources are fuel combustion, motor vehicle operation, Industrial processes and open burning operations. Krishnamurthy et al., (1987) reported that in a typical metropolis, the vehicular traffic is a chief source of air pollution

particularly for particulate pollution. United States Environment Protection Association USEPA (1990) groups particle pollution into two categories:

Table (1.9) National Ambient Air Quality Standards (NAAQS)

	Primary Standards		Secondary Standards	
Pollutant	Level	Averaging Time	Level	Averaging Time
Carbon Monoxide	9 ppm (10 mg/m^3)	8-hour	None	
	35 ppm (40 mg/m^3)	1-hour		
Lead	0.15 µg/m^3	Rolling 3-Month Average	Same as Primary	
	1.5 µg/m^3	Quarterly Average	Same as Primary	
Nitrogen Dioxide	0.053 ppm (100 µg/m^3)	Annual (Arithmetic Mean)	Same as Primary	
Particulate Matter (PM$_{10}$)	150 µg/m^3	24-hour	Same as Primary	
Particulate Matter (PM$_{2.5}$)	15.0 µg/m^3	Annual) (Arithmetic Mean)	Same as Primary	
	35 µg/m^3	24-hour	Same as Primary	
Ozone	0.075 ppm (2008 std)	8-hour	Same as Primary	
	0.08 ppm (1997 std)	8-hour	Same as Primary	
	0.12 ppm	1-hour	Same as Primary	
Sulfur Dioxide	0.03 ppm	Annual (Arithmetic Mean)	0.5 ppm (1300 µg/m^3)	3-hour
	0.14 ppm	24-hour		

Source: from EPA (1990)

- Inhalable coarse particles:

Such as those found near roadways and dusty industries, they are larger than 2.5 micrometers and smaller than 10 micrometer in diameter.

- Fine Particles:

Such as those found in smoke and haze are 2.5 micrometers (μm) in diameter or smaller. These fine particles can be directly emitted from sources such as forest fire, gases emitted from power plants, industries and automobiles react in air.

Annette (2005) reported that most concern is given to particles small enough to penetrate into the lungs reaching the alveoli when the delicate tissues involved in the exchange of oxygen and carbon dioxide are to be found.

1.3.6: Water pollution by Microorganisms:

Pollution of water occurs from a variety of sources Fig (1.3). Contamination of water with pathogenic organisms remains a major cause of epidemics of disease. Water borne outbreak diseases result from contamination of water with a variety of microorganisms and chemicals. Deutsche Vereining für wasserwirtschaft (DVWK) (2002) reported that, according to the published global water survey, over half of the word's major rivers are either polluted or in danger of drying up. Even now, some 10000 people die every day because they have no water or only polluted water to drink. Nearly 3 billion people live in catastrophically unhygienic conditions and without any proper sanitation; another huge problem is the pollution of our water resources by untreated effluent.

Leclerc et al. (2002) estimated that many classes of pathogens excreted in faeces are able to initiate waterborne infections, there are bacterial pathogens, including enteric and aquatic bacteria (*salmonella, campylobacter, shigella, vibrio*), enteric viruses and enteric protozoa (*cryptosporidium, Giardia, Toxoplasma*), which are strongly resistant in water and to most disinfectants.

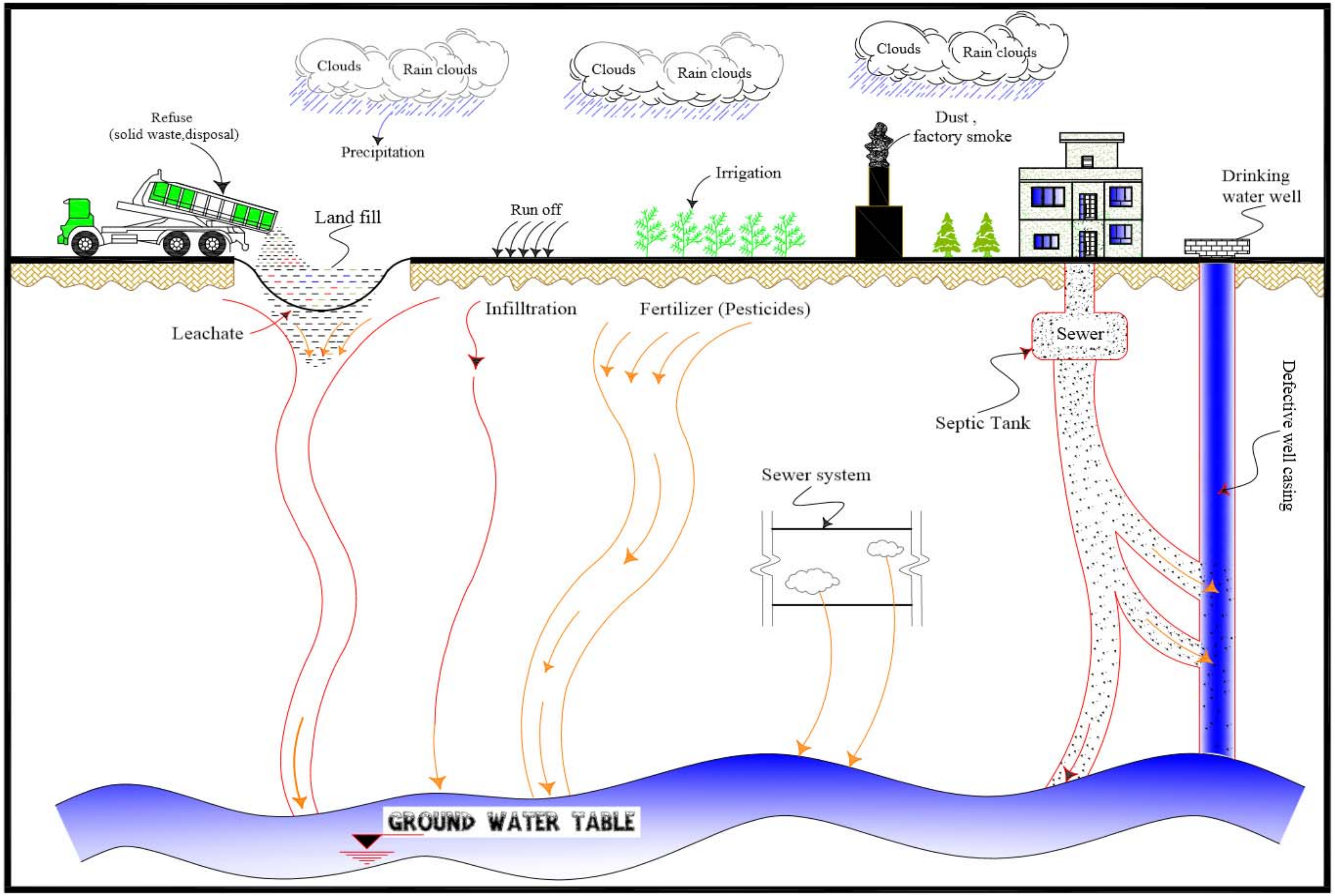
Payment et al. (2001) studied that waterborne bacterial disease cause a wide range of syndromes including: acute dehydrating diarrhea (cholera), prolonged febrile illness with abdominal symptoms (typhoid fever), acute bloody diarrhea (dysentery) and chronic diarrhea (Brainerd diarrhea). Most outbreaks of waterborne diseases are caused by fecal contamination of water by infected animals or people.

Eaton et al. (1998) reported that microbiological quality criteria have been established in several countries for water quality used for drinking and wastewater for irrigation purposes, the determination of the microbial quality of water relies on and requires monitoring for indications of waterborne pathogens. Tortora et al (2004) reported that indicator organisms are bacteria such as *coliform, E. coli and Enterococcus faecalis* that are very commonly found in the human or animal gut and their presence suggests sewage contamination. *E. coli and Enterococcus faecalis* are classified as good indicators of faecal contamination, as they are not normally present in water. Szewzyk et al. (2000) reported that coliform bacteria are common in the environment are generally not harmful. However the presence of these bacteria in drinking water is usually a result of a problem with the treatment system or the pipe which distribute water, and indicates that the water may be contaminated with germs that can cause disease. *Coliform bacteria* have been used as indicator organisms. Mater (1997) estimated that, although coliform bacteria are not themselves harmful they are likely to indicate the presence of pathogenic organisms and viruses.

Tortora et al. (2004) studied that *Fecal coliform* is bacteria whose presence indicates that the water may be contaminated with human or animal waste. Microbes in these wastes can cause short-term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. *Fecal coliform* bacteria are the organisms that are able to ferment lactose at 44-45 C^0 . *Fecal coliforms* may also originate from organically enriched water such as industrial effluents or from decaying plant materials and soils WHO (1997).

Schreijer et al. (1997) reported that as a result of self purification of wastewater, the coliform bacterial counts decreased and found 95% of all *coliform bacteria* were removed from sewage treatment plant effluent in a constructed wetland system using plant species. Green et al. (1997) reported that a significant removal of total coliform was achieved in dry summer.

Figure (1:3) Schematic representation of water pollution sources



1.3.7: Heavy metals contamination:

1.3.7.1 Lead (Pb):

Lead is a very heavy, soft, highly malleable, bluish- gray metal, it has poor electrical conductivity, it is highly resistant to corrosion and it is a relatively insoluble. Al-Manharawi et al,(1997) reported that metallic lead does occur in nature but it is rare, it is usually found in ore with zinc, silver and copper and it is extracted together with these metals, the main lead mineral is galena (PbS), which contains 86.6% lead, other common varieties are cerussite (PbCO3) and ($PbSO_4$), generally the average (Pb) concentration in the earth crust is equal to 15 mg/Kg. Human beings have been mining and using this heavy metal for thousands of years. Lead is very malleable and resistant to corrosion it is extremely used in building construction; it is a major constituent of the lead- acid battery used extensively as a car battery. Lead can also be found in some imported cosmetics such as kohl. It can leach from leaded china dishes, mugs and toys. It is used in ammunition and devices to shield x-rays leading to its exposure to the people working in these industries. Lead is frequently used in polyvinyl chloride (PVC) plastic which coats electrical cords. It is used in high voltage power cables as sheathing material to prevent water diffusion into insulation. It is also used as electrodes in the process of electrolysis. Lead as a soil contaminant is a wide spread issue, since lead is present in natural deposits and may also enter soil through leaded gasoline leaks from underground storage tanks or through a waste stream of lead paint or lead grinding from certain industrial operations. Lead also can be emitted into the air from motor vehicles and industrial sources, Clark et al., (1989) reported that motor vehicle pollution is considered as one of the main sources of lead pollution, the exhaust gases from motor vehicles diffuse and are diluted into a large area. Lead that is emitted into the atmosphere can be inhaled or it can be ingested after it settles out of the air.

According to Smith (1981) motor vehicles release approximately 80 mg of lead per kilometer distance traveled. Al- Saati (2001) found that there were three to six times increased lead level at high traffic locations in comparison to medium traffic roads.

Rose (1985) estimated that in the U.K the level of lead concentrations, primarily from fuel with urban road, run- off water contained about 2.4 mgL^{-1}. Use of lead in gasoline, paints and ceramic products, caulking and pipe solder has been dramatically reduced in recent years because of health concerns.

Al- Saati (2001) reported, in many countries including Britain, another source is lead in leaded petrol, the use of which has been banned in other countries. Al- Othman (2002), studied that Saudi- Arab lead content of gasoline used is about 0.84 g/L which is well above many other countries, hence the beginning of 2000 has started the production of unleaded fuels.

Needleman (2002) defined lead poisoning as a medical condition (also known as saturnism, plumbism or painter's colic) caused by increased levels of the metal lead in the blood. According to Couper (2006) lead poisoning was documented in ancient Rome, Greece, and China. Hosecroft and Sharpe (2001) stated that the lead salts are extremely toxic, the ingestion of soluble lead salt can cause acute poisoning, and long term exposure to a source of the metal, for instance, old water pipes or lead- based paints may result in chronic poisoning. Typical symptoms of lead poisoning are cholic, anemia, headaches, convulsions, chronic nephritis of the kidney, brain damage and central nervous system disorders. WHO (2006) reported that Lead is toxic to the nervous system, and children are especially susceptible to its effect. It is really absorbed through the intestinal tract and deposited in the central nervous system. Washington Post (2007) announced that, lead that is emitted into the atmosphere can be inhaled or it can be ingested after it settles out of the air. Bulut and Baysal (2006), Low et al., (2000) concluded that lead is rapidly absorbed into the blood stream and it is believed to have adverse effects on central nervous system, the cardiovascular system, kidneys and the immune system, lead exposure also affects the oxygen carrying capacity of the blood. Fischer, (2007) stated that long term exposure to lead or its salts (especially soluble salts or the strong oxidant PbO_2) can cause nephropathy and colic-like abdominal pains. United states center for Disease control (USCDC) (2002) stated that organic lead from gasoline additries may be absorbed directly through the skin; dermal exposure plays a role for exposure to organic lead among workers. According to WHO (2006) report, in 20th century, the use of lead in paint pigment was sharply reduced because of the danger of lead poisoning especially to children. By the mid- 1980, a significant shift in lead end use patterns had taken place. Much of this shift was a result of the U.S lead consumers compliance with environmental regulation that significantly reduced or eliminated the use of lead in non-battery products, including gasoline, paints, solders and water systems.

Between 2006 and 2007 many children's toys made in china were recalled, primarily due to lead in paint used to colour the product.

1.3.7.2. Mercury (Hg):

United Nation Environment Program (UNEP) (2009) reported that mercury found in various inorganic and organic forms in the environment, the three predominant forms of mercury are element mercury, Ionic mercury (also known as inorganic mercury), and Organic mercury with methyl mercury being the most important.

Mercury is distributed throughout the environment by both natural and anthropogenic process. The natural sources including Marine and aquatic environments, as well as volcanic eruptions can increase the atmospheric source by 4-6 times. However, recent studies suggest that anthropogenic sources (human causes) contribute to the majority of mercury releases. Anthropogenic sources can be divided into the following estimated percentages:

- 65% from stationary combustion (EPA 2007).
- 11% from Gold production.
- 6.8% from non-ferrous metal production, typically smelters.
- 6.4% from cement production.
- 3.0% from waste disposal, including municipal and Hazardous waste crematoria and sewage sludge incineration (Pacyna, et al 2006).
- 3.0% from caustic soda production.
- 1.4% from pig iron, and steel production.
- 1.1% from mercury production mainly from batteries.
- 2.3% from other sources

Once mercury is released into the environment it accumulates in the food chain. The higher up going in the food chain, the greater the concentration of mercury present in the organism. This phenomenon is known as bioaccumulation and is readily identified in fish.

According to USGS (2007) report, mercury is an extremely rare element in the earth's crust, having average crystal abundance by mass of only 0.08 ppm. According to a study by Manobar et al., (2002) mercury occurs in deposits through out the world and it is harmless in an insoluble form, such as mercuric sulfide, but it is poisonous in soluble forms such as mercuric chloride, methyl mercury. Patterson (1985) reported that mercury is unique among metals in that it can evaporate when released to water or soil. Microbes can also convert inorganic forms of mercury to organic forms which can be accumulated by aquatic life.

Mercury is used in, thermometers, barometers, manometers and it is used in a number of scientific research applications. Mercury is used in amalgam material for dental restoration, gaseous mercury is used in mercury- vapor lamps, liquid mercury was some times used as a coolant for nuclear reactors, and mercury is widely used in the manufacture of mascara. Historically, mercury was used extensively in hydraulic gold mining in order to help the gold to sink. According to EPA (2007) the use of mercury in medicine has greatly declined in all aspects, especially in developed countries. In 2003, Washington and Maine became the first states to ban mercury blood pressure device.

Mercury poisoning is also known as (hydrargaria or mercurialism) caused by exposure to mercury or to its compound salts a heavy metal which occurs in several forms all of which can produce toxic effects in high enough doses. It exists as vapor or as liquid metal and as inorganic salts and organomercurs compound (the most toxic forms of mercury are its organic compounds, such as dimethylmercury and methylmercury). Mercury can cause both chronic and act poisoning. Clifton (2007) concluded that toxic effects include damage to the brain, kidney and lungs. Davidson, et al. (2004), reported that toxic mercury result in several diseases including acrodynia (pink disease), hunter- Russell syndrome, and Minamate disease. Symptoms typically include sensory impairment (vision, hearing, speech), affected children may show red cheeks and nose, erythematous lips (red lips), loss of hair, teeth and hails hypotonia (muscle weakness).

Ngim et al., (1992) and liang et al,(1993) reported that case control studies have shown effects such as tremors, impaired cognitive skills and sleep disturbance in workers with chronic exposure to mercury vapor even at low concentrations in the range 0.7-42 µg/ $m^{3.}$. Mc Farland et al, (1978) stated that acute exposure 4-8 hours to calculated elemental mercury levels of 1.1 to 44 mg/m^3 resulted in chest pain, dyspnea, cough, hemoptysis, impairment of pulmonary function, and evidence of interstitial. According to WHO (1976) acute exposure to mercury vapor has been shown to result in profound central nervous system effects, including psychotic reactions characterized by delirium, hallucinations and suicidal tendency. WHO (1991) reported that long – term, low level exposure has been associated with more subtle symptoms of erethism, including fatigue, loss of memory, vivid dreams, and depression. Mason (1996) and kitameera (1974) reported that fish and shellfish have a natural tendency to concentrate mercury in their bodies often in the form of methyl mercury a highly toxic organic compound of mercury, the first occurrence of widespread mercury poisoning in human beings occurred in Minamata, Japan, now called minamata disease

1.3.7.3: Zinc (Zn):

Zinc is used as part of batteries and in alloys (e.g.) brass, most of the produced zinc is used to galvanize or Parkerizing steel and iron products to prevent corrosion, electrochemical properties of zinc make it a good material for a node material, Zinc oxides is perhaps the best known and most widely used Zinc compound as it makes a good base for white pigments in paint. Romic et al., (2003) studied that zinc is one of trace metals which is an essential element for the growth of plants and human beings it is necessary for sustaining all life but potentially toxic if it is used or available in high amount.

Hershfinkel et al., (2007) reported that zinc is a key factor in prostate gland function and reproductive organ growth, it is estimated that hundreds of thousands of proteins in the human body contain zinc prosthetic groups, most of zinc is contained in muscles and bones, Zink salts are effective against pathogens in direct application. Zinc deficiency occurs where insufficient zinc is available for metabolic needs. Zinc has been identified as one of the ten major factors contributing to disease in the developing nations. Zinc deficiency is usually nutritional but can also be associated with malabsorption, acrodermatitis enteropathica, and chronic liver disease. Even though zinc is a very essential requirement for a healthy body, excess zinc can be harmful. Excessive absorption of zinc can suppress copper and iron absorption. The free zinc ion in solution is highly toxic to plants, invertebrates and even vertebrate fish.

1.3.7.4: Copper (Cu):

Copper has the second highest electrical and thermal conductivity after silver. ADWG, (2004) reported that copper may occur in drinking water either by contamination of the source water or by corrosion of copper plumbing. Corrosion of plumbing is by far the greatest cause of concern.

Irwin et al., (1997a) stated that corrosively toward copper is a greatest in very acid water. Nriagu (1979) reported that copper mining, smelting operation and municipal incineration are regarded as the main sources of contamination. Copper is a malleable, ductile metal, it is valued for it is high electrical conductivity and, it is used extensively in products such as piping including water supply. Copper is used extensively in refrigeration and air conditioning equipment because of its ease of fabrication and soldering. Copper is used in electronics such as, copper wire, electromagnets; it has been used as water- proof roofing material since ancient times. It is used as a component of coins since ancient time.

According to WHO (2006) Bacteria will not grow on a copper surface because it is biostatic, for this reason copper is used as biostatic surfaces in hospitals. Hem (1985) studied that copper sulfate is used as a fungicide and as algae control in domestic lakes and ponds and it is used as gardening powders and sprays to kill mildew.

Bouwer and Ideloviteh (1987) estimated that copper is an essential trace nutrient to all high plants and animals, it is found primarily in the blood stream, as a co- factor in various enzymes and it plays a major role in enzyme functions. Copper is essential to human nutrition, however, in sufficient amounts copper can be poisonous and even fatal to organisms. Copper toxicity can occur from eating food that had been cooked in copper cookware. According to Flemming et al, (1989) copper toxicity can occur from high level of copper in drinking water for human varies depending on the source, too much copper in water has also been found to damage marine life. Johnson et al., (1998), Tsuji and Karagatzites (2001) estimated that the use of water that exceeds the Action level over many years could cause liver or kidney damage, short periods of exposure can cause gastrointestinal disturbance, including nausea and vomiting. Recent studies have found that people with mental illnesses such as schizophrenia had high tend levels of copper in their systems. Moore and Ramamoorth (1984) reported that soluble copper levels in uncontaminated fresh waters usually range between (0-1 ppb) increasing to (>2 ppb) in urban areas and (3-23 ppb) in rain water. According to Crompton, (1997) copper concentration in surface waters reaches (7ppb) in groundwater (3ppb) and in seawater ranges between (0.05-12ppb). Since copper contamination generally occurs from corrosion of household copper pipes, it can not be directly removed by the water system. Instead, EPA is requiring water systems to control the corrosiveness of their water if the level of copper at home taps exceeds an action level. The (Action Level) for copper has been set at 1.3 mgL^{-1} this is called Maximum Contaminant Level Goals (MCLG), because EPA believes this level of protection would not cause any of the potential health problems.

1.3.7.5: Manganese (Mn):

Dismukes et al., (2006) estimated that manganese is an essential trace nutrient in all forms of life; it is also an essential element for plants which plays an important role in many redox enzymatic reactions. It is also important in photosynthetic oxygen evolution in chloroplasts in plants. According to a report by public health (2005), manganese compounds are less toxic than those of other widespread metal such as nickel and copper. Elsner et al., (2005) studied that possible link between manganese inhalation and central nervous system toxicity in rates. According to environmental protection agency EPA (1984) and WHO (1981), manganese deficient in animals exhibit impaired growth, skeletal abnormalities, reproductive deficits, atoxia of the new born. Kawamura (1975) reported that in 1941 in an epidemiological study in Japan adverse effects in human beings the symptoms including lethargy, increased muscle tone, tremor and mental disturbance were seen due to high manganese concentration 28 mgL^{-1} in drinking water. Suzuki (1970) concluded that a progressive increase in the manganese concentration in drinking water is associated with progressively higher prevalence of neurological signs of chronic manganese poisoning and higher manganese concentrations in the hair of older persons.

1.3.7.6. Chromium (Cr):

Adriano (2001) reported that acidity of soil is one of several factors affect the availability of chromium for plant growth, however the effect of soil pH is different for the different species, acidic conditions increase the adsorption of Cr (VI) to particles whereas decrease the adsorption of Cr (III). Other factors affect the availability of chromium are CO_2 and O_2 concentration. Roskill (2000) reported that the greater use of chromium is in metal alloys as stainless steel, protective coatings on metal, magnetic tapes and pigments for paint, cement, paper and rubber. United states geological survey (USGS) (2001) reported that world mine production of chromites has increased from 13 million tones ore in 1990 to 13.7 million tones in 2000 in term of chromium. According to WHO (1998) chromium (Cr^{+3} trivalent) is an essential in human nutrition in amounts of 50- 200 µg/ day. It is necessary for the metabolism of insulin. It is also essential for animals, where as it is not known weather it is an essential nutrient for plants, but (Cr^{+6} hexavalent) is highly toxic. Research Triangle Institute for U.S Dept. of health and services (RTI) (2000) reported that human occupationally exposed to high levels of chromium, primarily Cr (VI) by inhalation, may include irritating respiratory effects, possible circulatory effects on stomach and blood, liver and kidney effects and increased risk of death from lung cancer. IARC (1990) stated that Cr (VI) is classified as carcinogenic to human beings.

1.3.7.7: Cadmium (Cd):

Cadmium is soft, bluish white, transition metal, malleable, and relatively water soluble. They are therefore more mobile in soil, generally more bioavailability and tend to bioaccumulate. It is not essential for plant or animal life. Cadmium is used in batteries, predominantly in rechargeable nickels-cadmium batteries, cadmium is used mainly for pigments, coatings, plating, and as stabilizers for plastics, it is used in electroplating and in photoconductive surface coating for photocopier drums.

Buildup of cadmium level in the water, air and soil has been occurring particularly in industrial areas. Plants may only contain small or moderate amounts of cadmium. According to WHO (1992), tobacco is an important source of cadmium uptake in smokers, as tobacco plants like other plants accumulate cadmium from the soil. WHO (1995a) reported that date from experimental animals and humans have shown that absorption via lungs is higher than gastrointestinal absorption (via the stomach) up to 50% of the inhaled cadmium may be absorbed. The gastrointestinal absorption of cadmium is influenced by the type of diet and nutritional status. People who live near hazardous waste site or factories that release cadmium in to the air have the potential for exposure to cadmium in air. Alloway (1997) studied that airborne cadmium comes primarily from the steel industry and waste incineration, followed by volcanic activity and zinc production.

Jarup et al., (1998) concluded that cadmium accumulates in the human body and especially in the kidneys, causing kidneys damage. International Agency for Research on Cancer IRAC (1990b) classified cadmium in class one, the agent (mixture) is carcinogenic to human, exposure to cadmium is linked to lung and prostate cancer. Damages have been reported by WHO (1991) in wild colonies of pelagic sea bird having cadmium level of 60-480 µg/g in the kidney. American Water Work Association AWWA (1998) reported that in aquatic systems, cadmium is most readily absorbed by organisms directly from the water in its free ionic form. The acute toxicity of cadmium to aquatic organisms is variable, even between closely related species. AWWA (1998) estimated that cadmium affects the growth of plants, stomata opening, transpiration and photosynthesis affected by cadmium in nutrient solutions.

1.3.7.8: Iron (Fe):

Iron is the most widely used of all the metals, accounting for 95% of worldwide metal production. Its low cost and high strength make it indispensable in engineering applications such as the construction of machinery and machine tools, automobiles, the hull of large ships, and structural components of buildings. Since pure iron is quite soft it is most commonly used in the form of steel, the main disadvantage of iron and steel is that pure iron, and most of its alloys, suffer badly form rust if not protected in some way. Painting, galvanization, passivation, plastic coating and bluing are some techniques used to protect iron from rust by excluding water and oxygen or by sacrificial protection.

Diagomanolin et al., (1947) studied that iron (as Fe^{+2}, ferrous ion) is a necessary trace element used by almost all living organisms. The only exceptions are several organisms that live in iron-poor environments and have evolved to use different elements in their metabolic processes, such as manganese instead of iron for catalysis or hemocyanin instead of hemoglobin.

Doulias et al., (2003) reported that excessive iron can be toxic, because free ferrous iron reacts with peroxides to produce free radicals, which are highly reactive and can damage DNA, protein, lipids and other cellular components.

Thus iron toxicity occurs when there is free iron in the cell. High blood concentrations of iron damage cells in the heart, liver and elsewhere can cause serious problems, including long-term organ damage and even death. Glei et al., (2006) reported that, in nature, iron is usually found in its oxidized form, for example iron III oxide, which is insoluble. Ferrous iron is soluble and its toxicity varies largely with the integrity of the gastrointestinal lining, Tehenbein (2005) estimated that the first indication of iron poisoning by ingestion is a pain in the stomach, as the stomach lining becomes ulcerated. This is accompanied by nausea and vomiting.

1.3.7.9: Aluminum (Al):

Beyers et al, (1993) reported that aluminum is found in all human tissues, but is most concentrated in the lungs, presumably from inhaled air. Phipps (1981) stated that unprocessed foods contain aluminum in very small quantities, although some vegetables and fruits may contain up to 150 mg/kg. Total daily intake is estimated at about 80 mg.

High aluminum intake originates from packaging, aluminum cooking vessels, aluminum-containing antacids.

Byczkowski, et al., (1984) and Oheme (1978) stated that Aluminum compounds are used to prevent hyperphosephatemia in renal disease and as antidotes. Until recently, aluminum was considered nontoxic. Because Alzheimer's disease patients have a high aluminum content in certain brain cells, research is now focused on high aluminum intake as a possible causal factor. In patients with this disease, the nerve fibers in the cerebal cortex are entangled and some of the nerve endings degenerate and form plaque. The brain becomes smaller, and part of the cortex atrophies.

Casey and Farr (1982) reported that aluminum toxicity includes reduction in net calcium ion uptake and a decrease in net uptake of magnesium and nitrate ions.

Duffus (1980) studied that aluminum is toxic to fish and this toxicity increases with increases in acidity as well as decreasing with higher amounts of available calcium.

De Fillips, et al (1994) reported that in human, aluminum can cause a rare- bone wasting disease, osteomalacia, and patients with high level of aluminum in their bones show signs of severe neuropathy and renal bone disease.

CHAPTER TWO: General Assessment of the Study Area

2.1: Tanjaro landfill:

2.1.1: Tanjaro landfill location:

Tanjaro landfill site is located approximately 10 km south of Sulaimani city center E 45° 19ˉ N 35^0 27ˉ Fig (2.1) and Fig. (2.2). It is bounded by Tanjaro River to the southwest, Tanjaro village to the west, cattle breeding farms to the east. Active gravel and sand open cast mining, cement block factories, and many other illegal factories are around the site nearly in every direction Plate (2.1), the site covers (45000 m^2).

The dumping area site is approximately 250 m southwest (on the embankment of Tanjaro River) close to the bridge on the road to Qaradagh near Tanjaro village (N23° 28◌́ 49.2◌̋, E45° 26 ◌́ 9.0◌̋). Tanjaro landfill is currently used for dumping disposals without any protection of environment. It does not meet the minimum technical and operational local or international standards. Tanjaro landfill has been operated by Sulaimani Municipality since 1998. It is an open dump area for all of wastes (domestic, commercial, industry, and wastes from hospitals) together without any segregation before dumping, Plates (2.2,2.3,and2.4). The collected wastes are transported by compacters, dumper, tractors, trucks, etc… from different sub-districts and quarters of city center, Plates (2.5).

In the landfill site, almost all rainwater soaks into the waste deposits. Waste in Tanjaro landfill is deliberately set on fire by the waste scavengers Plate (2.7) or due to its self incinerating (different gases will be released among them is methane due to decomposing of organic waste, depending on a study by Kazou Kamura (2002), methane concentration is over 50% from (1.5 to 3m) depth, this means that the concentration of methane is highest on the surface and close to the surface of landfill. Methane gas is incinerating if released and mixed with air creating a toxic gas release.

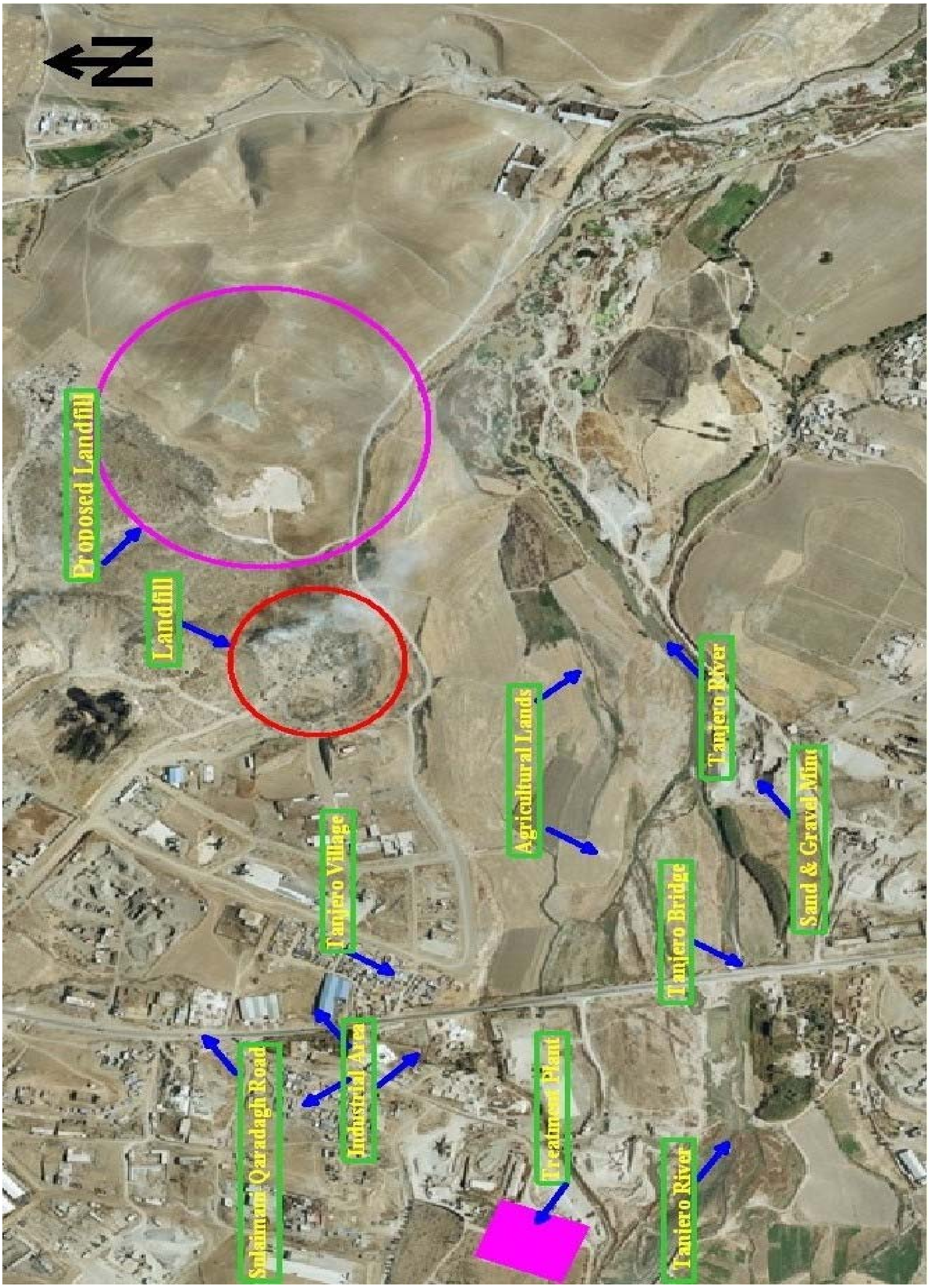


Figure (2.1) Satellite imagery map showing locations of studied area.
Source: Municipality project Group 28.03.2008

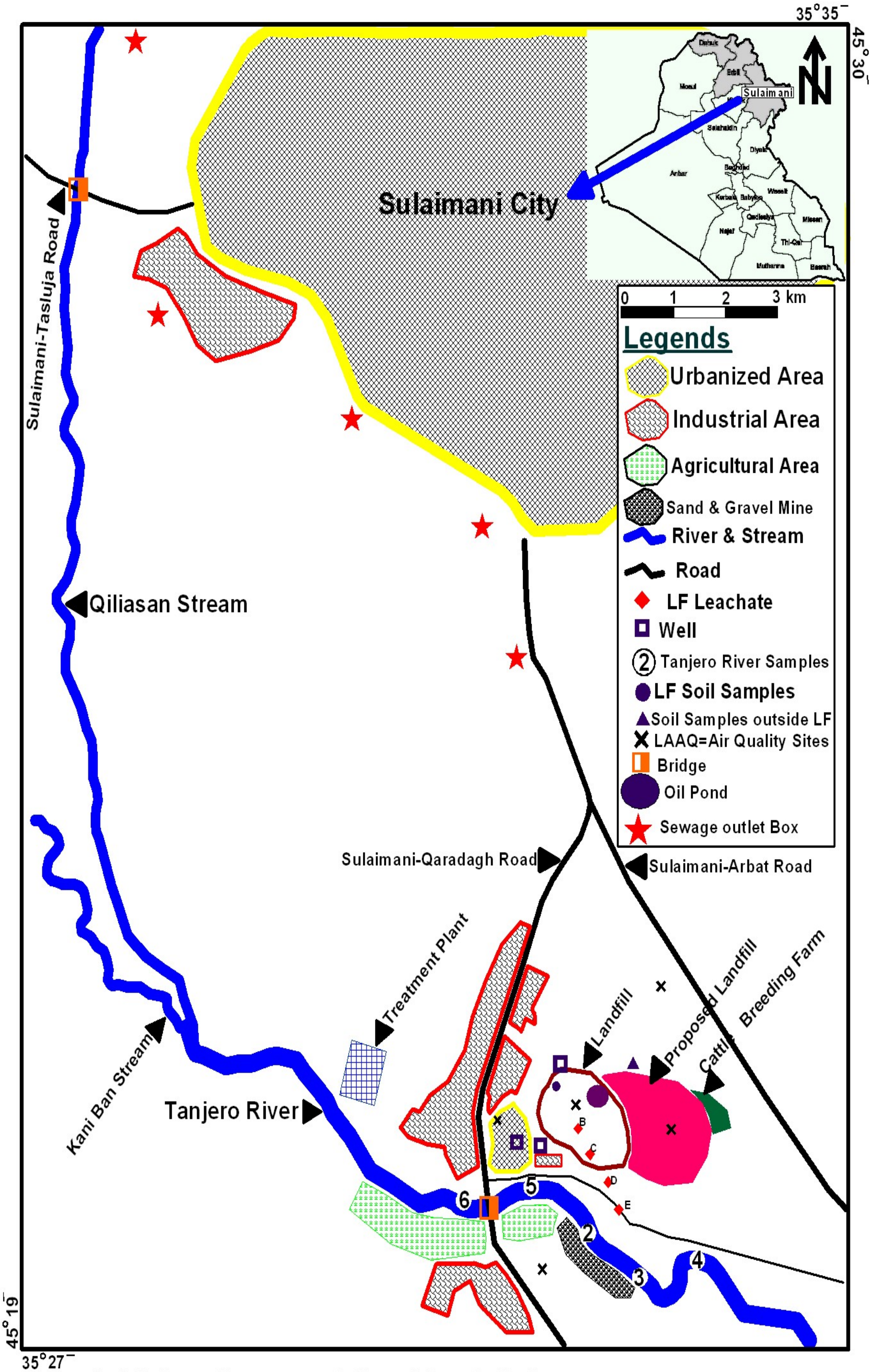


Figure (2.2) Schematic representation of the studied area

Plate (2.4) view of Tanjaro open dump area for dumping all wastes.

Plate (2.3) view of Tanjaro open dump area for dumping solid wastes.

Plate (2.2) view of Tanjaro open dump area for dumping of Hospital waste

2.1.2: Observations from visits to Tanjaro landfill site:

During the period of study the following observations had been recorded:

- Almost all cities in lraq, including Kurdistan cities practice open dumping for their disposal of solid waste.
- The open dump approach in Tanjaro landfill is the primitive stage of landfill development and remains the predominant waste disposal option.
- All the landfills in Iraqi Kurdistan region are owned by the local municipal government.
- Tanjaro landfill is equipped with compaction machinery, according to municipality of Sulaimani, Department of solid waste report, there are:
  4 Bulldozers, 2 Shuffles, 4 Truck carrying construction materials and four staff workers from municipality of Sulaimani.
- The extensive use of daily soil cover on newly deposited or compacted waste.
- No leachate management.
- No management of landfill gas.
- In Tanjaro landfill area neither permanent nor temporary capping material was used to prevent water infiltration into the waste tip. The absence of capping materials in landfill area is the main reason for leachate generation and migration beneath the landfill base, Plate (2.6).
- Birds are attracted to Tanjaro landfill site in large numbers, particularly when this site receives substantial amount of food waste, Plate (2.8)
- Tanjaro landfill site has potential harbour flies, vermin, and scavengers particularly when the waste contains food materials, Plate (2.8).
- Tanjaro landfill site is contaminated by leachate seepage, generated from the body of waste. The average thickness of the deposited waste is not known.
- Leachate pockets occur at several levels within the body of the waste.
- Leachate is present within the Tanjaro landfill and has migrated below the landfill base southwards, and has migrated following the topography of the site to the Tanjaro River, Plate (2.6).
- The generation and dispersion of leachate from Tanjaro landfill is slow, unsteady, non-uniform and sometimes discontinuous depending on the degree of compaction of

the waste, seasonal changes in water supply to the system and the amount and type of soil used for covering solid wastes.

- On the top of the second hill of Tanjaro landfill a pond of disused lubricating machine oil nearly 30 meter in diameter and more than 1 meter depth occurs. Contaminated oil from this pond could migrate towards ground water,Plate (2.9).
- Seasonal pollution is causing to pollute all agriculture land close to Tanjaro landfill.
- The presence of waste scavengers poses a safety hazard on them, and sometimes they deliberately start fires which cause serious air pollution, Plate (2.7).
- The negative impacts of scavenging (garbage picker) can be reduced by formalizing this work, by employing waste pickers directly, Plate (2.10).
- In Tanjaro Landfill site the entire necessary basic infrastructure (water supply, proper drainage system, wastewater treatment, leachate collection, proper solid waste covering and recycling) has not been established.
- In Iraqi Kurdistan Region, decision- makers and technical specialists are not aware of the importance of proper waste disposal and have limited legislation, regulations and guidelines. Some countries have made headway in this area. Gopalan, et al (1997) reported that in Chile the government has introduced a series of standards and guidelines in different parts of the country including requirements for environmental impact assessments (EIA_s) and leachate management. These guidelines pay special attention to the influence that climate conditions may have on waste landfills.

2.1.3: Dust from Tanjaro landfill area:

Dust from Tanjaro landfill, Plate (2.11) operations generates problem during periods of dry weather but can also arise from dusty waste as it is dumped. Dust is generally associated with, drying out of site roads, site preparation, restoration activities and the disposal of waste comprising fine particles.

2.1.4: Tanjaro Landfill fire:

Fires in waste on landfill sites are uncommon but occasionally they do occur and it is important for site operators (workers) to be aware of the dangers. In Tanjaro landfill site waste is torched deliberately plate (2.7). It should not normally be allowed as this will give rise to poisonous smoke plate (2.11) and odour can constitute a health risk.

2.1.5: Offensive odours at Tanjaro landfill site:

Offensive odours at Tanjaro landfill site may emanate from a number of sources including, organic decomposed waste, landfill gas, agriculture and sewage slugs, old waste disturbed by digging, malodorous wastes, and leachates. Good landfills practices will greatly reduce general site smell and reduce impact from odours which could lead to complains from local community. Good practice includes:

- Adequate compaction.
- Speedily disposal and burial of malodorous wastes.
- Effective use of appropriate types of daily cover.
- Effective landfill gas management.
- Effective leachate management.
- Rapid burial of excavated waste.

Plate(2.5) View of compactors and tractors for solid waste transportation

Plate (2.6) View of landfill leachate generation in Tanjaro landfill site.

GPS: N 35^0 29^- 000 E 045^0 26^- 112 Elevation 657.93 M

2.2: New proposed Tanjaro landfill area:

GPS: N 35^{0} 28^{-} 87 E 045^{0} 26^{-}50

Elevation 673.47 M

Increasing the awareness of people about the danger of municipal solid waste, hazard wastes including hospital waste, Plates (2.2, 2.3 and 2.4) dumping in an open area is an important issue to think about. Proper municipal solid waste management helps to improve public health, protect natural resources. Municipal solid waste Management (MSWM) is necessary to be thought about carefully, for this, information about, type, size and density of waste should be collected. At the present time the Municipality of Sulaimani proposed to build new landfill, it is within 200 donems which is equivalent to 50000 m^2 Fig. (2.1) and Fig.(2.2) just close to the present one, now the municipality of Sulaimani built a fence with block wall, Plate (2.12) and signed a contract with a foreign company to recycle all wastes before dumping, it will take two years to come to practice. The whole facilities will be established within the proposed site.

Plate (2.1) View of active gravel and sand cast

Plate (2.12) View of proposed Tanjaro landfill with block wall

Plate (2.7) View of Tanjaro landfill deliberately set on fire.

Plate (2.9)view of Pond of disused lubricating machine oil

Plate (2.11) View of smoke and dust arise from Tanjaro open dump area.

2.3: Population:

In a study by Salhi Rasha (1987), he concluded that in 1820 the population of Sulaimani reached (11000) inhabitants. In 1957 census conducted by the government indicated that Sulaimani inhabitants was (110171). The population of Iraq especially Kurdistan of Iraq has grown dramatically especially after liberation of Iraq in 2003. Recent estimation by the Municipality of Sulaimani, Department of planning, March 2008 Fig (2.3) indicates the expanding of Sulaimani city center, increasing number of new constructing areas, comparing master plan from 1925 to 2006 and 2027 as expected.

Date obtained from the Directorate of Statistics Sulaimani Governorate (Appendix 1) shows the population of Sulaimani city center for 2008 was (679563) while for the city of Sulaimani governorate (province) including districts, sub districts, towns, and villages was

1,696, 076 inhabitants. After uprising in (1991) and after liberation of Iraq in 2003, the migration of villagers to the city and also the influx of foreigners seeking work mainly caused this sharp increase in population. Sulaimani governorate (province) is now considered as one of the fastest growing cities in Iraq and especially in Kurdistan region.

According to data from the Directorate of Statistics Office in Sulaimani the estimated population of Sulaimani center in 2009 is (699950) while for the Sulaimani governorate including Garmean is (2360000) inhabitant. The Director of Sulaimani Municipal reported that Sulaimani consists of (16) district, (45) sub-districts and (2756) villages. UNWFP (2008) reported that 1893617 inhabitants of sulaimani governorate are distributed over 1042808 hectares (profile KRG, 2009), but 750552 of them lives in the sulaimani city (UNWFP, 2008).

Table (2.1) Number of Employee and Equipments.

	Service unit	Staff	Monitors	Environ. protectors perm.	Environs protector Temp.	Compactors	Tractors	Dumpers	Garbage container Auto.	Contract (Tractor Pickup)	Graders	Road cleaners Automobiles	Water tanker	Bin (garbage container)
1	Edara	9	4	4	7						14			
2	Sarkarez	7	17	33	41	8		1	1	13	2			8
3	Goezha	7	6	80	27	12	2	2	1	7	4			5
4	Ashti	7	16	43	55	11	1	1	1	9	2			5
5	Bakhtyare	6	8	36	15	5	2	1	1	4	2			1
6	Rzgari	7	14	74	48	11	3	3	1	9	2	2	1	14
7	Sarchnar	7	14	58	75	10	5	2	1	12				10
	Total exist	50	79	328	268	57	13	10	6	53	26	2	1	43
	Requireme	20	100	1000		100	10	10	10	10	20	10	10	1000

Reference: Sulaimani Municipality /Dept. of Services/ Sulaimani Municipality 2008

Plate (2.8) View of Tanjaro open dump harboring birds and scavenger doges.

2.4: Solid Waste Production:

As previously mentioned Sulaimani is one of the fast growing cities in Kurdistan Region. The annual rate of population growth in Sulaimani in previous 15 years (after liberation of Iraq in 2003) has dramatically increased (Appendix 1) and Fig. (2.3). All population require food, water, accommodation, electricity, etc… in their daily needs, huge amount of water converted to wastewater and finally reaches Tanjaro River, solid waste is produced and finally goes to Tanjaro landfill site to be dumped. Assuming solid waste producing rate equals nearly 1 kg per capita per day. According to the report announced by the municipality of Sulaimani, daily the municipality transfers nearly about (1000 tones) of MSW to Tanjaro landfill site.

According to the Municipality of Sulaimani, Department of Services (Table 2.1).

- Number of machines used for transporting Municipal Solid Waste (MSW) to Tanjaro landfill site is (80). {57 compacters, 13 Tractors and 10 dumpers}.
- According to the same source, number of machines required should be more than 200.
- Number of personnel working are 596, of which 328 are permanent and 268 are temporary, the actual required number should be more than 2000.

Figure (2.3) Sulaimani master plan………*Source: Municipality project Group 28.03.2008*

Plate (2.10) View of garbage pickers in Tanjaro open dump site.

2.5: Climate:

Information about climate condition is one of the factors which will decide the success of any project in a specific area.

Kurdistan Region of Iraq lies between the latitude 34^{0} 42΄ E and 37^{0} 22΄ and between longitudes 42° 25΄ E (taking account of Kirkuk) and 46° 15΄ E. Kifri which is 140 meters above the sea level is the lowest point. The highest point is the peak of Hasarost mountain in Erbil governorate with its 3607 meters Habib, (2003). The rain and the scarcity of water in Iraqi Kurdistan Region (IKR) is often a trouble for agriculture, therefore, some place of the region received a good amount of rain depending on the altitude. The KRG s ministry of agriculture divides the region into three zones depending on the rain (profile MOA, KRG, 2009). The first area includes all places that have more than 500 mm per year and is defined as a secured rain-fed line, the zone with the annual amount of rain between 300 to 500 mm per year, the zone is described as semi-secured rain-fed or semi-arid, the last category has less than 300 mm of rain per year classed as non-secured rain-fed line or arid (profile MOA, KRG, 2009).

Weather conditions can have critical effect on the efficient operation of landfill site. The designer will have obtained historical data relating to the site during the desk study stage of the site investigation and will have taken into account the weather condition likely to occur when designing leachate systems and surface water drains.

All meteorological measurements are taken from Sulaimani meteorological station Latitude: 35^0 $33^{ó}$ N, Longitude: 45^0 $27^{ó}$ E and Altitude: 884.8 m. Guest (1966) reported that Iraq climate is generally a semi-arid type and can be designated as subtropical which is characterized by wide durinal and annual range of temperature, Fig (2.4) and Fig. (2.5). Sulaimani region is characterized by cold, snowy weather in winter, warm and dry in summer. Stevanovic et al, (2003) studied that in winter Mediterranean cyclones moving from east to northeast over the region. Arabian Sea cyclones move northward passing over the Gulf carrying huge amount of moisture which brings intensive precipitation. The mountains are usually covered with snow three months in winter most of the mountain slopes are eroded the main causes of the erosion are the torrential rain and human activities (Habib, 2003).

The meteorological measurements that are taken from Sulaimani meteorology station are:

2.5.1 Temperature:

Is one of the biotic resources which affect biochemical reactions, microbial activities for decomposition of organic compound, rate of decomposition, all chemical, physical and biological processes will be directly and indirectly affected by the degree of temperatureFig (2.4) shows the mean yearly temperature value for Sulaimani city (1973-2008) the Meteorological parameters from (1973-2008) indicates that annual average temperature (18.51C^o) Table (2.2) and (Fig 2.5) which varies from maximum temperature (32 C^o) in July to minimum temperature in Jan. (5.39 C^o), Table (2.2).

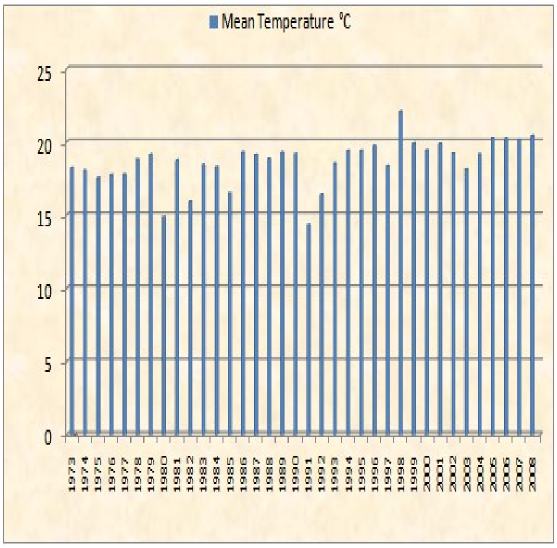


Figure (2.4) Mean yearly temperature for Sulaimani city (1973-2008)

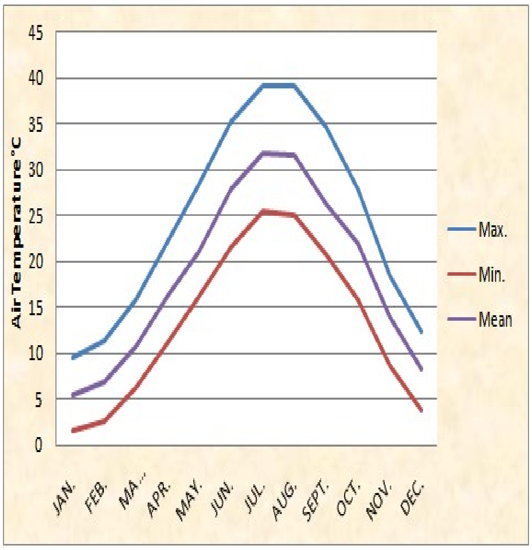


Figure (2.5) Max., min., and mean monthly Air temperature Sulaimani city (19732008)

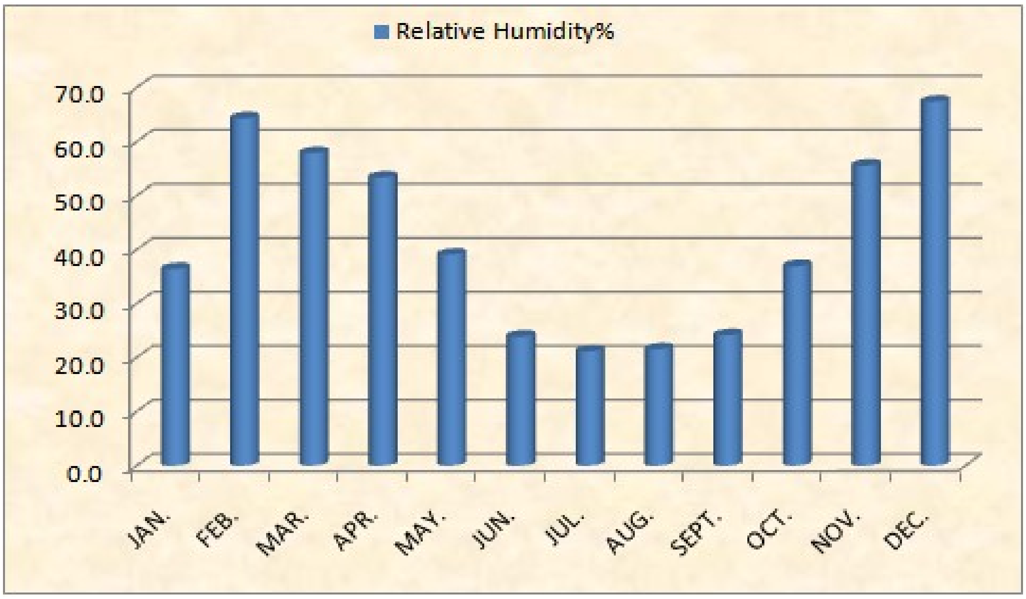


Figure (2.6) Mean monthly Relative humidity for Sulaimani city (1973-2008)

Table (2.2) : Mean monthly Climatic Parameters for Sulaimani City (1973 - 2008)

Parameters	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	mean
Air temperature©	5.39	6.86	10.8	16.3	21.21	27.9	31.7	31.6	26.2	21.91	13.9	8.24	18.51
Relative Humidity	36.4	64.3	57.9	53.4	39.08	23.9	21.2	21.6	24.1	36.95	55.6	67.4	69.04
Vapor pressure (m.)bars	6.26	6.27	7.22	9.03	9.5	8.06	8.61	8.32	7.35	8.2	7.59	6.9	7.78
Rainfall (mm)	123	138	114	86.8	39.89	4.95	3.1	0.15	3.41	37.56	78.5	118	62.31
Sunshine (hours)	4.93	5.24	6.58	6.68	9.31	11.1	9.77	11.3	10.1	7.65	5.82	5.33	7.81
wind Speed (m/sec)	8.8	8.18	8.84	1.54	7.451	1.09	9.31	8.76	6.67	7.851	7.75	7.98	7.02
Evaporation (mm)	51.8	57.5	109	144	250.7	342	417	369	264	165.8	78.6	51	191.8

Source: (Metrological Station, Sulaimani 2009)

2.5.2 Relative Humidity:

Relative humidity Fig (2.6) shows wide variations depending on location and time of the year within Sulaimani city**.** Relative humidity is important because the level of moisture within the air affects the rates of reaction and removal of some air pollutants. Griffith (1976) indicated that air temperature pattern is almost the exact inverse of the relative humidity Fig (2.7). Relative humidity varied between maximum (67% in December and minimum (21%) in July, Table (2.2).

2.5.3 Vapor Pressure:

Vapor pressure increases with increasing temperature and decrease with increasing rainfall .Vapor Pressure varies from (6.26 to 9.5 m.bars) in Jan. and May as minimum and maximum respectively, from the same vapor pressure parameters show annual average of 7.78 m.bars Table(2.2).

2.5.4 Rainfall:

Duration, intensity, frequency and size of rain drop are all important and affect; runoff which will cause washing out of pollutants to near by streams, rivers, lakes and reservoirs.

The variation between years is high and long period may pass without too much rain. The average mean monthly rainfall was ranging from 0.15mm in August as minimum to 138mm in Feb. as maximum and the average 62.31mm Table (2.2), in general most of the precipitation is occurring from Dec. to March, Table (2.2). While in summer, rain is absent FAO (2002) and the region suffers from high evaporation Fig (2.9) with a dry period between July and September. Fig (2.8) shows that rainfall distribution over time is very irregular. There are wet years Fig (2.8) with the annual rainfall, during 1974 and 1992 were 998.6mm and 1017mm respectively, while for 1999 was 338.9mm regarded as dry year. Fig (2.10) shows the mean monthly rainfall vs. relative humidity for sulaimani city.

2.5.5 Wind:

Regarding landfill, prevailing winds and the seasonality and direction of strong winds will have been taken into account when designing the sequence and direction of tipping so as to minimize the detrimental effects of odour, dust, and litter on local communities. The wind pattern should also be taken into account when locating permanent and temporary gas vents and landfill gas combustion exhausts so as to avoid exposure of local residents to vent and combustion emissions and potential odors.

In Sulaimani city the direction of wind varies widely this city is famous with special local cyclone which locally known by "Rashaba" meaning "the black wind" which causes changing in local climate. The highest speed of wind in Sulaimani city for the period from 1973 till present is (8.84 m.s) in March. and Jan. while in Jun. it reaches minimum speed (1.09 m/sec), Table (2.2).

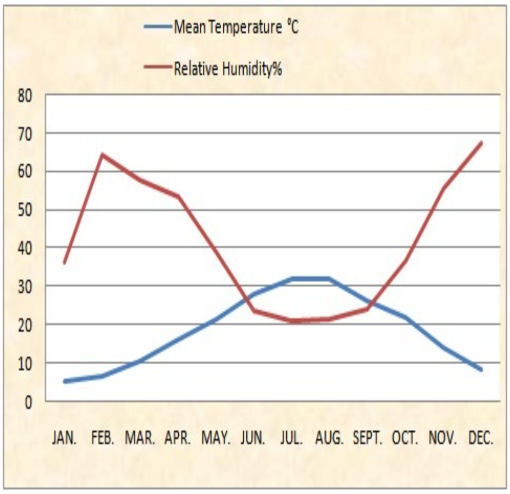


Figure (2.7) Mean monthly Temperature vs. Relative humidity for Sulaimani city (1973-2008)

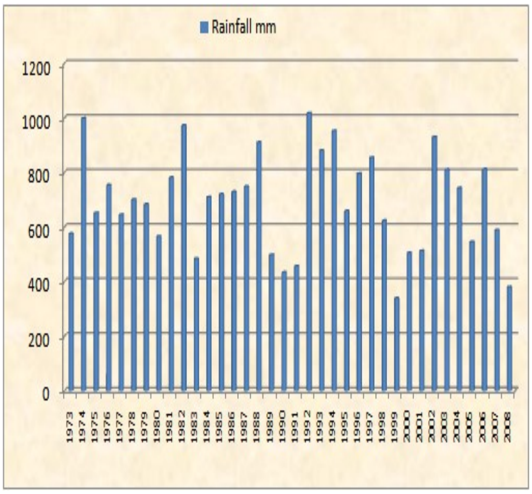


Figure (2.8) Mean yearly Rainfall for Sulaimani city (1973-2008)

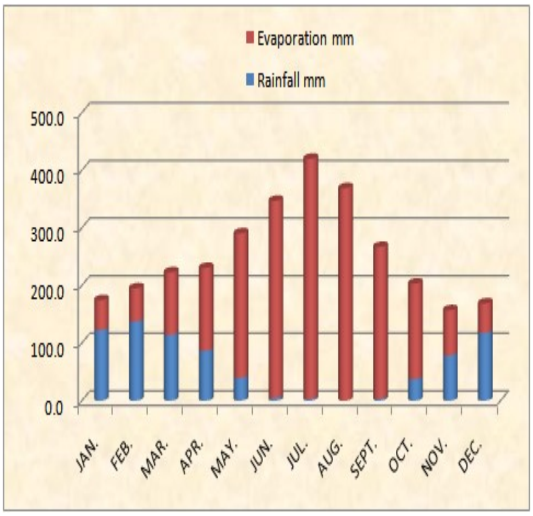


Figure (2.9) Mean monthly Rainfall vs. Evaporation for Sulaimani city (1973-2008)

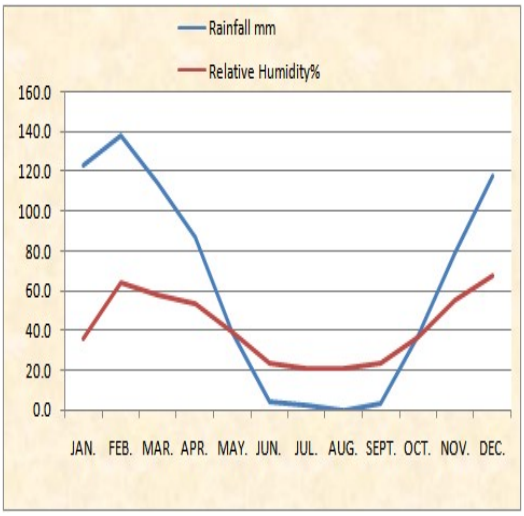


Figure (2.10) Mean monthly Rainfall vs.relative humidity for Sulaimani city (1973-2008)

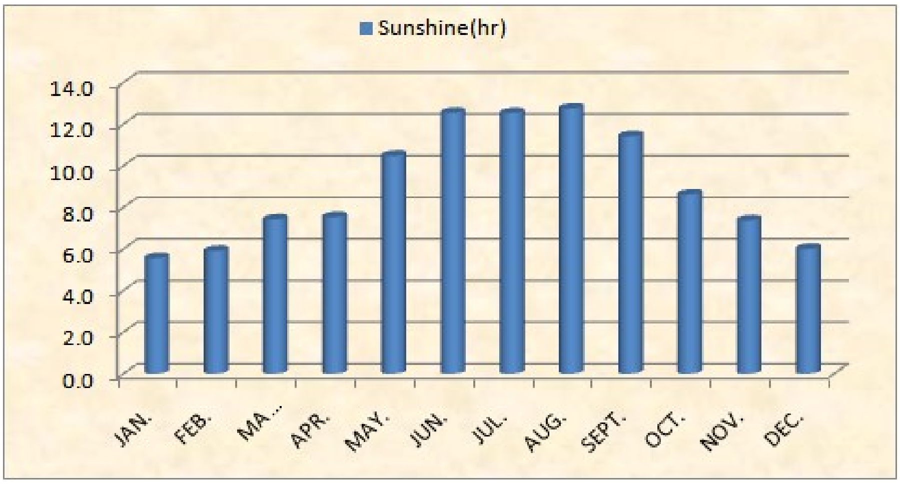


Figure (2.11) Mean monthly sunshine hours for Sulaimani city (1973-2008)

2.6: Geology of the area:

According to the tectonic classification of Buday (1980) and Buday and Jassim (1987), the area is located mainly in the high folded zone and partly in the thrust and imbricate zones. The basin is included in the Western Zagros Fold-Thrusted Belt which was deformed by Laramide and posts Laramide orogenies. During these orogenies, both Iranian and Arabian Plates collided directly at the north of the studied area in the Miocene (Buday, 1987, Karim 2006, Karim and Surdashy, 2005). The northern and northeastern boundary of the basin coincides with the boundary between the high Folded and Imbricated Zones. In this basin, the anticlines and synclines are high in amplitude and tight; in most cases, they are turned toward the southwest due to the stress of the overriding Iranian plate.

Nearly all the rocks of the basin are sedimentary and range in the age from Cretaceous to Recent. In the area, the wider distribution is of Cretaceous age rocks, which consist mostly of pelagic limestone and clastic rocks. The Clastic rocks belong to the Tanjaro and Kolosh Formations (Upper Cretaceous and Paleocene) which are exposed in the synclines, while the resistive limestone is exposed along axes and limbs of anticlines these rocks are covered, sporadically, by thick layers of recent sediments in the low lands (plains and valleys). The study area is a part of a large hydrological basin defined by Ali, (2007) as sharazoor-piramagroon. The followings are a brief description of the geological formation of the Tanjaro landfill site:

1. Alluvium:

The alluvium or alluvial deposits and soil cover all surface of the dumping area. The thickness of the alluvium sediments is about 2 meters which is consisting of mixture of clasts in the size of gravel, pebble, sand and clay. The clasts of the coarse fraction consist of unsorted and angular aggregate that are mainly consist of the limestone fragments of Kometan and Balambo formations. These sediments derived from nearby mountains by running water as debris flow or as stream bed and deposits rapidly in the plain during Quaternary as alluvium fan.

2. Tanjaro Formation:

Below the alluvium, about 400m of Lower part Tanjaro Formation comprising the foundation of the dumping area.

3. Lower Part of the Tanjaro Formation:

According to Ali (2007) report the thickness of the lower part of the Tanjaro formation is about 140 m. This part is not exposed below the dumping area but it is exposed in some small areas around the area especially along the road cut that surrounds the dumping area. The sandstone beds are deposited by turbidity current and contain graded bedding, plat debris, cross bedding and ball and pillow structures. The sandstone beds are compact and sound which have light grey weathering color while the fresh color is dark grey. The strata of this part are dipping 48 degrees toward S60W plate (2.13) and Fig (2.12).

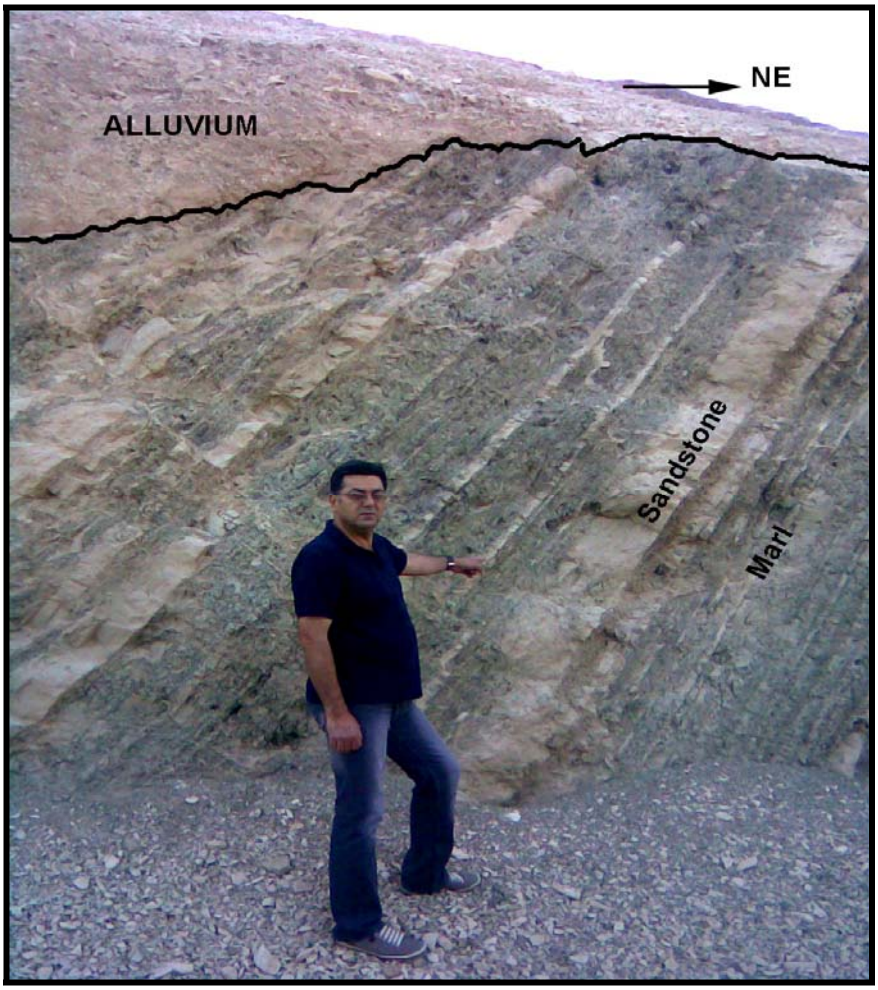


Plate (2.13) lithology and dipping angles of the Lower part of Tanjaro Formation inside the dumping area along the road cut.

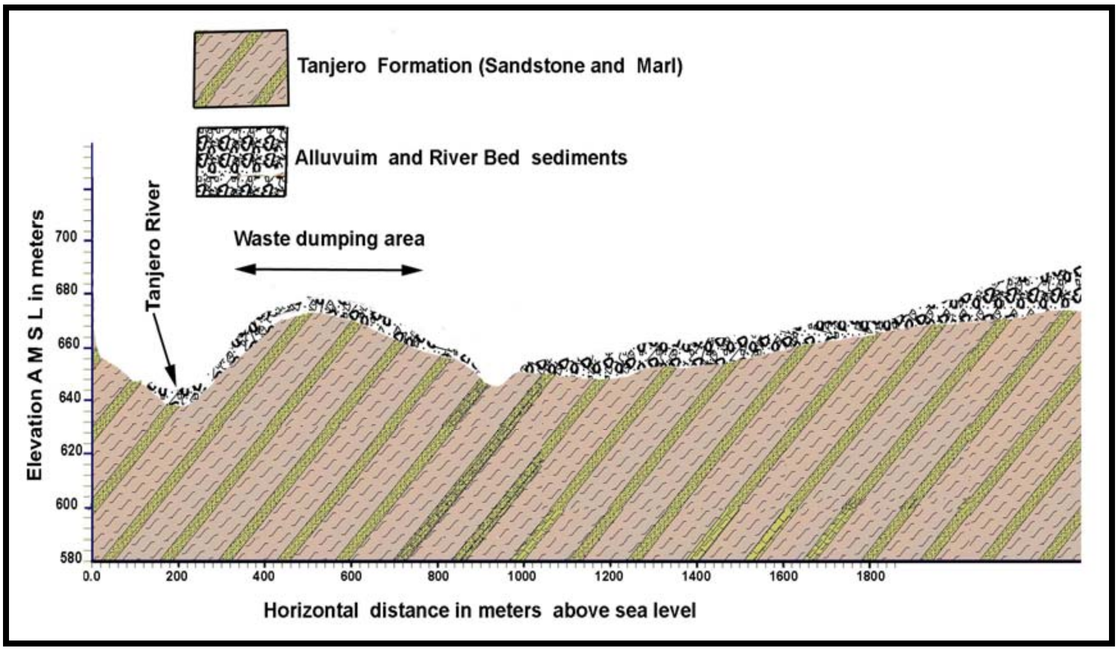


Fig (2.12) Geologic cross section of the dumping area showing Alluvium and Tanjaro formation.

2.7: Tanjaro River:

Tanjaro River includes Sewage water from Sulaimani center, Industrial area, drainage water (includes agricultural drainage water), over flow from different farms, sewage from villages along side the Tanjaro River and leachate from Tanjaro landfill site. There is a possibility of ground water, contamination due to percolation of some of applied chemicals especially where irrigation takes place because the farmer usually using fertilizers, pesticides and insecticides.

2.7.1: Tanjaro River location:

Tanjaro River starts in sulaimani governorate between the Azmar and Baranan mountains. Tanjaro River runs along the southern prophecy of Sulaimani city, in east – southeast direction finishes in the Darbandikhan lakes Habib (2003), while Mustafa (2006) estimated that Tanjaro River extending from Northwest to southeast of Sulaimani city between (35^0 35◌́ 01◌̋) and (35^0 28◌́ 44◌̋) North, (45^0 21◌́ 39◌̋) and (45^0 26◌́ 17◌̋) East. It is elevated between (656-787 m) above sea level.

Darbandikhan dam (49) year old in 2010,has a basin of 120 km^2, a storage capacity of 3 BCM (Billions Cubic Meter) and can produce 37000 Kw/h hydroelectricity, It is built on the Sirwan and Tanjaro rivers and is situated 75 km south of sulaimani . Its length is of 535 m and its height is of 128 m. The dam is constructed with rock fill and concrete. Darbandikhan dam main purposes are to produce hydroelectricity and irrigation.

KRG (2009) reported that the Ministry of Water Department of Statistics shows that 64 MW (Million Watt) was produced in 2008 where the maximum production could be 324 MW (Million Watt).

2.7.2: Main sources of water to the Tanjaro River:

Both Qiliasan and Kani pan streams, and other tributaries, springs, sewage effluents all together form Tanjaro River. Qiliasan stream is found from both Sarchinar springs and Chaq- Chaq stream near Qiliasan village. Kani pan is representing one of the two main tributaries of Tanjaro River located south of Bakrajo village.

2.7.3: Role of Tanjaro River

Tanjaro River is used as a source for irrigation purposes; it is used by factories located along Tanjaro River (factories for building construction materials and segregation of sand and gravel), Plate (2.1). It is one of the sources of water for Darbendikhan reservoir.

2.7.4: water supply sources to Sulaimani city:

According to the latest information from Directorate of Water and Sewage Sulaimani (Dec.2009), the city of Sulaimani is supplied daily with 265000 m^3 water:

- Dokan one project provides 56000 m^3/day.
- Dokan two project provides 160000 m^3/day.
- Sarchnar spring provides 048000 m^3/day.
- Local wells in sulaimani provide 001000 m^3/day (appendix 2 and 3)

According to the same reference the domestic water consumption per capita per day including water losses is 420 Litters per day. This is converted nearly into sewage. This means that a city (sulaimani) with nearly 700000 inhabitants is faced with the disposal of 315000 m^3 of domestic sewage daily and finally discharged through sewer pipelines and they combine with rain water to dispose away to Tanjaro River.

2.7.5 Sources of Tanjaro River Pollution:

According to Nature Iraq (2008) report, Tanjaro River could be polluted from the following sources:

- Sewage from Sulaimani center, this includes:
  -Raw influent (sewage) which comes from household waste liquid, from toilets, baths, showers, kitchens, sinks, and so forth that is disposed of via sewers.
  -Municipal wastewater includes residential, commercial and industrial liquid waste and includes storm water runoff.
- Sewage from Qalawa
- Sewage from Qiliasan.
- Sewage from Industrial region in Sulaimani
- Sewage from Wluba.
- Sewage from Bakrajo.
- Sewage from Kani Goma
- Sewage from Shekh Abbas

- Sewage from Tanjaro village
- Sewage from illegal and legal factories which are located on Tanjaro River.
- Runoff from excess irrigation processes is rich in pesticides and fertilizers.
- Leachate from Tanjaro Landfill.

They are all together discharged through sewer pipelines and they combine with rain water to dispose away to Tanjaro River. Sewage systems for Sulaimani city are not capable of handling storm water. Heavy storms contribute more flows causing over flows, finally forming of seasonal pollution.

Sulaimani disposes its municipal waste water through six main sewage effluent boxes around the city to the environment, which at the end disposes away to Tanjaro River and its tributaries. Kamees (1979) recorded that the flow of one of these sewage effluents at Wluba area equal to 2773 m^3/day in summer and 51917 m^3/day at the end of spring. The population of Sulaimani city was 640553 during 2006 Appendix (1) which means that every effluent channel discharges twice in 1979. During 2008 the population of Sulaimani center was 679563 Appendix (1) which means, every effluent channel discharge nearly 4 times in 1979. Untreated sewage waste water of Sulaimani city is classified under point source of potential pollution according to FAO (1978).

2.8: Sulaimani Sewages outfalls:

According to Nature Iraq (2008) report Sulaimani sewage outfalls are:

- Sewage 1 (Sarchinar) : (GPS: N 35^0 33◌́ 0.99◌̋ E 45^0 22◌́ 9.29◌̋)
- Sewage 2 (Industrial Area): (GPS: N 35^0 33◌́ 22.6◌̋ E 45^0 22◌̋ 59. 0◌̋)

These are the sewage boxes outlet, located in the industrial area, which is located on the southwest side of Sulaimani city. Waste is discharged by the Sulaimani oil Refining Station and many other factories and houses near the sugar factory quarter to the Qiliasan stream.

- Sewage 3 (Albisaka): (GPS: N $35^0$33◌́ 16.4◌̋ E 45^0 24◌́ 19.2◌̋).

  It is on a sewage outflow box. Sewage comes from the houses in the southwest of Sulaimani city.

- Sewage 4 (Qalawa) (GPS: N 35^0 32◌́ 27.8◌̋ E45^0 25◌́ 32.6◌̋) elevation= 772 m
- Sewage 5 (Wluba) (GPS: N 35^0 32◌́ 38.1◌̋. E 45^0 24◌́ 20.2◌̋) elevation = 769 m

  The discharge comes from house of Wluba.

- <u>Sewage 6 (shekh Abbas)</u> (GPS: N 35^0 31′ 44″ E 45^0 25′ 14.1″) elevation= 755m.

Tanjaro River is passing through Tanjaro valley which passes through many agricultural areas, in which farmer families depend mainly on untreated urban wastewater in Tanjaro River for their vegetables′ field irrigation. Surface irrigation methods are always applied by farmers. Vegetables generally receive waste water irrigation at least three (3) times per week. Tanjaro River crossing many urban agricultural lands with 1167.3 km^2 catchments area, 66.7 km length, 11% average slope of its valley according to Foodservice (1980). Finally Tanjaro River destination will be Darbendikhan reservoir, water from this reservoir discharges to Diyla, which represents a great tributary for Tigris River.

2.9: Location for ambient air quality assessment:

Table (2.3): Location descriptions for ambient air quality assessment.

S.N.	Location	Code	Coordinates	
			X	Y
1	North of Tanjaro Landfill	NTL_1	N 35^0 29′ 03	E 045^0 25′ 87
2	East of Tanjaro Landfill	ETL_2	N 35^0 28′ 87	E 045^0 26′ 50
3	Center of Tanjaro Landfill	CTL_3	N 35^0 29′ 00	E 045 26′ 11
4	West of Tanjaro Landfill	WTL_4	N 35^0 28′ 97	E 045 25′ 65
5	South of Tanjaro Landfill	STL_5	N 35^0 28′ 71	E 045 25′ 59

2.10: Location description for soil sampling:

Most of the area close to landfill site is under dry farming, wheat being the main crop. There are also scattered spots of irrigated lands close to Tanjaro River cropped with vegetables. The majority of the land close to landfill site can be put under good class for dry farming. The existing soils close to and around landfill site have surface brown to dark brown layers, lime accumulation appears in sub- surface layers due to leaching of lime from the surface layers, they are also regarded as calcareous. Soil samples from landfill site were very hard, dark in color with odour and classified as fine texture soil.

CHAPTER THREE: Materials and Methods

3.1 Introduction:

The assessment of the Tanjaro landfill site and Tanjaro River included a comprehensive investigation of the meteorological data (collected from metrological station in Sulaimani), Geological, Groundwater, Landfill leachate, landfill gas, landfill soil, Tanjaro River both standing and running conditions and measurement of water quality at 3 different well locations close to landfill site. Based on this assessment, implication of the landfill can be determined and recommendations can be made to control the negative effects of Tanjaro landfill on the environment.

The sampling sites were selected from the following locations:

3.1.1 Wells for drinking water:

Different wells (for drinking water) were selected. The well sites were selected near to the landfill site various locations based on the distance from the landfill site.

<u>Location number one</u>: (well number one): GPS: N 35^0 29´ 027 E 045^0 25´ 818
Elevation 675.91 M

Single house (belong to a family from southern Iraq) located adjacent to the landfill area site to the west direction of landfill site.

<u>Location number two</u>: (well number two): GPS: N 35^0 28 ´ 959 E 045^0 27´ 71
Elevation 665.55M

It’s a well (in cement block factory) located to the south of well number one and (180-200m) away to the southwest of landfill site area and its located at lower point of the hill which the landfill site is located.

<u>Location number three</u>: (well number three): GPS: N 35^0 28´ 978 E 045^0 25´ 659
Elevation 675.91 m

This well is located in House number 14 in Tanjaro village it is a private house nearly in the middle of the village. Its (350-400 m) away from the south west of the landfill site area and it is located in an area close to the main road between Sulaimani city and Qaradagh.

3.1.2 Tanjaro River:

Five different locations from Tanjaro River were identified to collect samples during different periods of time from (27 October 2007) through (7 April 2009)

Location number one: (station No.6): GPS: N 35^0 28´ 717 E 045^0 25´ 597
Elevation 655.49 M

Close to Qaradagh Bridge, Plate (3.1)

Location number two: (station No.5): GPS: N 35^0 28´ 695 E 045^0 26´ 639
Elevation 657.62 M

Nearly 500m from Qaradagh Bridge exactly opposite to Tanjaro landfill site,Plate (3.2)

Location number three: (station No.2): GPS: N35^0 28´ 934 E 045^0 25´ 967
Elevation 657.32M

Nearly 500m from the second location to the east direction of Darbandekhan reservoirs, Plate (3.3)

Locations number four: (station No.3): GPS: N 35^0 28´ 852 E 045^0 26´ 479
Elevation 658.54 M

Nearly 500m from the third location also to the east direction of Darbandekhan reservoirs plate (3.4).

Locations number five: (station No.4) GPS: N 35^0 28´ 886 E 045^0 26´ 869
Elevation 659.24 M

Nearly 500m from the forth location also to the east direction of Darbandekhan reservoirs plate (3.5).

3.1.3 Tanjaro landfill leachate:

GPS: N 35^0 29´ 000 E 045^0 26´ 112
Elevation 657.93 M

Leachate samples were collected within Tanjaro Landfill site area and down hill, the hill where the landfill site is located. Leachates were collected from (B) station, plate (3.7) located at landfill site Fig (2.2), where as both (C, D) stations plates (3.8) and (3.9) respectively were located down hill, the same hill were landfill site is located Fig (2.2).

Plate(3.1) Site of station No.6

Plate(3.2) Site of station No.5

Plate(3.3) Site of station No.2

Plate(3.4) Site of station No.3

Plate(3.5) Site of station No.4.

Plate (3.6) View of using instruments in study area for direct measurements.

3.1.4 Soil Samples:

Soil samples were collected from (0 to 30) cm depth from surface and beneath 30 cm from sub-surface. Surface and sub-surface soil samples were taken from selected stations at Tanjaro landfill site and from 500-600 m from landfill site, in order to determine the levels and the effect of leachate contamination especially trace elements during seasonal pollution. This directly and indirectly affects the surrounding area close to Tanjaro landfill site. The collected samples from different stations were mixed together for each site alone and then a composite sample was taken for analysis. The samples were dried and stored in polythene bags prior to analysis.

3.2 Scheme of Samples collection:

3.2.1 Tanjaro River samples:

Samples from Tanjaro River (both standing and running condition) were collected from the selected sites. Samples were taken in three bottles Shelton (1994), for physical, chemical and biological analysis. Wastewater samples from Tanjaro River were collected in sterilized plastic bottles and in special sterilize glass bottles with stopper for bacteriological analysis as described by Ghannoum et al., (1981) which provided by microbiology Laboratory Department of Biology, College of Science University of Sulaimani. Samples were kept airtight to avoid any contamination and immediately transferred to Laboratory for analysis. Amber bottles (dark glass) capacities of (250 ml) were used to collect samples for determination of biochemical oxygen demand (BOD_5).

However at each sampling site (Tanjaro River, leachate from Tanjaro Landfill site and drinking water from wells), samples were taken then acidified by adding (5 ml) of concentrated (HNO_3) to conserve the trace elements in the solution then stored at($-20C^0$) for trace heavy metal determination.

3.2.2 Well water samples:

The wells selected for ground water sampling were located close and adjacent to the landfill site and close to landfill area. Water from these wells is used for drinking and other life activities. Water samples were collected for physical, chemical and biological analysis as previously mentioned to determine the levels of contamination (if existed) from deep percolation of leachate from Tanjaro landfill area. The location of wells selected for water sampling is shown in Fig (2.2).

3.2.3 Leachate samples from Tanjaro landfill site:

Leachate samples were collected during different periods of time and seasons depending on the amount of rainfall, leachate samples were collected 24 hours after rain.
Leachate samples were collected from B, C, and D stations as previously mentioned; these stations were located close to each other.

B- Station:

Is located nearly in the middle of landfill site (it was in running condition), Plate (3.7)

C- Station:

Is located down hill where landfill site is located (it was in standing condition) Plate (3.8)

D-station:

Is located down hill (it was making a pond close to the local road in the area near landfill site, Plate (3.9)

The same procedures were used as previously mentioned for collecting and analysis of samples, (see section 3.2.1)

3.3 Analytic methods:

3.3.1 Field measurements:

The following parameters were measured immediately in the field and also in the Lab. of Soil and Water Sciences Dept. College of Agriculture, the mean values were calculated. Potential of Hydrogen ion (pH), electrical conductivity (EC), Temperature C^0, dissolved oxygen (DO), and turbidity of Tanjaro River, leachate from Tanjaro landfill and wells water, were measured as described by APHA (1998).

Plate(3.7)Site of station B in the middle of Tanjaro landfill site.

Plate(3.8) Site of station C down hill where landfill site is located

Plate (3.9) Site of station D Close to the local road.

3.3.1.1 Temperature:

A clean digital electronic thermometer ranged between (0-50 C^o) was used to measure the temperature and expressed in degree centigrade according to APHA (1998), the thermometer was left in collected samples for a few minutes to obtain a constant condition for reading.

3.3.1.2 Potential of Hydrogen ion (pH):

Using a portable pH meter (pH 330i/SET-(2004).WTW, Germany company) as described by APHA (1998), specific standard buffer solutions 4, 7 and 9 were used for calibration of the pH meter before taking readings for all collected samples.

3.3.1.3 Electrical conductivity (EC):

Portable EC meter (model LF 318/SET- WTW company- Germany) as described by APHA (1998), was used for Electrical conductivity measurements, the results were corrected to (25 C^0) and the reading were expressed in $\mu S.cm^{-1}$. The calibration of instrument was done using standard solutions (*0.1N KCl*) given by Manufacture Company.

3.3.1.4 Dissolved oxygen (DO):

Samples were measured at the site using a special oxygen- sensitive membrane electrode (Inolab.Oxi 730 WTWcompany Germany) results were expressed in ($mgO_2\ L^{-1}$), as described by APHA, (1998)

3.3.1.5 Turbidity:

Turbidity meter model (pHoto Flex/ photo Flex Turb. WTW company Germany), was used to measure Turbidity according to AWWA (1998), after calibration with turbidity standards, the results were expressed in terms of nephelometric turbidity unit ((NTU).

3.3.1.6 Colour:

The colour of each collected sample was measured in the laboratory by using (Photospektral WTW lab company Germany) according to Sincero (2003).

3.3.2 Laboratory measurements:

The samples were analysed in the laboratory at Sulaimani University, College of Agriculture, Department of Soil and Water Sciences; College of Science, Department of chemistry, Department of Biology, Department of Geology and at the Kurdistan Institution for Strategic Studies and Scientific Research.

3.3.2.1 Total Dissolved Solids (TDS):

Total Dissolved Solids had been calculated according to formula giving by Welch (1952) as follows:

T.D.S= EC×F……………………………………………… (2)

EC = Electrical conductivity in $\mu S.\ cm^{-1}$

F = Constant factor 0.64.

3.3.2.2 Total Hardness, Calcium Hardness and Magnesium Hardness:

Total Hardness, Calcium Hardness and Magnesium Hardness, for all collected samples had been calculated depending upon procedure giving by Theroux et al., (2001). Using the following formula given bellow:

- Total Hardness as $CaCO_3$ (ppm) = (ppm Ca^{2+} × 2.496) + (ppm Mg^{2+} × 4.115)…(3)
- Calcium Hardness as $CaCO_3$(ppm) = (ppm Ca × 2.496)……………………………(4)
- Magnesium Hardness as $MgCO_3$(ppm)= (ppm Mg × 4.112)………………………..(5)

3.3.2.3 Biochemical Oxygen Demand (BOD_5):

Amber bottles (dark glass) capacity of 250 ml used for measurement of oxygen content before and after incubation for five days(20 C^0) by a special oxygen –sensitive membrane electrode (InoLab.OX;730,WTW company –Germany), as described by APHA,(1998). Biological Oxygen Demand (BOD_5), for all collected samples had been calculated according to the following equation:

$BOD_5 = DO – DO_5$ (mgO_2L^{-1})………………………………………………. …. (6)

DO = Dissolved Oxygen at the time of sampling.

DO_5 = Dissolved Oxygen after five days incubation of samples at 20 C^0 according to the procedure described by APHA (1998)

3.3.2.4 Nitrate Nitrogen(NO_3) and Nitrite Nitrogen (NO_2):

Both Nitrate Nitrogen (NO_3) and Nitrite nitrogen (NO_2) were determined in the same Lab. by using a digital Nitrate-Sensitive membrane electrode (nitrite sensitive membrane electrode) (Ino lab.pH/ Ion/cond. 750 multiparameter, Laboratory-2005, WTW company- Germany) according to the instructions edited by the instrument user manual. The results were expressed in (mg L^{-1}).

3.3.2.5 Cations:

Sodium (Na^+), Potassium (K^+) were measured using Flame Photometry at Kurdistan Institution for Strategic Studies and Scientific Research according to Gary et al,.(1986) and Beaty (1988) , while both Calcium (Ca^{+2}) and Magnesium (Mg^{+2}) were measured by titration method using EDTA (*0.01 N*) as described by Jackson (1958).

3.3.2.6 Anions:

Reactive phosphorus of each collected sample was determined at the Kurdistan Institution for strategic studies and scientific research using a spectrophotometer (UV-VIS Spectrophotometer meter /TU.1800.U.K) as recommended by APHA,(1998).Results were expressed in (mg L^{-1}). While chloride (Cl^-) and (SO_4^{2-}) were measured using Dionex Ion chromatography according to Gary et al,. (1986) and Beaty (1988)

3.3.2.7 Carbonate (CO_3^{-2})and bicarbonate (HCO^-_3):

Carbonate CO_3^{-2} analysed using (*0.1M*) NaOH, when pH reaches 8.3 the amount of (CO_3^{-2}) in solution can be calculated according to the following equation:
1ml (0.1M NaOH) = 30.01 mg L^{-1} CO_3^{-2} while HCO_3^- measured using (*0.1M*) HCL till the pH of solution reaches 4.3 according to the following equation (mg/L of HCO_3^-)can be calculated: 1 ml (*0.1M*) HCL=61.02 mg L^{-1} HCO_3^- according to Wilhelm et al.,(1988).

3.3.2.8 Trace Elements:

Using Wattman filter paper for filtering all collected samples prior to determination. Samples were transferred to (50ml) polyethylene bottle with a cap. This was acidified by (3-5) ml Nitric Acid (HNO_3) to conserve the elements in the solution. The concentration of the trace metals (Hg, Pb, Cu, Zn, Cd, Cr, Al, Fe, Mn and Zn) were analysed using Perkin- Elmer/Optical Emission Spectrometer Optima 2100 DV, (Inductively Coupled Plasma mass spectrometer ICP) as recommended by Gary et al,. (1986) and Beaty (1988), results were expressed by mgL^{-1}, while the same samples were analysed at the Kurdistan Institution for Strategic Studies and Scientific Research using an Atomic Absorption Spectrophotometer, "Perkin-Elmer".

3.3.2.9 Bacteriological analysis:

Tanjaro River water, well water and leachate from Tanjaro Landfill site samples were collected in sterilized Pyrex glass bottles with stopper. Samples were kept air tight to avoid any contamination and samples were then immediately taken to the microbiology laboratory for microbiological testing.

The methods used in this study are explained below:

- Total bacterial count:

Pour plate method used as described by APHA (1998), using nutrient agar as cultivated medium. Plates were incubated at 37 C^0 for 24 hrs. Results expressed as
CFU. ml^{-1} (Colony Forming Units) / 100 ml of sample (volume of sample used).

- Total coliform count:

Most probable Number (MPN) procedure used as described by APHA (1998), using a series of three set of tubes of Lactose Broth, each set consists of five tubes, each tube contains double strength of lactose broth, the other 2 sets contain single strength of lactose Broth . Tubes were inoculated with measured amounts of waste water, if after incubation at 37 C^0 gas is seen in any of the Lactose broth; it is presumed that coliforms are present in waste water sample. The results were reported as Colony Forming Units {CFU) per volume of sample used.

- Thermotolerant (fecal) coliform bacteria:

Most Probable Number (MPN) procedure was used as described by APHA (1998), using Mac-Conkey broth as cultivated medium. Durham tubes with samples inside incubated at 44 C^0 for 24 hrs in water bath. According to Baruah and Barthakur (1999) buffered peptone water was prepared to give appropriate dilution of microbial counts.

3.4 Ambient Air Quality:

Five locations were selected as shown in Fig (2.2) within study area site for ambient air quality measurements. Close to Tanjaro landfill site area, there are major industrial/ mining activities and oil refining factories. Analysis of ambient air quality standards (SO_2, NO_x, CO and HC) and (SPM and RPM_{10}) measurements had been performed.

3.4.1 Particulate Matter (PM):

Ambient particulate matter was analysed to calculate both:
Suspended particulate matter (SPM) and Respirable particulate matter of 10 micrometer in diameter (RPM_{10}), using vacuum pump, Buchner funnel, conical flask and Glass Fiber Circle (GFC) as shown in plate (3.10).

3.4.2 Suspended Particle Matter (SPM):

Suspended Particle matter (SPM) calculated in µg/ m^3 which was obtained from the mass difference between glass fiber circle mass before and after putting on the Buchner funnel and starting vacuuming.

3.4.3 Respiratory Particulate Matter (RPM_{10}):

While (RPM_{10}) measured by using calibrated polarizing Microscope (Leitz SM-LUX-POL) provided by Geology Department/ College of Science/ University of Sulaimani and expressed as number of respiratory particulate matter of 10 micro diameter per one cubic meter. The counting of (RPM_{10}) was carried out at 30 random microscopic fields.

3.4.4 Gaseous Pollutants:

Gaseous Pollutants including (SO_2), NO_x, CO) and Hydrocarbon HC were analysed directly in the field using a portable gas analyzer (Drager- Multiwarn/ Germany), Plate (3.22). The instrument was calibrated against high purity standard gases, following the instrument instruction manual given by Drager laboratories. The 24 hour average concentrations of gaseous pollutants were estimated from measurements conducted for about 15 minutes at each location. Weather conditions were normal and there was no excess wind during the measurements. The measured values were logged into the instrument memory, and subsequently downloaded.

Plate (3-11), View of Gas analyser
Drager- Multiwarn/ Germany

Plate (3-10), View of instruments
for particulate matter

3.5 Methods of soil analysis:

Undisturbed and disturbed soil sample had been collected from both landfill site and site close and around to landfill during a dry, hot season in 27-10-2007, for undisturbed samples a rigid steel cylinder with an outside diameter of 5.7cm, and 4cm high was forced into the leveled surface of the soil until the upper edge of the cylinder was leveled with the surrounding soil surface. The cylinder and contents was then dug out of the soil, the two faces of the soil cores were leveled and smoothed, the undisturbed samples along with disturbed samples from each site were brought to the laboratory for assessing soil moisture content, bulk density, particle density, Particle size distribution and some other selected physical and chemical properties. All the physical and chemical analysis was carried out on soil materials passing through (2mm) sieve. Soil moisture content was determined by gravimetric methods as described by Richards (1965).

Particle size distribution was performed by BS. 1377 (1975), Avery and Bascomb (1982). Dry bulk density for undisturbed soil cores according to the procedure given by Blake (1965), and O'Connell (1975). While the particle density of soils refers to the density of the solid particles estimated using the pycnometric method according to Blake (1965), Vickers (1983) and smith (1982).

3.6 Statistical Analysis

Statistical analysis was conducted for the data obtained during the studied period, using software program Excel, all data were expressed as mean, ±S.D and correlation between different physico chemical parameters had been calculated with the help of computer.

CHAPTER FOUR Results and Discussion

4.1: Physiochemical Analysis:

4.1.1 Temperature:

The water temperature ranged between 10 - 22 C^0, 10-20.6 C^0, 9.8- 22.8 C^0 and 12.6-21.4 C^0 for Tanjaro River standing and running condition, Tanjaro landfill leachate and well water respectively, Table (4.1).

The minimum temperature was recorded 10 C^0 for 6R location for Tanjaro River running during Nov. 2007 while the maximum temperature 22 C^0 was recorded for 5p and 6p Tanjaro River (standing) during Oct.2007 .The minimum temperature 9.8 C^0 was recorded for (C) Tanjaro landfill leachate location during Feb.2009.

While the maximum temperature 22.8 C^0 was recorded for (D) Tanjaro landfill leachate location during March 2008 .The minimum temperature 12.6 C^0 was recorded for well water number one during Feb. 2009 while the maximum temperature 21.4 C^0 was recorded for well water number one during May. 2008, while the average mean temperature C^0 values for studied samples were demonstrated in Figure (4.1).

Significant variation of temperature among different months in studied area was observed. Temperature values showed marked variation in Tanjaro river standing and running condition. Statistical analysis indicated that, correlation is positively highly significant ($p<0.99$) between Temperature and BOD_5, While significant ($p<0.005$) and positive correlation between Temperature and pH, TDS and Total hardness were recorded in case of studied samples.

Table (4.1) shows variation in Tanjaro River, Tanjaro landfill leachate and well water temperatures maybe due to:

- Air temperature, this was obvious throughout the present study, such phenomenon was observed by other researchers as Guest (1966) and Odum (1971).
- Due to the introduction of sewage in Tanjaro River.
- Probably due to many environmental factors among them solar radiation and Gale wind. (Sulaimani city is famous with gale wind) Ganjo et al., (2006).
- Entering a wide range of municipality pollutants. The effect of the composite composition of sewage effluent.

Table (4.1): Temperature Values (C^0) represented as (mean, ± S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	20.4	17.5	18.5	17.2	10.5	10.0	10.0	14.9	4.52	
3P	20.5	18.8	U	17.1	16.5	14.2	14.4	16.9	6.78	
4P	21.0	17.6	U	17.0	15.6	12.8	13.1	16.2	6.73	
5P	22.0	17.6	U	18.0	17.0	15.7	15.9	17.7	7.01	
6P	22.0	21.8	U	19.1	17.0	15.7	15.9	18.6	7.49	
Mean	21.2	18.6	18.5	17.7	15.3	13.7	13.9	17.0	2.79	
± S.D	0.78	1.84		0.89	2.75	2.38	2.45	1.85	0.84	
2R	U	17.7	16.9	17.3	10.9	10.0	10.1	13.8	6.29	
3R	U	16.2	17.5	17.4	12.2	11.3	11.7	14.4	6.07	
5R	U	18.0	17.3	15.2	13.5	12.2	12.9	14.9	6.02	
6R	U	10.0	19.1	20.6	17.0	15.3	15.8	16.3	7.02	
Mean		15.5	17.7	17.6	13.4	12.2	12.6	14.8	2.46	
± S.D		3.73	0.97	2.23	2.62	2.26	2.41	2.37	0.89	
Tanjaro landfill leachate										
B	U	U	18.7	19.2		10.1	11.2	14.8	8.50	
C	U	U	22.8	18.0		9.8	10.3	15.2	9.25	
D	U	U	20.7	19.1		10.0	10.5	15.1	8.92	
Mean			20.7	18.8		10.0	10.7	15.0	5.51	
± S. D			2.05	0.67		0.15	0.47	0.84	0.84	
Well Waters										
Number One	17.5	17.7	18.1	20.8	16.1	12.6	13.2	16.6	2.88	
Number Two	19.0	18.9	17.5	21.4	18.0	13.0	13.5	17.3	3.05	
Number Three	16.7	16.1	18.0	17.8	15.0	17.0	17.1	16.8	1.03	
Mean	17.7	17.6	17.9	20.0	16.4	14.2	14.6	16.9	2.02	
± S. D	1.17	1.40	0.32	1.93	1.52	2.43	2.17	1.56	0.71	

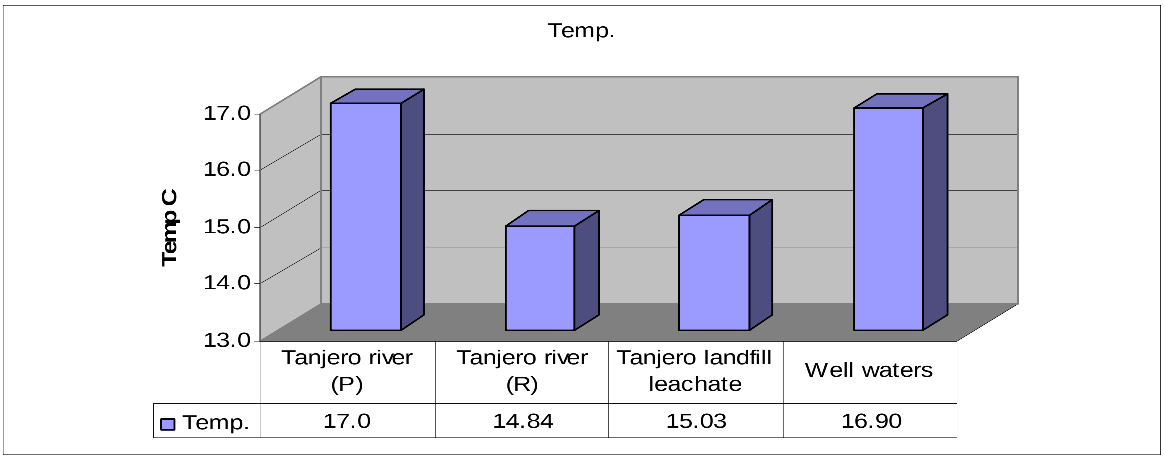


Figure (4.1): Demonstrates the average mean temperature (C^0) values in Tanjaro River, Tanjaro landfill leachate and well water

4.1.2: Hydrogen Ion Concentration (pH):

Table (4.2) and Fig (4.2) shows the pH value of leachate sample collected from Tanjaro landfill site during different period of times were analysed and was found to be moderately alkaline to strongly alkaline. The pH value ranges from (7.8 to 8.8) with the average mean value of (8.11). Maximum pH value was observed in April as 8.8 and 7.8 as minimum value in March and May in Tanjaro Landfill leachate. The pH value shows marked variation in different months due to the effect of rainfall during wet season causing washing down of landfill site components, as closing wet season Feb.2009 to April. 2009 Table (4.2) causing an increase in pH values. According to Eckert (1988) one of the causes of alkalinity is due to the presence of high calcium carbonate Table (4.9). A significant and positive correlation ($P< 0.05$) between pH and temperature was recorded in case of Tanjaro River, leachate and well water. Significant and positive correlation ($P< 0.005$) between pH of collected samples and BOD_5 was observed. There was no significant correlation observed in the changes of heavy metal concentrations with the pH of Tanjaro River, leachate and well water.

The concentration of $CaCO_3$ of Tanjaro landfill leachate was within the range 180-1170 mgL^{-1} with the average mean value of 281.2 mgL^{-1} therefore Tanjaro landfill leachate sample was classified as very hard according to Heath (1982) and Soundara Panian et al., (1985). While, the $CaCO_3$ content for Tanjaro landfill soil ranged from 33% to 51% for surface and sub- surface soil respectively, Table (4.38).

Hydrogen ion concentration (pH) values of landfill leachate of this study exceed the recommended standard values according to Lee and Jones (1991 b), the typical concentration values of (pH) ranged (5- 7.5) for municipal landfill leachate.

Hydrogen ion concentration of the Tanjaro River samples Table (4.2) Fig (4.2) ranged between 7.6 - 9.35 with the mean value of 7.8 for standing and for running condition ranged between 7.1 and 9.3 with the mean value of 7.96. The pH show marked variation for Tanjaro River running and standing condition, this is due to introduction of domestic sewage in Tanjaro River and geological formations. These values are within the guideline range given by EU (2004) and Canada (2005) for suitability of Tanjaro River to aquatic life Chapman (1996). The results from this study were higher than those obtained by Khwakaram (2009) on untreated wastewater of Kostae cham, Sulaimani, and results of Shekha (1994) and Ali (2003) on Arbil city sewage, Upadhyay (2004) wastewater treatment in Delhi, and results of Sayo (2005) on Alaro River receiving industrials effluent as a point source.

The pH value for all well water samples was in the range of 7.2 to 9.7 with the mean value of 8.2 according to APHA (1998) were described as moderately to strongly alkaline. The pH value for well water number 1 and 2 which are close to landfill site range from 8 to 9.7 Table (4.2), pH value for well's water showed variation in different locations, however increase in pH value was observed in wet season. Alkalinity of well water is due to Infiltration of leachate from landfill site towards ground water especially during wet season and may be due to the Geological formations of the studied area. The pH values of wells water close to landfill area is moving in the direction of moderately to strongly alkaline comparing the recorded (pH) values to the guideline values recommended by WHO (2006), EU (2006) and Canada, (2006) for drinking water quality standards, the (pH) values of all investigated well water during the studied period were on the safe side except well number one and two during Feb. 2009, (Appendix11).

4.1.3: Electrical Conductivity (EC):

The Water used for irrigation whether taken from a river or from wells, is never pure water but always contains dissolved salts. Much of the water applied to the land will be taken up by the crop and transpired if the water contains much dissolved salts; a proportion of the salts will be left behind in the soil. Continuous irrigation will lead to a build-up of salts in the root zone of the crop, unless precautions are taken to leach from them out of the profile at regular intervals. According to the U.S. Dept. Agri (1954), the salt content of irrigation water is commonly specified in practice by its electrical conductivity. The United States salinity, laboratory (1954) and Allison (1964) grades the quality of irrigation water, based on its soluble salt content into four grades:

EC less than 0.25 mmhos/cm
EC between 0.25 – 0.75 mmhos/cm
EC between 0.75 – 2.25 mmhos/cm
EC > 2.25 mmhos/cm

Electrical conductivity (EC) less than 0.25 mmhos/cm which do not contain enough soluble salts to cause any trouble, those with EC above 2.25 mmhos/ cm which are so saline that they can only be used under very limited conditions.

Table (4.2): Hydrogen Ion Concentration (pH) Values represented as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	7.8	7.7	7.6	8.4	9.4	7.9	7.9	8.1	0.61
3P	7.7	7.9	U	7.9	7.8	7.9	7.8	7.8	2.96
4P	7.8	7.9	U	7.8	7.8	7.8	7.9	7.8	2.96
5P	7.8	7.9	U	7.7	7.7	7.9	7.7	7.8	2.94
6P	7.7	U	U	7.8	7.8	7.7	7.6	7.7	3.76
Mean	7.7	7.8	7.6	7.9	8.1	7.8	7.8	7.8	0.15
± S.D	0.06	0.09		0.28	0.71	0.09	0.13	0.23	0.25
2R	U	7.8	8.1	7.7	8.4	8.0	8.0	8.0	3.03
3R	U	7.4	7.1	7.7	8.4	7.5	7.7	7.6	2.91
5R	U	8.1	8.0	8.0	8.74	8.0	8.1	8.2	3.09
6R	U	7.8	7.1	9.3	8.9	7.5	7.6	8.0	3.14
Mean		7.8	7.6	8.2	8.6	7.8	7.9	7.9	0.38
± S.D		0.29	0.55	0.76	0.24	0.29	0.24	0.39	0.22
Tanjaro landfill leachate									
B	U	U	7.8	7.8	U	8.4	8.0	8.0	4.28
C	U	U	7.8	7.8	U	8.5	8.2	8.1	4.32
D	U	U	7.8	7.8	U	8.6	8.8	8.3	4.43
Mean			7.8	7.8		8.5	8.3	8.1	0.36
± S. D			0.00	0.00		0.10	0.42	0.13	0.20
Well Waters									
Number One	8.0	8.1	8.0	8.1	7.9	9.6	9.3	8.4	0.71
Number Two	8.1	8.0	8.0	8.1	8.8	9.7	9.4	8.6	0.72
Number Three	7.7	7.6	7.5	7.4	7.2	8.2	8.1	7.7	0.36
Mean	7.9	7.9	7.8	7.9	8.0	9.2	8.9	8.2	0.57
± S. D	0.21	0.26	0.29	0.40	0.79	0.84	0.72	0.50	0.27

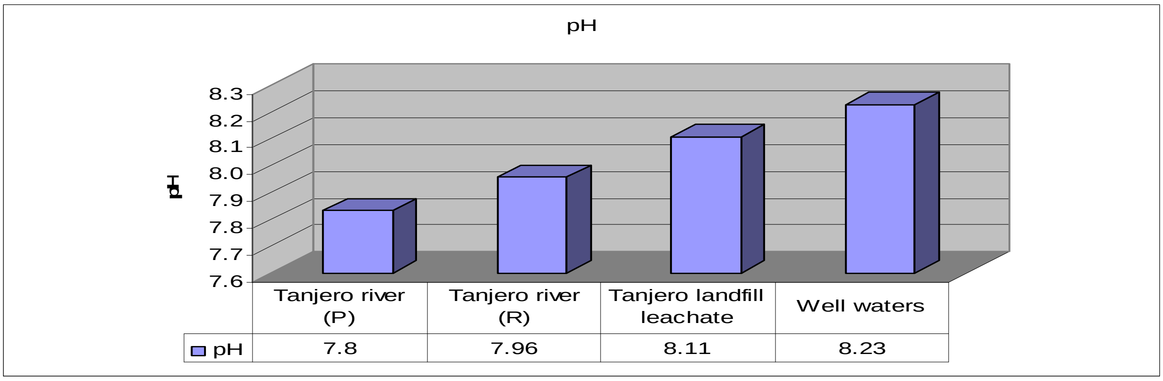


Figure (4.2): Demonstrates the mean values of pH in Tanjaro River, Tanjaro landfill leachate and well water

From Table (4.3), it seemed that values of electrical conductivity in the Tanjaro River standing condition ranging from 440 µs/cm to 1007 µs/cm with the mean value of 876.4 µs/cm while for running condition the value ranged from 455 µs/cm as minimum, 1019 µs/cm as maximum and 781.94 µs/cm as mean value. EC values were high in the majority of Tanjaro River samples which is reflecting the effect of effluent sources from residential and agriculture area where large amount of drainage water and sewage from different sources enter into the main stream (Tanjaro River). High temperature during dry season also lead to higher evaporation rates, hence increasing the concentrations of salts and solids in Tanjaro River, Wetzel (1975) and Goldman (1987) reported that the value of electrical conductivity is related to climate, soil and geological origin of area, the effect of input and output as well as evaporation. However it appears from Table (4.3) the EC values for Tanjaro River are higher than that of Arbil city sewage which studied by Shekha (1994) and ranged between 430-946 **µs/**cm.

The average mean values obtained from this study Fig (4.3) were less than those obtained by Khwakaram, (2009) on Kostae Cham untreated wastewater (1699 **µs/**cm in 2007 and 1753 **µs/**cm in 2008) , Mustafa (2006) on Tanjaro wastewater (933 – 1810 **µs/**cm) and by AL – Othman (2002) on Wadi Hanifa stream water (1463 – 4800 **µs/**cm).

Correlation coefficient indicates highly positively significant ($P<0.001$) correlation was exhibited for EC with TDS, TSS, Total Hardness and Na^+.

Electrical conductivity of Tanjaro landfill leachate Table (4.3) ranges from minimum value of 14800 **µs/**cm to maximum value of 38200 **µs/**cm with the mean value of 24117 µs/cm Fig (4.3), which indicate a high concentration of dissolved solids and salts of the leachate produced in Tanjaro landfill leachate site. The EC values were higher than concentration ranges for components of Municipal landfill leachate (Lee and Jones, 1991b), and higher than field and laboratory values of leachate composition from the Marbella landfill with the EC average value of 24195 **µs/**cm Vadillo et al., (1999) and higher than results obtained by Bocanegra et al, (2001) on Mar del Plata landfill leachate, Argentina.

The EC values for well water remain high due to high concentrations of dissolved solids. From Table (4.3) it seemed that values of EC in the well water ranged from 636 **µs/**cm to 1640 with the mean value of 1125 µs/cm these EC values for well water are close to the results obtained by Mustafa (2006). Electrical conductivity values for well water were higher than permissible standards. Appendix (5)

Table (4.3): Electrical Conductivity (EC) (µs/cm) Values represented as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	925	1002	965	835	774			900.2	94.01
3P	890	1004	U	824	749			866.8	398.77
4P	891	1004	U	820	727			860.5	397.92
5P	890	1007	U	837	772			876.5	401.34
6P	894	975	U	826	440			783.8	406.23
Mean	898	998.4	965	828.4	692.4			876.4	121.82
± S.D	15.18	13.20		7.30	142.39			44.52	65.33
2R	U	1010	522	850	748			782.5	392.18
3R	U	1019	471	822	764			769.0	395.99
5R	U	1006	970	845	778			899.8	412.82
6R	U	0950	486	815	455			676.5	369.28
Mean		996.3	612.3	833.0	686.3			781.9	169.79
± S.D		31.31	239.46	17.11	154.65			110.6	105.79
Tanjaro landfill leachate									
B	U	U	28300	31600	U	15018	15000	22479.5	13508.98
C	U	U	32500	35170	U	15025	14950	24411.3	15167.70
D	U	U	34000	38200	U	14850	14800	25462.5	16190.97
Mean			31600	34990		14964	14916	24117.8	10686.98
± S. D			2954.66	3303.68		99.08	104.08	1615.37	1753.78
Well Waters									
Number One	1532	1567	733	636	1420	684	679	1035.9	443.21
Number Two	1010	1027	874	902	1180	672	649	902.0	192.47
Number Three	1395	1430	1600	1023	1640	1546	1436	1438.6	205.29
Mean	1312	1341	1069	853.7	1413.3	967.3	921.3	1125.5	226.6
± S. D	270.6	280.7	465.23	197.98	230.07	501.18	445.97	341.6	124.8

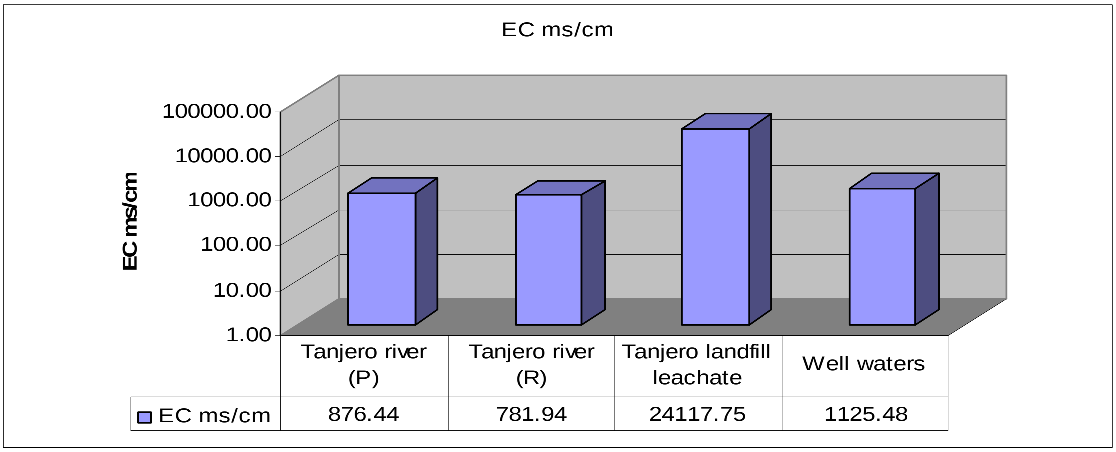


Figure (4.3): Demonstrates the average mean values of EC(µs/cm) in Tanjaro River, Tanjaro landfill leachate and well water

4.1.4: Total suspended solids (TSS):

The ground water is normally not contaminated with suspended solids due to the filtering ability of the soil. Domestic and industrial use of water results in a large variety of suspended matter which is both organic and inorganic in nature. Cains (1968) stated that biologically active (live) suspended solids may include disease- causing organisms as well as organisms such as toxin- producing strains of algae.

Kearney (1973) stated that water containing suspended solids can not be used for industrial purpose since it may chemically interfere with the process. Frequent chocking of pipeline, filtration units, corrosion and erosive failures, sludge deposition are some of the problems associated with high suspended solids in industrial process water. According to Quinby- Hunt et al., (1986), removal of total suspended solids of wastewater is one of the main objectives of wastewater treatment.

Total Suspended Solids (TSS) values Table (4.4) and Fig (4.4) for Tanjaro River ranged from 32 – 272 mgL^{-1} with the average mean value 155.8 mgL^{-1} for standing condition while for running condition the values ranged from 48 – 776 mgL^{-1} with the average means value 269.87 mgL^{-1}. The mean value of TSS for Tanjaro River running condition, nearly similar to those data recorded by Khwakaram (2009) for Kostay cham wastewater 234 mgL^{-1} in 2007 and 238 mgL^{-1} in 2008, and also close to data obtained by Mustafa (2006) for wastewater of Sulaimani city 210 mgL^{-1}. According to recommended standards by ESC (1998) and Pescod (1992), Tanjaro river samples recorded high Total Suspended Solids values this may be due to the nature of municipality pollutants which were damped in an open area in Tanjaro landfill site, land use activities close to Tanjaro River and finally due to the 60 factories which are located on Tanjaro river site. Location number 6P recorded maximum Total Suspended Solids during Oct. 2007, which regarded as an active gravel and sand open cast mining area. Total Suspended Solids values in Tanjaro River showed marked variation between 6 P and other location, however slight variation between other locations had been observed, on the other hand TSS values showed marked variation in different months during the study period.

Regarding Tanjaro landfill leachate, the value for total suspended solids (TSS) ranged from 408 mgL^{-1} as minimum value to 42852 mgL^{-1} as maximum value with the mean value of 5350.5 mgL^{-1}. The total suspended solids for Tanjaro landfill leachate values were relatively high, however this may be due to the nature of municipality pollutants which composed of different sorts of wastes (domestic, commercial, industrial, hazards, and hospital wastes). Chemical and physical analysis of leachate properties of municipal pollutant verifying this phenomenon. Total suspended solid values were recorded significant and positively correlated ($P<0.005$) with both BOD_5, and temperature of collected samples in the study area.

While Total suspended solid values for well water ranged from 40 mgL^{-1} as minimum value to 124 mgL^{-1} as maximum value with the average mean value of 75.90 mgL^{-1}. Concentrations of total suspended solids in well water samples exceed the permissible value for natural water according to Hynes (1974). The high values were recorded due to the location sites of well water close to Tanjaro landfill site especially well water number one.

4.1.5: Total dissolved solid (TDS):

Alka (2004) defined total dissolved solid as a term applied to all matters that remain as residue upon evaporation after drying at a definite temperature. Richards (1965) reported that dissolved solids in industrial waste waters are undesirable for many reasons, accelerate corrosion and interfere with the colour and taste of the many finished products. Ayers and Westcot (1985) stated that the magnitude of electrical conductivity EC depends on the amount of dissolved solids in wastewater. WHO (2006) reported that total dissolved solids concentrations in water vary considerably in different geological regions owing to differences in solubility of minerals.

Results in Table (4.5) for Tanjaro river, standing condition the TDS values ranged from 550 to 1648 and 827.8 mgL^{-1} as a minimum, maximum and mean values respectively, the maximum value was recorded during Oct. 2007 at 5 P, where there were not any rainfalls, while in case of running condition the value ranged from 610 to 3815 mgL^{-1} with the mean value of 1540.67 mgL^{-1}. Higher values of TDS were observed in summer months followed by rainy and winter months. Marked variation was observed in TDS values in different months, locations and conditions. These results (standing condition) were similar to those obtained by Mustafa (2006) on Sulaimani sewage wastewater, while the values for Tanjaro river running condition were higher than those obtained by the same researcher. According to FAO (1985), guidelines for interpretation of water quality for irrigation is severe if the value of TDS is more than 2000 mgL^{-1} appendix (7) this means that in case of Tanjaro river running condition during March 2008 with the values of 3805 and 3815 mgL^{-1} for location 3 R and 6 R respectively were not used for irrigation according to

Table (4.4): Total Suspended Solids (TSS) concentration values (mgL^{-1}) represented as (mean±S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	168	076	196	056	078			114.8	62.73
3P	104	160	U	120	169			138.3	67.48
4P	196	152	U	118	157			155.8	74.95
5P	260	032	U	114	175			145.3	105.75
6P	272	116	U	192	199			194.8	103.12
Mean	200	107.2	196	120	155.6			155.8	42.47
± S.D	68.99	53.62		48.27	46.00			54.22	10.35
2R	U	256	468	228	260			303.0	166.10
3R	U	140	776	048	159			280.8	315.09
5R	U	148	437	257	164			251.5	160.79
6R	U	112	584	124	157			244.3	225.12
Mean		164.0	566.3	164.3	185.0			269.9	197.83
± S.D		63.25	153.48	96.26	50.09			90.77	46.10
Tanjaro landfill leachate									
B	U	U	8036	1756	U	969	876	2909.3	2887.37
C	U	U	6868	0597	U	522	487	2118.5	2509.22
D	U	U	42852	0408	U	415	420	11023.8	16119.56
Mean			19252	920.3		635.3	594.3	5350.5	9268.80
± S. D			20446.5	729.8		293.8	246.2	5429.1	10013.9
Well Waters									
Number One	110	118	124	54	72	54	62	84.9	31.24
Number Two	105	107	100	72	79	64	59	83.7	20.08
Number Three	059	057	094	40	59	54	51	59.1	16.73
Mean	91.3	94.0	106.0	55.3	70.0	57.3	57.3	75.9	20.89
± S. D	28.11	32.51	15.87	16.04	10.15	5.77	5.69	16.31	10.52

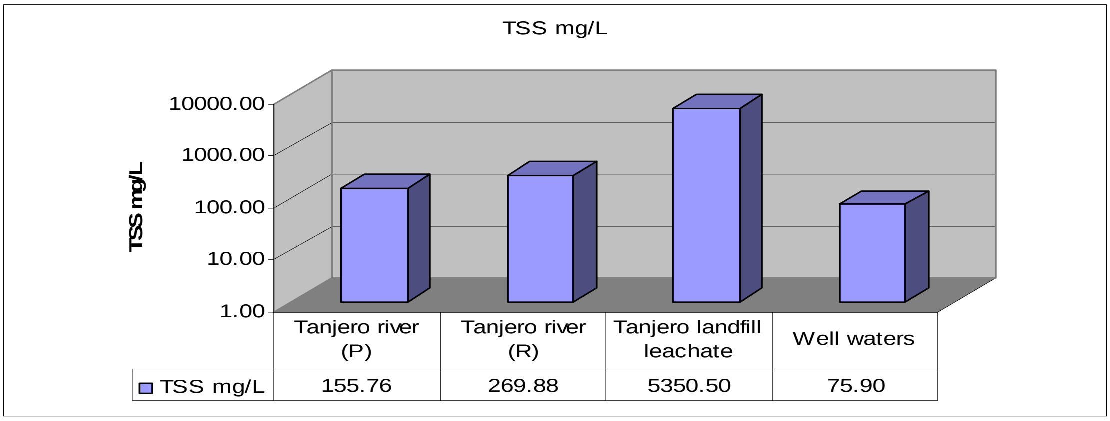


Figure (4.4): Demonstrates the average mean values of TSS mgL^{-1} in Tanjaro River, Tanjaro landfill leachate and well water

Table (4.5): Total dissolved solids (TDS) concentration values (mgL^{-1}) represented as (mean ±S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	680	550	850	595	U			668.8	320.27
3P	856	610	U	690	U			718.7	403.51
4P	860	1380	U	790	U			1010.0	598.31
5P	1648	690	U	697	U			1011.7	677.42
6P	704	720	U	835	U			753.0	415.52
Mean	949.6	790	850	721.4				827.8	96.74
± S.D	399.2	336.53		93.77				276.51	161.34
2R	U	1655	1453	785	U			1297.7	780.28
3R	U	1225	3805	625	U			1885.0	1579.04
5R	U	1000	1575	635	U			1070.0	675.10
6R	U	1305	3815	610	U			1910.0	1586.09
Mean		1296.3	2662.0	663.8				1540.4	1021.30
± S.D		271.8	1326.5	81.4				559.9	670.6
Tanjaro landfill leachate									
B	U	U	42456	22820	U	21809	21150	27058.8	16189.89
C	U	U	42900	23150	U	22100	22050	27550.0	16411.80
D	U	U	54440	37270	U	32710	30110	38632.5	22052.83
Mean			46598.7	27746.7		25539.7	24436.7	31080.4	10436.62
± S. D			6794.4	8249.1		6211.4	4933.8	6547.1	1375.1
Well Waters									
Number One	500	505	520	440	500	444	430	477.0	37.32
Number Two	512	525	510	535	480	530	520	516.0	18.27
Number Three	295	298	254	201	280	250	242	260.0	34.18
Mean	435.7	442.7	428.0	392.0	420.0	408.0	397.3	417.7	19.27
± S. D	121.9	125.68	150.77	172.10	121.6	143.43	141.85	139.64	18.38

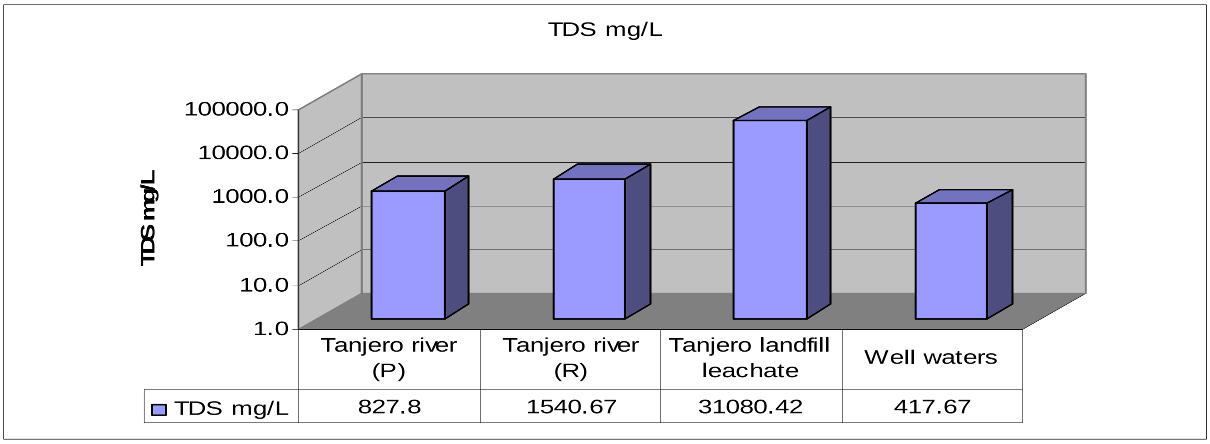


Figure (4.5): Demonstrates the average mean values of TDS (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

recommendation given by ESC (1996) and Pescod (1992) which indicate that the value of TDS should not exceed 3500 mgL^{-1} ,while the TDS value for the typical domestic wastewater 500mgL^{-1}, appendix (8).

Total dissolved solids for Tanjaro landfill leachate ranged from 21150 as the minimum value to 54440 mgL^{-1} as the maximum, with the average mean value of 31080 mgL^{-1}. According to Lee and Jones, (1991 b) appendix (9), the values of TDS ranges from 1000 to 20000 mgL^{-1}, the higher values for Tanjaro landfill leachate is due to uncontrolled condition for Tanjaro landfill because it is regarded as an open dump area, while sanitary landfills in USA and Europe are capped and under control.

The total dissolved solids for well water ranged between 201 to 532 with the mean average value of 417.66 mgL^{-1}, results of well water samples show that TDS are in the range of acceptable water (500-1000 mgL^{-1}) according to Canada (2005), WHO (2006), and IQS (1996) appendix (6), while TDS values grater than 300 mgL^{-1} according to EU (2004) is not in the range of permissible. Significant and positive correlation ($p< 0.005$) between TDS of collected samples and BOD_5 was observed in study area. Significant and positive correlation in TDS and TSS, Total hardness and most of heavy metals was observed in Tanjaro River, Tanjaro landfill leachate and wells water. According to EU (2004), both well number 1 and 2 which their positions located close to Tanjaro landfill site were not in the ranges of palatable water. Anne et al., (1993) estimated that there are 75% of landfills in the US are polluting groundwater. The majority of those landfills are called "sanitary" landfills in which there was little or no regard given to their sitting, construction, operation, and closure for the potential impact of leachate generated within landfill on groundwater quality.

4.1.6: Turbidity

Davis and Cornwell, (1991), Sincero and Pacquias (2003) estimated that particles such as clay, silt, sand, algae, plankton, microorganism, and other substances suspended in water, scattered the passage of light through water and does not allow free passage, the visual depth of such water samples are restricted. According to Allan (1995) turbidity values in any aquatic system affecting by many factors among them, stream depth, water velocity the amount of clay and silt. Turbidity measurement is carried out using a Nephlometer and is expressed in Nephlometric Turbidity Unit (NTU). Turbidity water is never a pleasing sight and hence public water should be turbid free.

During this investigation for Tanjaro River as shown in Table and Fig (4.6) the maximum value of Turbidity was observed in November 2007 as 645 NTU at 3P and 4P location (Standing condition) and minimum value of Turbidity 4.5 NTU. While for running condition for Tanjaro River, the maximum value of turbidity was observed, in March 2008, as 1980 NTU, at 6R location close to the Quaradagh Bridge where all factories and active gravel and sand open cast mining are located. The other reason for high Turbidity value is due to waste water effluent that comes from Sulaimani city. Tanjaro River ranged from 1.08 to 289 NTU. Lak (2007) recorded turbidity at Erbil wastewater channel, within the range 23- 143 NTU, probably linked the high turbidity value to wastewater effluent that comes from both industrial region within Erbil city. While turbidity level was observed along Erbil waste water channel by Yahya (2008) with the minimum and maximum turbidity value level were 1.38 and 193 NTU during Jan. and April 2007 respectively.

Turbidity in Tanjaro river standing condition ranged from 4.5 to 645 with the mean value of 133.4 NTU Table (4.6), while in case of running condition turbidity values ranged from 10 to 1980 with the mean value of 703.6 NTU. Turbidity showed marked variation within Tanjaro River locations. Analysis revealed significant variation in turbidity values were observed within months in case of Tanjaro River, Tanjaro landfill leachate and well water. Correlations coefficients showed positive significant ($P< 0.005$) correlation with BOD_5, and negatively correlated with DO were exhibited. Rump (1999) reported that high turbidity reduces the amount of light passing through water from the surface and lowers photosynthesis rate that leads to reduce DO level.

The maximum value for turbidity 790 NTU was observed in May 2008 for Tanjaro landfill leachate at B location and the minimum value 440 NTU at B location, with the mean value of 586 NTU Table (4.6), high value for turbidity is due to the washing down of landfill components during rainfall period .

For well water, the maximum value for turbidity was 14.5 NTU for well water No.3 during Feb. 2009 Table (4.6) with dissolved oxygen DO 0.4 mgL^{-1} , Table (4.9) while the minimum value for turbidity was 0.3 NTU for well water No. 3 during May 2008 with dissolved oxygen DO 4.50 mgL^{-1}. The values for turbidity were accepted as compared with WHO (2006), EU (2004), Appendix (5) standards during Nov. 2008 well water number 3 (House number 14), while for well water number 1 was accepted during March.2008 and for well number 2 (cement block factory) during November 2007, Table (4.6).

Table (4.6): Turbidity concentration Values (NTU) represented as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	U	180	13.9	15.0	365.0			143.5	158.25
3P	U	4.5	U	30.0	59.0			31.2	25.75
4P	U	645	U	425.0	600.0			556.7	315.78
5P	U	26.0	U	59.0	70.0			51.7	32.60
6P	U	35.0	U	25.0	60.0			40.0	25.35
Mean		178.1	13.9	110.8	230.8			133.4	93.59
± S.D		270.0		176.4	244.3			230.2	48.4
2R	U	1099	984	10.0	634.0			681.8	522.21
3R	U	1030	976	14.0	890.0			727.5	527.29
5R	U	0435	375	395	722.0			481.8	257.14
6R	U	0980	1980	70.0	664.0			923.5	805.83
Mean		886.0	1078.8	122.3	727.5			703.6	413.34
± S.D		304.6	665.1	183.9	114.3			316.9	245.0
Tanjaro landfill leachate									
B	U	U	440	790	U	573	570	593.3	333.29
C	U	U	528	708	U	655	657	637.0	344.78
D	U	U	464	469	U	595	583	527.8	286.52
Mean			477.3	655.7		607.7	603.3	586.0	76.23
± S. D			45.5	166.7		42.4	46.9	75.41	60.9
Well Waters									
Number One	0.8	0.8	0.7	6.4	5.5	5.0	5.0	3.5	2.54
Number Two	0.7	0.6	0.5	5.2	13.0	0.4	0.4	3.0	4.75
Number Three	0.8	0.7	0.6	0.3	3.4	14.5	14.3	4.9	6.54
Mean	0.8	0.7	0.6	3.9	7.3	6.6	6.6	3.8	3.07
± S. D	0.08	0.08	0.12	3.23	5.05	7.20	7.08	3.26	3.25

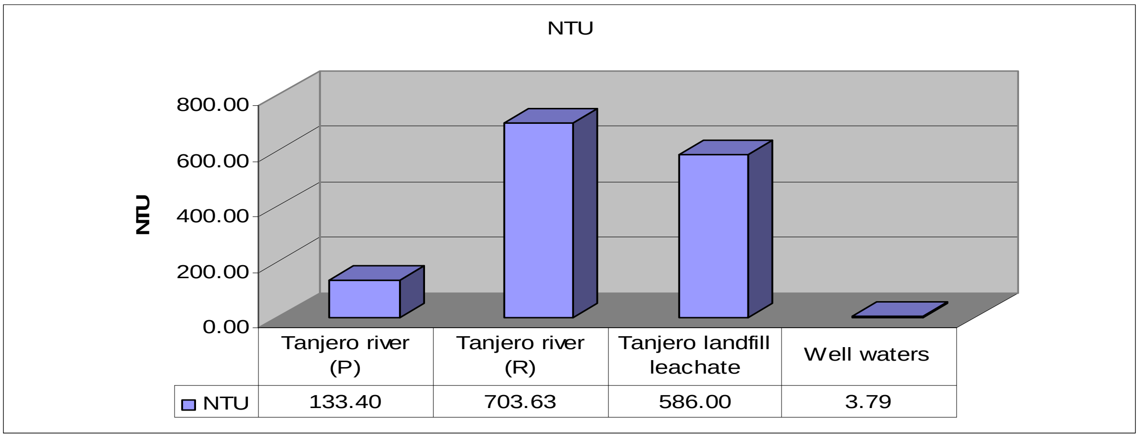


Figure (4.6): Demonstrates the average mean values of Turbidity (NTU) in Tanjaro River, Tanjaro landfill leachate and well water

4.1.7: Colour:

According to Malcolm (1985) colour is an important water quality indicator. Pure fresh water may not contain any colour, odour and taste. Industrial and domestic use of water increase dissolved as well as suspended matter content leading to colouring of water according to WHO (2006) industrial effluents is an important source for contamination of water.

For this study, colour values for Tanjaro River ranged from 69 to 208 with the average mean value of 95.1 (Hazeen) for standing condition. While for running condition ranged from 72 to 263 (Hazeen) with the average mean value of 113.08 (Hazeen), Table and Fig (4.7). Khwakaram (2009) estimated the mean values of colour for Kostay cham raw wastewater ranged 216 and 215 (Hazeen) unit in 2007 and 2008) respectively. The relatively high values of colour in the Tanjaro River related to the sewage effluents, industrial wastes and land use activities. For standing condition in Tanjaro River the mean value of colour is less than running condition, this is due to the precipitating effect of suspended matter which is regarded as one of the main source for colouring of water.

While the mean value of colour for Tanjaro landfill leachate ranged from 339 to 8753 (Hazeen) with the mean average value 3307.17 (Hazeen), the high values of colour in leachate is directly related to the nature and composition of municipality solid wastes for Tanjaro landfill, rain water percolates through the landfill and dissolves the organic and inorganic substances of the solid waste produces leachate that migrates to adjacent areas, resulting in gross pollution of soil, surface water and groundwater. The composition of colour, of this leachate derives from rainfall reactions associated with decaying waste.

The values of colour for well water ranged from 40 to 54 with the average mean value of 47.1 (Hazeen). Colour values were recorded positively and highly significant correlation ($P< 0.001$) with TDS, TSS and Total hardness. According to recommended standards by WHO (2006), IQS (2001) and Canada (2005), colour values should not exceed more than 15, 10, 15(Hazeen) respectively, appendix (5), so according to these standards the studied wells water stand out of the normal ranges, contamination plume may have formed as a result of leaching into the ground water system and has been described in various case studies Freeze, et al., (1979).

Table (4.7): Colour values (Hazeen) represented as (minimum, maximum and mean values during the study period.

Location	Date of Sampling							
	2007		2008			2009		
	Oct	Nov.	March	May	Nov.	Feb	April	
	27	13	19	9	27	17	7	Mean
Tanjaro River								
2P	143	112	79	78	77	79	80	92.6
3P	92	103	U	79	100	81	89	90.7
4P	123	208	U	95	185	97	99	134.5
5P	114	98	U	79	103	80	84	93.0
6P	69	71	U	74	84	79	80	70.2
2R	U	221	83	72	80	85	87	104.6
3R	U	263	104	104	75	109	109	127.3
5R	U	135	95	86	99	97	99	101.8
6R	U	217	112	89	107	91	95	118.5
Tanjaro landfill leachate								
B	U	U	8410	3016	U	3430	411	3816.7
C	U	U	8753	7350	U	397	339	4209.7
D	U	U	6402	379	U	399	400	1800.2
Well Waters								
Number One	52	53	54	52	50	46	49	50.8
Number Two	48	45	52	48	51	45	43	47.1
Number Three	44	43	43	42	45	40	44	43.0

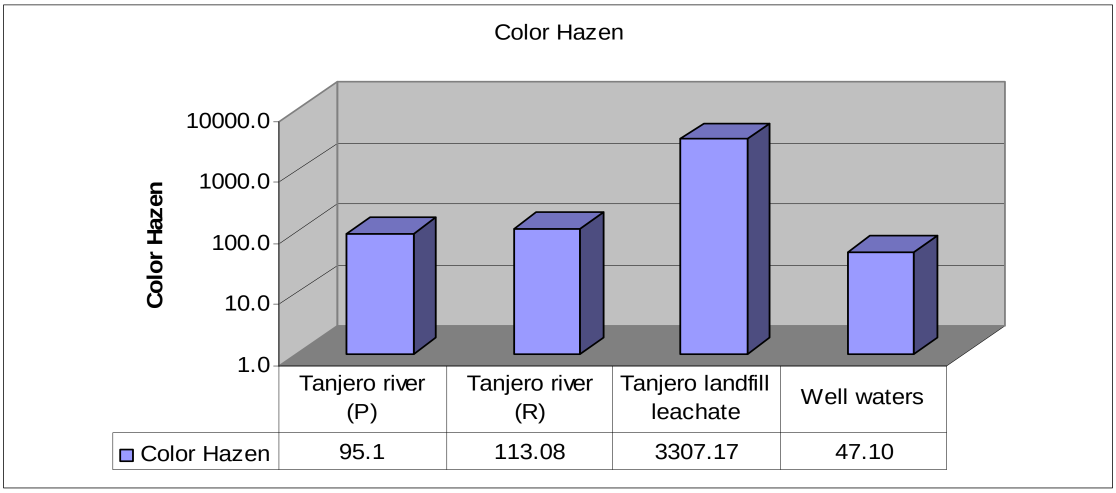


Figure (4.7): Demonstrates the average mean colour (Hazeen) values in Tanjaro River, Tanjaro landfill leachate and well water

4.1.8: Total Hardness:

A commonly indicated water quality parameter is its hardness, due to the presence of Ca and Mg in combination with anions such as carbonate and sulfate Hammer (1986). According to US salinity Laboratory staff (1954) the presence of these two divalent cations (Ca^{+2} and Mg^{+2}) are essential for ensuring soil permeability as well as for the growth of crops. The sum of Ca hardness and Mg hardness named the total hardness. The total hardness may express as:

Total hardness as $CaCO_3$ = 2.497× (Ca mgL^{-1}) + 4.118× (Mg mgL^{-1})……………(7).

It is better to avoid hard water for drinking ,according to Al - Manharawi and Hafiz (1997) increasing hardness of water has a health effect, which causes precipitation of salts in vessels, formation of stone and pre-mature aging. On the other hand, extra hardness will mean the consumption of more soap in washing and also scale formation in cooling water circuits and boilers, according to Venkateswarlu (1985) very soft water induces corrosion in iron pipe line. In term of hardness, the water quality is designated as shown in Table (4.8) below.

Total hardness of Tanjaro river standing condition ranged from 185 mgL^{-1} as $CaCO_3$ at location 3P and 6P during 9 May 2008 Table (4.9) this may be due to the dilution effects of rainfall and subsequent runoff often significantly lower hardness concentrations, while the maximum value 285 mgL^{-1} as $CaCO_3$ at location 6P Table (4.9) may be due to the location of 6p where is located adjacent to the active gravel and sand open cast mining activities.

Table (4.8): Demonstrates the value of Hardness VS. Water Quality.

Soundarapandian et al., (1985)		Heath (1982)	
Hardness as mgL^{-1} of $CaCO_3$	Description of water	Hardness as mgL^{-1} of $CaCO_3$	Description of water
0 - 50	Soft water	0 -60	Soft
50 -100	Moderately soft	61 – 120	Moderately hard
100 – 150	Neither hard nor soft	121 – 180	Hard
150 – 200	Moderately hard	> 180	very hard
200 – 300	Hard water		
Greater than 300	Very hard.		

While for running condition the Total Hardness concentration ranged from 143 to 285 with the mean value of 233.8 mgL^{-1} as $CaCO_3$, the maximum value occurred during Nov. 2007 and 2008 due to the effect of evaporation which caused an increase of cations concentrations, Goldman and Horne (1983). According to Table (4.8) Tanjaro river classified as hard water.

The values of this study are lower than those obtained by Khwakaram (2009) on Kostae cham raw wastewater, with the mean values of total hardness ranged from 535 and 550 mg $CaCO_3$ L^{-1} in 2007 and 2008 respectively, Nizar (2008) on Tanjaro river ranged from 204.96 to 388.06 mgL^{-1} as $CaCO_3$, Mustafa (2006) on Tanjaro river and its basin ranged from 260 to 440 mgL^{-1} as $CaCO_3$ and from 294 to 320 mgL^{-1} as $CaCO_3$ of surface water, Aziz (1997) on Rawandiz river ranged from 80 to 538 mgL^{-1} as $CaCO_3$ while the concentration of $CaCO_3$ according to study by Al- Othman (2002) on stream water along Wadi hanifah ranged from 500 to 1791 mgL^{-1} .

The concentration value of equivalent $CaCO_3$ for Tanjaro landfill leachate ranged from 180 to 1170 with the mean concentration value of 281.9 mgL^{-1} as $CaCO_3$. The values obtained from this study are lower than, the concentration ranges for components of Municipal landfill leachate according to Lee and Jones, (1991 b) appendix (9). Tanjaro landfill leachate samples were classified according to Table (4.8) as very hard.

Total Hardness of wells′ water ranged from 25 to 117 with the mean concentration value of 90.2 mgL^{-1} as $CaCO_3$. The maximum value was obtained at well water number one location adjacent to Tanjaro landfill 117 mgL^{-1} as $CaCO_3$ Table (4.9) due to the effect of Tanjaro landfill leachate penetrating downward toward ground table.

Correlation coefficient showed positive high significant correlation ($P< 0.001$) with BOD_5 and negative correlation with DO. While a significant high positive correlation ($P < 0.001$) was exhibited for Total hardness as $CaCO_3$ with TDS, TSS.

The results of well water relating to the Total Hardness as $CaCO_3$ are within the permissible limits recommended by WHO (2006) 500 mgL^{-1}, IQS (2001) 500 mgL^{-1} and EUDWS (2005) 150-500, appendix (4). The values of this study are lower than those obtained by Mustafa (2006) on groundwater close to Tanjaro river and its basin with the mean values 418-468 mgL^{-1} for wet and dry seasons respectively, Muhammed (2008) on well water in Halabja, Sulaimani ranged from178.84 to 636.46 mg $CaCO_3$. L^{-1}. So, results in Table (4.8), indicated that the water from wells in the study area classified as moderately soft water

Table (4.9): Total Hardness (mg $CaCO_3$ L^{-1}) values represented as (mean, ± SD) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	± SD	
Tanjaro River										
2P	232	232		200	285	263	255	244.5	29.62	
3P	250	200		185	209	197	190	205.2	23.47	
4P	215	268		225	270	220	210	234.7	27.07	
5P	250	215		207	215	198	190	212.5	20.81	
6P	232	232		185	285	215	210	226.5	33.49	
Mean	235.8	229.4		200.4	252.8	218.6	211	224.7	18.71	
± SD	14.7	25.3		16.7	37.8	26.8	26.5	24.6	8.2	
2R		285	268	185	200	275	260	245.5	42.14	
3R		250	232	268	175	233	227	230.8	31.26	
5R		285	253	250	175	257	214	239.0	38.67	
6R		143	268	232	164	272	240	219.8	54.07	
Mean		240.8	255.3	233.8	178.5	259.3	235.3	233.8	29.04	
± SD		67.2	17.0	35.6	15.2	19.2	19.6	29.0	20.1	
Tanjaro Landfill Leachate										
B			420	310	1170	330	330	512.0	370.3	
C			290	285	215	307.5	268	273.1	35.40	
D			180	250	267	375	720	358.4	213.8	
Mean			296.7	281.7	550.7	337.5	439.3	281.2	112.9	
± SD			120.1	30.14	536.9	34.37	245.0	193.3	210.9	
Well Waters										
Number One	115	112	117	43	40	90	95	87.4	32.98	
Number Two	104	104	102	96	89	25	35	79.3	34.20	
Number Three	98	105	98	100	110	103.5	112	103.8	5.61	
Mean	105.7	107.0	105.7	79.7	79.7	72.8	80.7	90.2	15.14	
± SD	8.6	4.3	10.0	31.8	35.9	41.9	40.4	24.7	16.4	

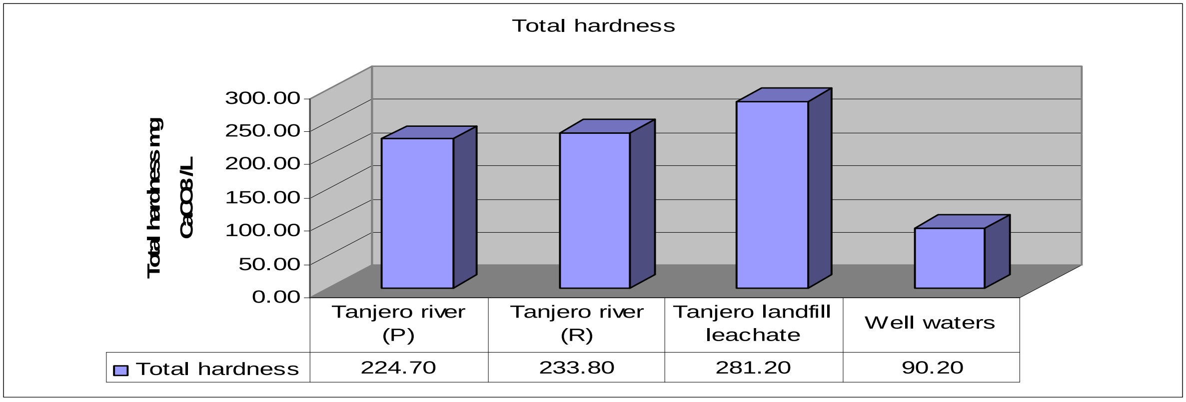


Figure (4.8): Demonstrates the average mean value of total hardness (mg $CaCO_3$ L^{-1}) in Tanjaro River, Tanjaro Landfill Leachate and well water

4.1.9: Dissolved Oxygen (DO):

Dissolved oxygen concentration in Tanjaro River Table (4.10) ranged from 0.9 to 14.2 mgL^{-1} for standing condition, while for running condition ranged from 0.11 to 6.43mgL^{-1}. An overall mean of dissolved oxygen concentration recorded for the study period during the entire sampling time was 4.4 mgL^{-1} and 4.2 mgL^{-1} for standing and running conditions in Tanjaro River respectively, Fig (4.9). The minimum dissolved oxygen concentration 0.11 mgL^{-1} was observed at location 5R during 27th Nov. 2008, while the maximum dissolved oxygen concentration 14.2 mgL^{-1} was observed at location 6P during May. 2008, Table (4.10). Significant differences were observed between the studied sites running and standing conditions of Tanjaro River.

Statistical analysis indicated a negative significant correlation ($P < 0.005$) between water temperature and DO in both running and standing condition of Tanjaro River. On the other hand, statistical analysis revealed a negative highly significant correlation ($p < 0.001$) between DO and both BOD_5 and turbidity.

Variation in dissolved oxygen levels attributed to several important factors.

- Water temperature:

Oxygen depletion during November 2008 Table (4.10) is coincident with maximum water temperature as well as high microorganism's densities that created anaerobic condition as a result of organic matter decomposition Benerji ,(1997).

- Degree of turbidity:

Maximum dissolved oxygen concentration 14.2 mgL^{-1} Table (4.10) during the study period is coincident with low value of Turbidity 25 NTU at location 6P during May 2008 while the minimum dissolved oxygen concentration 0.11mgL^{-1} is coincident with high value of turbidity 722 NTU, Table (4.6).

- Sewage effluents:

Sewage effluents that discharge to Tanjaro River and its tributaries are responsible for low dissolved oxygen concentration. The low oxygen content of the effluent serves to dilute the concentration of oxygen in stream water which finally causes deficiency in dissolved oxygen.

- Flow rate:

Increasing rainfall and rising discharge from springs around the area bring an influx of more highly oxygenated water. This result comes in accordance with the result of Maulood and Hinton (1980). While dissolved oxygen increased gradually downstream to the direction of Darbandekhan reservoir due to the re-aeration by turbulence and self purification (Tchnobanoglous and Burton, 1991).

These results were nearly similar to those obtained by Yahya (2008) on Erbil wastewater discharge effect on the water quality of Greater Zab River the values of DO ranged from undetected to 7 mgL^{-1}. Khamees (1979) reported on dissolved oxygen on Sulaimani sewage water the values ranged from 0.2 to 7 mgL^{-1} .

Dissolved oxygen concentration for all Tanjaro landfill leachate samples from different locations, during different times of collection Table (4.10) were less than 1.0 mgL^{-1} except for location C during March 2008, was equal to 2.79 mgL^{-1} . According to Anne Jones (1993) the high oxygen demand of Municipal landfill leachate can cause depletion of dissolved oxygen from leachate, which promotes the conversion of sulfate to hydrogen sulfide which is highly obnoxious in leachate causing a "rotten egg" smell.

While dissolved oxygen concentration for well water Table (4.10) recorded from the minimum value of 0.36 mgL^{-1} for well water number 3 which was located in the Tanjaro village (House number 14) during Feb. 2009, and the maximum value 6.36 mgL^{-1} for well water number 1 during March.2008, while the average mean concentration value of dissolved oxygen for wells′ water was 2.65 mgL^{-1} Fig (4.9).

Table (4.10): Dissolved oxygen (DO) concentration values (mgL^{-1}) represented as (mean, ± S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	U	4.3	2.6	13.9	1.2			5.5	5.56	
3P	U	5.6	U	6.2	1.3			4.3	3.04	
4P	U	5.2	U	5.9	1.0			4.0	2.89	
5P	U	4.8	U	4.9	1.2			3.6	2.49	
6P	U	5.0	U	14.2	0.9			6.7	6.05	
Mean		4.9	2.6	9.1	1.1			4.4	3.45	
± S.D		0.5		4.6	0.1			1.7	2.5	
2R	U	4.7	4.0	4.9	1.2			3.7	2.23	
3R	U	5.6	4.2	6.43	1.3			4.4	2.77	
5R	U	6.2	5.2	5.8	0.1			4.3	3.13	
6R	U	5.3	5.4	5.8	0.4			4.3	2.91	
Mean		5.5	4.7	5.7	0.8			4.2	2.31	
± S.D		0.6	0.7	0.6	0.6			0.6	0.05	
Tanjaro landfill leachate										
B	U	U	0.6	0.6	0.4	0.4	0.4	0.5	0.26	
C	U	U	2.8	0.6	0.4	0.4	0.4	0.9	0.97	
D	U	U	0.4	0.6	0.4	0.4	0.4	0.4	0.22	
Mean			1.3	0.6	0.4	0.4	0.4	0.6	0.39	
± S. D			1.3	0.02	0.00	0.00	0.00	0.27	0.60	
Well Waters										
Number One	U	U	6.4	5.1	3.5	0.4	0.4	3.1	2.7	
Number Two	U	U	4.1	3.9	2.5	0.4	0.4	2.3	1.85	
Number Three	U	U	4.0	4.5	3.4	0.4	0.4	2.5	2.06	
Mean			4.8	4.5	3.1	0.4	0.4	2.65	2.16	
± S. D			1.3	0.6	0.6	0.03	0.02	0.5	0.5	

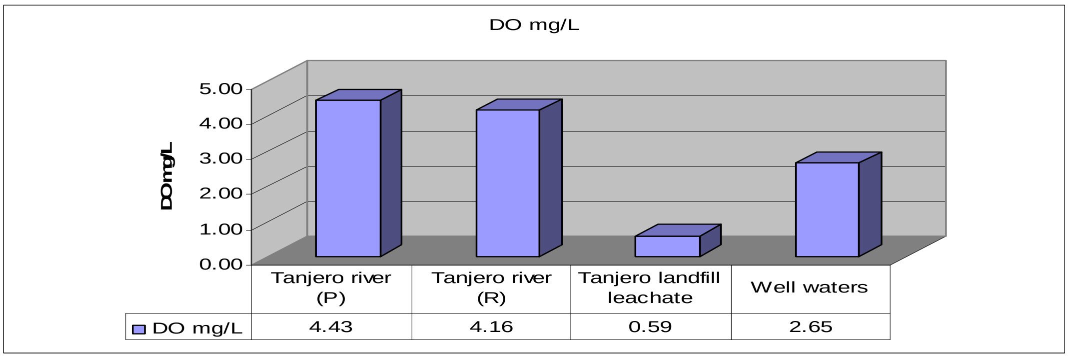


Figure (4.9): Demonstrates the average mean values of (DO) mgL^{-1} in Tanjaro River, Tanjaro landfill leachate and well water.

4.1.10: Biochemical Oxygen Demand (BOD):

Ciaccio, (1972) defined Biochemical Oxygen Demand BOD as the measure of the presence of organic materials in aqueous solution which will be oxidized biologically and in turn, will support the growth of micro-organisms. According to Sawyer and Mackereth et al., (1978), biochemical oxygen demand is the quantity of oxygen required by micro-organisms to decompose the organic substances in sewage. Therefore, the more organic material there is in the sewage, the higher the biochemical oxygen demand.

The standard 5-day (biochemical oxygen demand) value is BOD_5 commonly used to define the strength of municipal wastewaters to evaluate the efficiency of treatment by measuring oxygen demand remaining in the effluent, and to determine the amount of organic pollution in water. Mark,(2000) estimated that BOD_5 is among the most important parameters for the design and operation of sewage treatment plants.

The results of this study showed that a wide range of BOD_5 values were recorded along Tanjaro River standing condition, Table (4.11) the minimum and maximum values ranged from 0.96 to 13.9 mgL^{-1} during Nov. 2008 and May 2008 recorded in location 6P respectively, with the mean value 3.7 mgL^{-1} . While for Tanjaro River (running condition) the values ranged from 0.16 to 6.05 mgL^{-1} during Nov. 2008 and May 2008 recorded in locations 5R and 6R as minimum and maximum values respectively with the mean value 2.39 mgL^{-1} , Table (4.11) due to:

- The effluent discharge enriched with untreated domestic waste, and industrial waste water from Sulaimani sewage and wastewater. These results are proportional to the data revealed and reported by Kayabali et al., (1999. Antoine and Benson (1988) that an increase in BOD values of river Wye and the river Lygg and in the tributary of the river Wye owing to the increase of organic pollution.
- Location number 6 is under Qaradagh bridge where most of the factories were located close to this location.
- Probably linked to the amount of rainfall that lets to wash down all pollutants from different areas and bring it to Tanjaro River supported by the data reported by Anber (1984).

Rashid et al., (2000) and Al- Sarraf (2006) found the impact of Diyala River, which rises up BOD value of Tigris River. According to Yahya (2008) the minimum and maximum values for Erbil wastewater values ranged from 5 to 208 mgL^{-1} during Jan. and Sept. respectively. While other studies had been conducted for Erbil wastewater channel by

Aziz (2006) registered BOD value for Great Zab River ranged from 1.3 to 4.6 mgL^{-1} , while Lak (2007) reported BOD value for Great Zab River ranged from 1 to 65 mgL^{-1} , Ganjo (1997) recorded BOD value for Ruwandiz river ranged from 0.2 to 5.8 mgL^{-1} . According to Pandey et al, (2005) the BOD value for untreated city sewage water ranged from 100 to 400 mgL^{-1} . Bitton (2005) classified wastewater, with the BOD ranged from 0 to 220 mgL^{-1} as a weak to medium wastewater. Meanwhile Tanjaro River, Erbil wastewater, Ruwandiz River, and Greater Zab River can be regarded as a weak wastewater. Nabi (2005) estimated that BOD value is influenced by, nature and concentration of organic substances in the wastewater to be broken down, number of micro- organisms, adaptation of micro- organisms, nature and quantity of nutrients for the micro- organisms, Temperature and light.

It was obvious that the BOD concentration for Tanjaro River decreased gradually during traveling from Sulaimani (main source for pollution) till Darbandekhan reservoir which was coincided with the increase of Dissolved oxygen concentration. The statistical analysis revealed a negative high significant ($p<0.001$) correlation between BOD_5 and DO. On the other hand positive significant ($P<0.005$) correlation was observed between BOD_5 and temperature, Turbidity, TSS and TDS respectively. This may be attributed to the natural self purification of the polluted Tanjaro River. Nomour and Le Pimpec (2001) defined self-purification as a natural process whereby a stream, over a given distance becomes less toxic and this procedure depend on climate, geology and other environmental parameters. Beyers and Odum (1993) reported that natural self purification of surface water processes results in a decline in nutrient concentrations to normal levels that improve water quality down stream of the contamination source.

Generally, BOD_5 for Tanjaro landfill leachate were under 3 mgL^{-1}, Table (4.11) the highest value was recorded in location C during March 2008, with the value of 2.1 mgL^{-1}, while the minimum value was recorded in location D during March, 2008 with the value of 0.06 mgL^{-1}. The low values of BOD_5 for Tanjaro landfill leachate were recorded during the present study because Tanjaro landfill site is regarded as an open dump area during winter, rainwater enters the landfill and filters through the exposed waste, dangerous chemicals released by the decomposing wastes which harm aquatic organisms even if present in only very small quantities and finally due to the present of heavy metals in the leachate which do not let micro-organism, to grow.

Table (4.11): Biochemical Oxygen Demand (BOD_5) Concentration Values (mgL^{-1}) represented as (mean ±S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	U	3.47	0.99	8.7	3.2			4.1	3.39	
3P	U	3.37	U	5.7	4.2			4.4	2.55	
4P	U	3.84	U	5.7	3.9			4.5	2.57	
5P	U	1.93	U	2.1	2.2			2.1	1.14	
6P	U	5.80	U	13.9	0.9			6.9	5.97	
Mean		3.7	0.99	7.2	2.9			3.7	2.6	
± S.D		1.4		4.4	1.3			2.4	1.8	
2R	U	3.56	0.76	3.89	1.10			2.3	1.75	
3R	U	4.76	0.69	6.05	1.04			3.1	2.71	
5R	U	1.93	0.95	0.65	0.16			0.9	0.77	
6R	U	3.86	3.41	5.09	0.38			3.2	2.24	
Mean		3.5	1.5	3.9	0.7			2.4	1.58	
± S.D		1.2	1.3	2.4	0.5			1.3	0.8	
Tanjaro landfill leachate										
B	U	U	0.3	0.4	0.2	0.2	U	0.3	0.18	
C	U	U	2.1	0.4	0.1	0.1	U	0.7	0.77	
D	U	U	0.06	0.1	0.1	0.1	U	0.1	0.05	
Mean			0.8	0.3	0.1	0.1		0.3	0.34	
± S. D			1.10	0.17	0.03	0.06		0.34	0.51	
Well Waters										
Number One	U	U	2.5	2.0	1.9	0.3	U	1.7	1.12	
Number Two	U	U	1.8	1.0	1.2	0.2	U	1.1	0.73	
Number Three	U	U	1.5	0.8	0.3	0.04	U	0.7	0.58	
Mean			1.9	1.3	1.1	0.2		1.1	0.73	
± S. D			0.49	0.64	0.80	0.11		0.51	0.30	

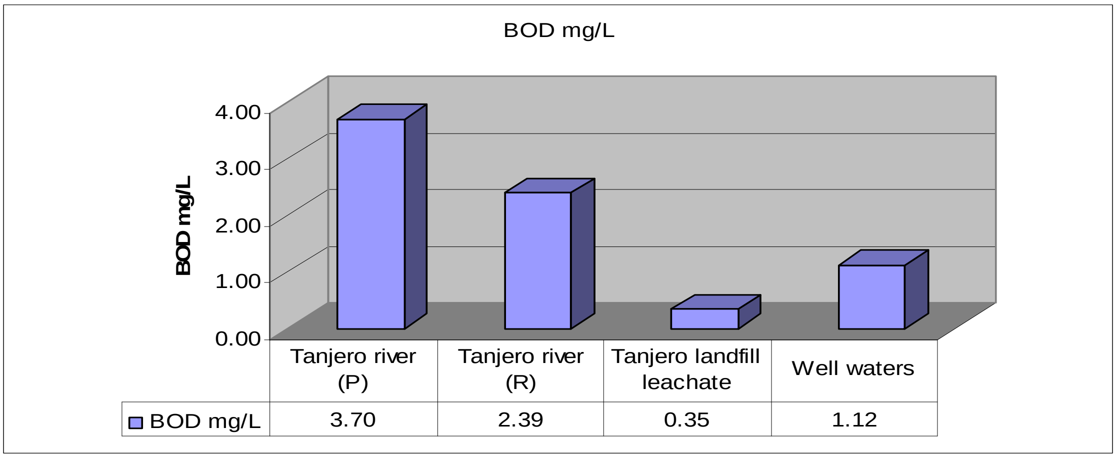


Figure (4.10): Demonstrates the average mean values of BOD (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water

Values for BOD_5 for wells´ water (drinking water) showed in Table (4.11) ranged from 2.46 mgL^{-1} as the maximum value for well number 1 during March. 2008, and the minimum value was recorded in location well number 3 with the value of 0.04 mgL^{-1} ,with the mean average value of 1.12 mgL^{-1} . Higher mean values for BOD_5 for ground water recorded by Mustafa (2006) ranged from 4 to 5.8 mgL^{-1} for wet and dry season respectively. According to Al- Manharawi and Hafiz (1997), the BOD should be Zero for drinking water. Hynes (1974) tabled the water quality depending on the BOD values as shown in Table (4.12). Drinking water for well number 1, 2 and 3 are categorized as clean to fairly clean waters.

Table (4.12) classification of water quality depending on BOD:

BOD (mgL^{-1})	Water quality
1	Very clean
2	Clean
3	Fairly clean
5	Doubtful
≥ 10	Bad

Reference: Hynes 1974

4.2: Major Cations

4.2.1: Calcium (Ca):

Calcium occurs most commonly in sedimentary rocks in the minerals calcite, dolomite and gypsum. It also occurs in igneous and metamorphic rocks chiefly in the silicate minerals. Calcium is the most abundant cation in the body. It is important to the formation of bones, teeth, blood clotting, normal muscle, nerve activity, glycogen metabolism, synthesis and helps prevent hypertension. Lind (1979) studied that, calcium is the major constituent of the cell wall for the higher aquatic plants.

Table (4.13) shows the values of calcium Ca^{+2} concentration in Tanjaro river standing condition ranged from 64 mgL^{-1} to 128 mgL^{-1} respectively with the average mean value of 109.7 mgL^{-1}, while for running condition the values ranged 88 mgL^{-1} , 216 mgL^{-1} respectively with the average mean 125.7 mgL^{-1}.

Table (4.13): Demonstrates the minimum, maximum and mean concentration values of calcium (Ca^{+2}) in Tanjaro river, Tanjaro landfill leachate and well water:

Sample location	Min. (mgL^{-1})	Maxi. (mgL^{-1})	Mean (mgL^{-1})
Tanjaro river Standing	64	128	109.7
Tanjaro river Running	88	216	125.7
Tanjaro landfill leachate	144	1600	1223
Well water	12	60	43

In general it is observed that samples from all different locations taken during different period of time have a relatively high level of calcium (Ca^{+2}) for both running and standing condition and they were above the recommended standards. The excess in calcium concentration is due to discharging of sewage effluents directly to Tanjaro River and its tributaries and also due to location of Tanjaro landfill site close to Tanjaro River. Different values of calcium concentration were recorded by other researchers, Mustafa (2006) on Tanjaro River and its tributaries the values ranged from 70.2 to 86.1 mgL^{-1} with the mean value of 80.4 mgL^{-1}.

Table (4.13) shows that the values of calcium concentration in Tanjaro landfill leachate ranges from 144 mgL^{-1} to 1600 mgL^{-1} with the average mean value of 1223 mgL^{-1} Results obtained from this study exceeded the standard concentration values recommended by Lee and Jones (1991b) appendix(9). The results also exceeded those obtained by Vadillo (1999) on Marbella landfill southern Spain. High concentration level of calcium content in Tanjaro landfill leachate illustrated the impact of municipal solid waste components which were dumped in Tanjaro open dump area. Leachate from Tanjaro landfill site considered to be one of the main contributors to Tanjaro River, ground water and soil pollution.

The concentration values of calcium in well water ranged from 12 mgL^{-1} to 60 mgL^{-1} and 43 mgL^{-1} as mean average concentration values.

Calcium concentration values in ground water for the study area were within the values recommended by Langmuir (1997), appendix (6).

4.2.2: Magnesium: (Mg^{+2})

Lindberg et al., (1990) concluded that Magnesium ions are essential to all living cells and Magnesium ions are essential to the basic nucleic acid chemistry of life and thus are essential to all cells of all known living organisms. Giannini et al., (2000) reported that many enzymes require the presence of magnesium ions for their catalytic action. Hem, (1985) reported that excess magnesium intake causes diarrhea, while deficits cause neuromuscular problems, tremors, muscle weakness, irregular heartbeat, high cholesterol levels, pregnancy problems and vascular spasms.

Tanjaro River wastewater samples standing condition showed in Table (4.14), that the Mg concentrations varied between 18.5 and 32 with 22.6 mgL^{-1} as mean average value. Maximum concentration values 32 mgL^{-1} were recorded at location close to Tanjaro landfill area during March and May 2008 respectively Table (4.14) and this is due to heavy rainfall during spring time causing washing down of pollutants from Tanjaro landfill area towards Tanjaro River. While values for running condition ranged from 14.5 to 27 with 20.7 mgL^{-1} as mean value again the maximum concentration value was recorded at location close to landfill area during May, 2008. According to Langmuir (1997), the maximum concentration value for unpolluted surface water is 4.1 mgL^{-1} ,appendix(6), this shows that both standing and running conditions water in Tanjaro river were more than the acceptable level according to Langmuir (1997). Values obtained from this study were higher than those obtained by Mustafa (2006) on surface water from Tanjaro river with the mean value of 9 mgL^{-1} , but lower than concentration values in sewage wastewater samples ranged from 38.8, 67.9 and 51.3 mgL^{-1} as min., maxi., and mean values recorded by Mustafa (2006). Results were relatively lower than those obtained by Al- Othman (2002) on stream water along Wadi Hanifah with Magnesium concentration values ranged from 32 to 184 mgL^{-1} .

Magnesium concentration values for Tanjaro landfill leachate ranged from 13.37, 900 and 354.25 mgL^{-1} as min., maxi. and average mean values respectively. The values were above the typical concentration range of magnesium in municipal landfill leachate is from 30-500 mgL^{-1} Lee and Jones (1991b), appendix (9). According to Venkateswarlu (1999) report Magnesium concentration value above 300 mgL^{-1} is toxic.

Table (4.14): Magnesium (Mg^{+2}) concentration values (mgL^{-1}) represented as (mean ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	± SD
Tanjaro River									
2P	22	22	32.0	32.0	26.0			26.8	5.02
3P	20	20	18.0	19.5	22.0			20.0	1.27
4P	24	23	19.7	19.0	24.0			21.9	2.41
5P	23	23	18.9	19.0	23.5			21.5	2.32
6P	25	U	19.9	21.0	26.4			23.1	10.67
Mean	22.8	22.0	21.8	22.1	24.4			22.6	1.06
± SD	1.9	1.4	5.7	5.6	1.8			3.3	2.2
2R	U	23.0	17.5	27.0	16.8			21.1	10.31
3R	U	25.0	14.5	24.5	19.7			20.9	10.28
5R	U	23.0	19.5	24.0	19.0			21.4	9.80
6R	U	24.0	16.5	24.0	14.3			19.7	9.83
Mean		23.8	17.0	24.9	17.5			20.7	4.1
± SD		0.9	2.1	1.4	2.4			1.7	0.7
Tanjaro landfill leachate									
B	U	U	570	440	260	20.2	14.65	261.0	239.27
C	U	U	780	675	370	19.2	13.37	371.5	343.64
D	U	U	900	720	452	25.9	53.5	430.3	381.89
Mean			750	611.7	360.7	21.8	27.2	354.3	331.83
± S. D			167.0	150.4	96.3	3.6	22.8	88.0	73.4
Well Waters									
Number One	20	19.5	27.5	10.0	10.0	10.5	10.0	15.4	7.02
Number Two	19	19.8	17.2	11.0	19.5	11.5	11.0	15.6	4.21
Number Three	18	18.9	15.7	12.0	14.0	39.0	30.0	21.1	9.80
Mean	19	19.4	20.1	11.0	14.5	20.3	17.0	17.3	3.47
± SD	1.00	0.5	6.4	1.00	4.8	16.2	11.3	5.8	5.9

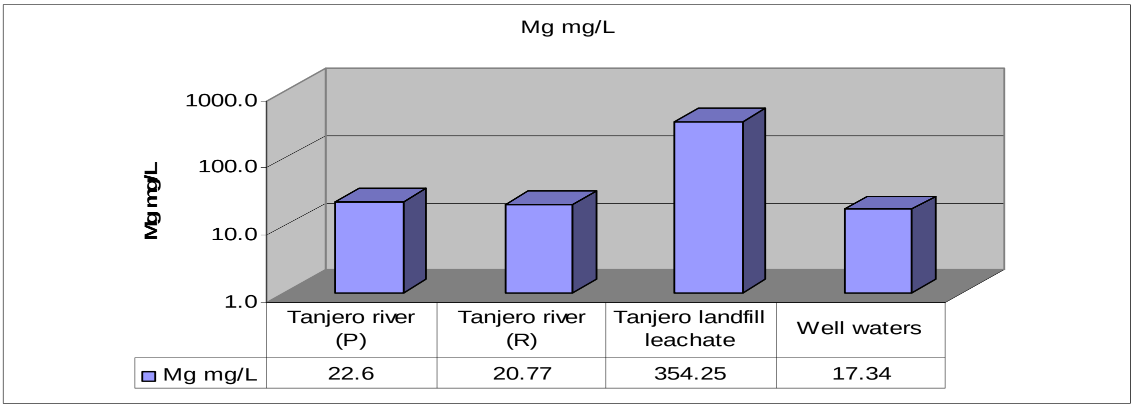


Figure (4.11): Demonstrates the average mean concentration Mg^{+2} (mgL^{-1}) values in Tanjaro River, Tanjaro landfill leachate and well water

The values were lower than those obtained by Vadillo et al., (1999) on the urban solid waste leachate of the Marbella landfill southern Spain 189.2 mgL^{-1}. While the values recorded by Kazuo Kamura (2002) on landfill leachate in the central part of Boso Peninsula in Japan were less than 20 mgL^{-1}.

Wells´ water values Table (4.14) ranged from 10 to 39 and 17.34 mgL^{-1}as mean values. The maximum concentration values were recorded at well water number three (House No.14) during Feb. 2004. Results showed the average mean Magnesium concentration values were more than permissible level recommended by Langmuir, (1997) which is equal to 7 mgL^{-1} in groundwater. Values were nearly similar to those obtained by Mustafa (2006) on groundwater in areas close to Tanjaro River. The results obtained from this study were lower than those obtained by Al-Abdulal'aly (1998) on Riyadh groundwater the values ranged from 41 to 53 mgL^{-1} .

4.2.3 Sodium (Na^+):

Sodium concentration values shows in Table (4.15) ranged from 13.2 to 319 with the average mean value of 53.6 mgL^{-1} for standing condition in Tanjaro river, the min. value 13.9 mgL^{-1} recorded at locations 6P, 3P, and 2P during March and May 2008 respectively while for running condition values ranged 6.58, 279 and 84.49 mgL^{-1} as min., maxi. and average mean values respectively, the maxi. value 279 mgL^{-1} recorded at 6P during Nov.2008. The values were higher than 6.3 mgL^{-1} permissible level recommended by Langmuir (1997), for sodium concentration values in surface water, appendix (6). The high concentration value of sodium for Tanjaro River was due to human activities (cultivation, using chemical fertilizer, pesticides and insecticides). The values obtained from this study are lower than those obtained by Khwakaram (2009) on Kostae cham raw wastewater ranged from 104.5 to 109.9 mgL^{-1} during 2007 and 2008 respectively. Values of this study close to those obtained by Mustafa (2002) on sewage wastewater for Sulaimani city with the mean value of 52.9 mgL^{-1} .

The average mean concentration values of sodium for Tanjaro river were 53.6 mgL^{-1} and 84.49 mgL^{-1} for standing and running condition during 2007, 2008 and 2009, Fig(4.12) , these values were higher than those results obtained by Mustafa (2002) on Tanjaro surface water and Nizar (2008) on Tanjaro River.

The sodium concentration for the Tanjaro landfill leachate Table (4.15), ranged from 59 to 11513 mgL^{-1} with the average mean value of 5144.3 mgL^{-1}.

Sodium concentration was above the Lee and Jones, (1991b) guideline for the typical concentration range of chemical composition of municipal landfill leachates 200-1500 mgL^{-1}, appendix (9). The results was also above the average value 2768.1 mgL^{-1} obtained by Vadillo et al., (1999) on the chemical composition of the urban solid waste leachate of the Marbella landfill (southern Spain). The results were nearly similar to those obtained by Kazuo, (2001) on solid waste leachate from Japan's landfill, with the mean sodium concentration value of 4810 mgL^{-1}.

For well water Table (4.15) adjacent to Tanjaro landfill site, the sodium concentration values were ranged from 43.4 to 205 mgL^{-1} with the average mean value of 120.9 mgL^{-1} . The results showed that sodium concentration values were more than the permissible level 30 mgL^{-1} recommended by Langmuir (1997) appendix (6). The maximum concentration value 205 mgL^{-1} for wells water adjacent to Tanjaro landfill site were close to the maximum recommended levels and standards of water quality, recommended by WHO (2006) 200-250 mgL^{-1} , EU (2004), 200 mgL^{-1} , Canada (2005) 200 mgL^{-1} and IQS (1996), 200 mgL^{-1} , appendix(4). Results were close to those obtained by Bocanegra, et al., (2001) on the contamination of ground water resulting from leachate in landfills at Mardel plata (Argentin) with the sodium concentration level ranged from 42 to 244 mgL^{-1} with the average mean value of 112.39 mgL^{-1}. The excess of sodium concentration in groundwater may be due to the effect of Tanjaro landfill leachate, and resulting from action of detergents. The maximum concentration value 205 mgL^{-1} recorded at well water number three, (House No.14 located at the Tanjaro village), may be due to the action of detergents.

Table (4.15): Sodium (Na^+) Concentration Values (mgL^{-1}) represented as (mean ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	± SD
Tanjaro River									
2P	53.3	65.8	48.0	13.2	72			50.5	23.02
3P	48.7	52.3	19.7	13.9	50			36.9	18.53
4P	49.3	57.2	26.3	19.5	54			41.3	17.22
5P	48.0	60.3	19.7	15.1	59			40.5	21.67
6P	55.9	U	13.2	46.1	319			108.5	131.80
Mean	51.1	58.9	25.4	21.5	111			53.6	35.89
± SD	3.4	5.7	13.5	13.9	116.6			30.6	48.3
2R	U	63.2	22.4	6.58	247			84.8	103.13
3R	U	62.7	15.8	6.65	201			71.5	84.04
5R	U	65.8	19.9	8.80	263			89.4	110.01
6R	U	67.1	16.5	6.58	279			92.3	117.69
Mean		64.7	18.6	7.2	247.5			84.5	111.48
± SD		2.1	3.1	1.1	33.6			9.9	15.8
Tanjaro landfill leachate									
B	U	U	5592	7236	2697	59	U	3896.0	3060.86
C	U	U	11513	10950	1546	215	U	6056.0	5339.46
D	U	U	6579	12171	2975	199	U	5481.0	4684.03
Mean			7894.7	10119.0	2406.0	157.7		5144.3	4643.17
± SD			3172.2	2570.3	757.64	85.8		1646.4	1461.4
Well Waters									
Number One	110	129	43.4	105	158	131.5	98.5	110.8	35.86
Number Two	105	98	59.9	105	65.8	148	101	97.6	29.14
Number Three	154	198	97.0	165	205	150	112	154.4	40.18
Mean	123	141.7	66.8	125.0	142.9	143.2	103.8	120.9	27.86
± SD	26.9	51.1	27.4	34.6	70.8	10.2	7.2	32.6	22.4

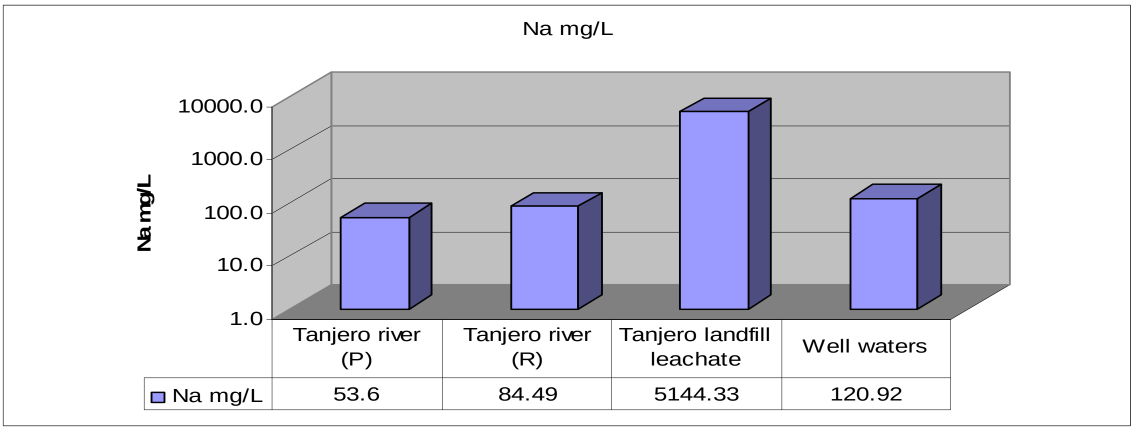


Figure (4.12): Demonstrates the average mean concentration value Na^+ (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

4.2.4 Potassium (K^+):

Potassium concentration values Table (4.16) ranged from 5.43 to 78.4 with the average mean value of 29.4 mgL^{-1} for standing condition, while for running condition the values ranged from 3.8 to 70.58 with the average mean value of 20.7 mgL^{-1}. The results showed that these concentrations are well above the permissible limits recommended by Langmuir (1997) who reported that concentration of potassium in surface water is equal to 2.3 mgL^{-1} , high potassium concentration levels in Tanjaro river may be due to the Tanjaro landfill site located close to Tanjaro river and its tributaries, using of chemical potassium fertilizer by farmers, and due to the pollution of Tanjaro river and its tributaries with sewage from Sulaimani city. Results were above those obtained by Mustafa (2006) on Tanjaro River while agree with those reported by Khwakaram (2009) who investigated the mean concentration values of potassium for Kostae cham raw wastewater 21.6 to 23.6 mgL^{-1} for 2007 and 2008 respectively.

The results for Tanjaro landfill leachate ranged from 70.6 to 4867 with the average mean value of 1861.5 mgL^{-1}. These results nearly agree with those reported by vadillo et al., (1999) on Marbella landfill leachate (south Spain), the average concentration value of potassium is equal to 1553 mgL^{-1}. While results obtained by Kazuo kamura (2001) on landfill leachate in Japan equal to 2070 mgL^{-1}.

Values of potassium concentrations for well water adjacent to Tanjaro landfill site ranged from 0.23 to 3.98 with the mean value of 1.2 mgL^{-1}. The results showed that these concentrations are within permissible limits Langmuir (1997) for ground water the maximum recommended level is 3 mgL^{-1} except well water number 1 during Oct. 2007 appendix(6). These results also agree with maximum recommended levels and standards of water quality, recommended by WHO (2006) and EU (2004), 10-12 mgL^{-1}, and agree with those reported by Mustafa (2006) on groundwater close to Tanjaro river basin. Lee et al, (2002) estimated the potassium concentration values for series wells located in the mine area in Korea with the mean value ranged from1.67 to 2.5 mgL^{-1}.

Table(4.16): Potassium(K^+)concentration values(mgL^{-1})represented as (mean±S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	± SD
Tanjaro River									
2P	8.5	47.0	5.4	7.7	78.4			29.4	32.38
3P	9.2	39.0	U	8.5	45.7			25.6	20.43
4P	9.2	78.4	U	15.2	69.8			43.1	36.66
5P	8.9	23.5	U	7.9	20.5			15.2	9.68
6P	13.2	U	U	47.1	3.5			21.3	19.92
Mean	9.8	46.9	5.4	17.3	43.6			29.4	18.64
± SD	1.9	23.1		16.9	31.8			18.4	12.6
2R	U	31.2	6.3	6.7	3.8			12.0	12.37
3R	U	54.9	4.3	8.6	7.6			18.9	22.51
5R	U	70.6	5.5	9.2	23.5			27.2	28.65
6R	U	62.7	4.3	8.9	23.5			24.9	25.52
Mean		54.9	5.1	8.4	14.6			20.7	23.09
± SD		17.0	0.9	1.1	10.4			7.4	7.8
Tanjaro landfill leachate									
B	U	U	3265	3154	1304	70.6	70.6	1572.8	1499.07
C	U	U	4867	4025	1895	78.0	70.6	2187.1	2097.88
D	U	U	3209	4812	502	89.9	510	1824.6	1918.49
Mean			3780	3997	1233.7	79.5	217	1861.5	1905.00
± SD			941.5	829.3	699.1	9.74	253.6	546.6	397.8
Well Waters									
Number One	3.98	2.79	2.30	0.34	0.7	0.63	0.58	1.6	1.41
Number Two	1.95	1.25	0.33	0.23	0.5	0.82	0.79	0.8	0.60
Number Three	2.0	1.89	0.75	0.45	0.65	0.95	0.8	1.1	0.62
Mean	2.6	2.0	1.1	0.3	0.6	0.8	0.7	1.2	0.83
± SD	1.16	0.77	1.04	0.11	0.10	0.16	0.12	0.50	0.48

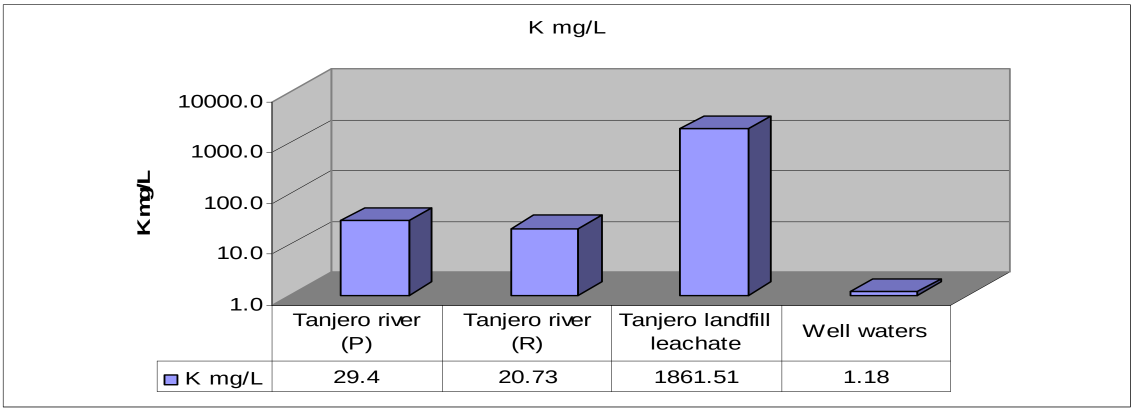


Figure (4.13): Demonstrates the average mean concentration K^+ (mgL^{-1}) values in Tanjaro River, Tanjaro landfill leachate and well water.

4.3: Major Anions

4.3.1: Chloride: (Cl^-)

Chloride concentration in Tanjaro river (standing condition) samples ranged from 18 to 59 with the average mean concentration value 35.4 mgL^{-1}, while for running condition ranged from 7.8 to 39.2 with the average mean concentration value of 24.48 mgL^{-1} . Chloride concentration in Tanjaro river (standing and running conditions) samples exceeds the recommended value in surface water. Table (4.17) this increase, could be due to the absence of dilution, thus the water evaporated while it was running, sewage effluents of Sulaimani city, industrial wastes from factories located on Tanjaro river and from polluted irrigation water with fertilizers, pesticides and insecticides used by farmers according to a report by Moore and Ramamorthy (1984) the main sources of chloride are industrial wastes, organic wastes and fertilizers. Results obtained from this study are lower than those recorded by Mustafa (2006) on sewage wastewater from Sulaimani city ranged from 55.8 to 75.8 mgL^{-1} for surface water and sewage wastewater respectively. The mean values of chloride concentration values for raw wastewater in Kostae chame were 63.7 and 67.3 mgL^{-1} for 2007 and 2008 respectively (Khwakaram 2009). Similar observations were made by Al-Saadi et al., (1979) and Sarker, et al., (1980). In the River Derwent (UK), the chloride concentration is relatively high due to the high atmospheric inputs and evapotranspiration Neal et al., (1998). The seasonal fluctuation of chloride occurs where the significant variation in the atmospheric temperature around the year directly affects the evaporation. The chloride concentrations peak in the summer because of increasing evaporation rate due to the higher air temperature and direct solar radiation MEPA, (1999).

Concentration of chloride ion in the Tanjaro landfill leachate Table (4.17) varying between 65 mgL^{-1} and 9008 mgL^{-1} with the average mean value of 3459 mgL^{-1} . Maximum concentration value 9008 mgL^{-1} was recorded during May 2008, while the lowest value recorded during Feb. 2009 may be due to seasonal fluctuation in the atmospheric temperature around the year directly affects the evaporation. The results of this study exceed the standard values recommended by Lee and Jones (1991 b) appendix (9) the typical concentration values of chloride ranged from 100 to 2000 mgL^{-1} for municipal landfill leachates.

Table (4.17): Chloride (Cl^-) concentration values (mgL^{-1}) represented as (mean ± S.D) during the study period.

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	± SD	
Tanjaro River										
2P	42.2	31.6	19.0	40.0	20.0			30.6	10.84	
3P	34.3	34.0	U	38.0	35.0			35.3	15.88	
4P	37.2	34.0	U	36.0	34.0			35.3	15.85	
5P	34.9	36.0	U	38.0	36.0			36.2	16.24	
6P	35.5	U	U	59.0	18.0			37.5	25.17	
Mean	36.8	33.9	19.0	42.2	28.6			35.4	5.68	
± SD	3.2	1.8		9.5	8.8			5.8	3.9	
2R	U	32.0	16.0	39.2	16.0			25.8	15.35	
3R	U	36.0	7.9	38.0	16.0			24.5	16.89	
5R	U	35.0	9.8	37.0	15.0			24.2	16.13	
6R	U	34.0	7.8	35.0	17.0			23.5	15.58	
Mean		34.3	10.4	37.3	16.0			24.5	13.30	
± SD		1.7	3.9	1.8	0.8			2.1	1.3	
Tanjaro Landfill Leachate										
B	U	U	5931	6710	6725	65	95	3905	3439	
C	U	U	4291	4397	659	97	84	1905	2050	
D	U	U	4501	9008	9000	68	260	4567	4242	
Mean			4907	6705	5461	76.7	146.3	3459	3124	
± SD			892.4	23	4311	17.67	98.59	1525	1808	
Well Waters										
Number One	20.7	20.5	19.9	15.2	5.7	5.5	7.8	13.6	7.09	
Number Two	25.0	24.0	20.7	40.8	8.0	5.0	5.7	18.5	13.11	
Number Three	19.9	20.7	18.6	19.9	9.4	31.9	20.9	20.2	6.54	
Mean	21.9	21.7	19.7	25.3	7.7	14.1	11.5	17.4	6.41	
± SD	2.74	1.97	1.06	13.63	1.87	15.39	8.24	6.41	6.03	

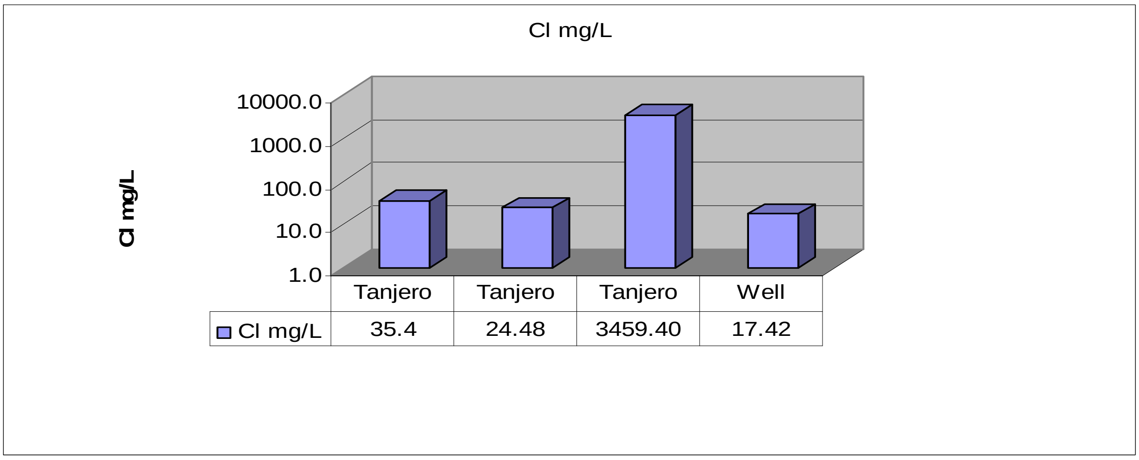


Figure (4.14): Demonstrates the average mean concentration Cl^- (mgL^{-1}) values Tanjaro River, Tanjaro Landfill Leachate and Well water.

The results of this study is less than those obtained by Vadillo et al., (1999) on the Urban solid waste leachate of the Morbella landfill (Spain), with the mean average concentration value of chloride 4652.7 mgL^{-1}, while the standard value recommended according to (Spain) standards is 2000 mgL^{-1} .

Concentration of chloride ion in well water adjacent to Tanjaro landfill site ranged between 5 mgL^{-1} and 40.8 mgL-1 with the average mean value of 17.42 mgL^{-1}, the chloride (Cl^-) concentration values were within the recommended value 20 mgL^{-1} Langmuir (1997), appendix (6), except samples from well number 2 and well number 3 during May 2008 and Feb. 2009 respectively. Results from this study were less than those obtained by Mustafa (2006) on ground water close to Tanjaro village ranged from 106 to 115.4 mgL^{-1} for wet and dry season respectively. Bocangra et al., (2001) in landfills at Mardel plata (Argentina) on groundwater contaminated with landfill leachate, chloride concentration values ranged from 39 to 303 mgL^{-1} with the mean value of 86.07 mgL^{-1} . High chloride levels in groundwater can contribute significantly to infiltration by sewage. The presence of high concentrations of chloride and nitrogenous material together in water supplies may signal of the possible pollution from human or animal wastes. According to Al- Hassany, (2003) report, high chloride concentration in groundwater of AL-Dora in Baghdad city may be due to domestic rather than agricultural.

High concentration of chloride in drinking water (from groundwater) which may be due to use of salts containing high levels of chloride ions has increased tremendously, it could be due to the excessive use of chloride as a disinfectant in various processes of water purification to make it fit for human consumption as drinking water.

4.3.2 Sulfate (SO_4^{-2}):

The results in Table (4.18) shows the sulfate (SO_4^{-2}) concentration values recorded in Tanjaro River from 53 mgL^{-1} to 122 mgL^{-1} with mean average value of 77.8 mgL^{-1} for standing condition, while for running condition the recorded values ranged from 31.7 mgL^{-1} to 81.9 mgL^{-1} and 56.84 mgL^{-1} as average mean value. Samples from location number 6P during Nov. 2008 (standing condition) records a relatively higher sulfate concentration value of 122 mgL^{-1} , and this was due to location of 6P which is close to active gravel and sand open cast mining activities. Tanjaro river samples of both standing and running conditions are characterized by high (SO_4^{-2}) content that is higher than permissible level recommended by Langmuir, (1997) concentration of sulfate value for surface water should not exceed 30 mgL^{-1}. The sulfate (SO_4^{-2}) concentration was initially extremely high on account of the use of fertilizers, pesticides in farming areas close to Tanjaro River. In these areas domestic and sewage effluents from Sulaimani city is discharged directly into Tanjaro River. Finally Tanjaro landfill site regarded as one of the main sources of contamination of Tanjaro River with sulfate (SO_4^{-2}) which is due to the penetrating of rainwater through waste deposits (especially industrial wastes), sulfates from industrial wastes can be discharged into Tanjaro River. The results of this study were higher than those obtained by Mustafa (2006) on Tanjaro surface water 32 mgL^{-1} to 72 mgL^{-1} with the mean value of 53.7 mgL^{-1}. While the values were less than those obtained by Nizar (2008) on Tanjaro River 70.08 mgL^{-1} to 227.52 with the mean value of 168.17 mgL^{-1} . Sayo (2005) Alaro River is receiving industrial effluent as a point source the level of sulfate in the effluent was 52 mgL^{-1} , level of sulfate in the effluent could be ascribed to the use of sulphuric acid or sulphate salts, which are commonly used in several industries. It was comparatively lower than the sulfate levels of 662 mgL^{-1} , 257 mgL^{-1} and 168 mgL^{-1} reported from other pollution studies elsewhere in rivers receiving industrial wastewater or effluents of higher sulfate contents (Seleznev and Selezeva, 1999; Stamatis, 1999; River and Litvinov, 1997.

The values of sulfate concentration for Tanjaro landfill leachate were ranged from 131 mgL^{-1} to 1105 mgL^{-1} with the average mean value of 459.2 mgL^{-1}, high concentration values of sulfate recorded for leachate was due to municipal solid waste disposal especially industrial wastes which contains high level of sulfate compounds, the leachate was produced by the rainfall during the storm contains high level of sulfate concentration. The results showed that, sulfate concentration values for Tanjaro landfill leachate are above the permissible limits recommended by Lee and Jones (1991) on the chemical composition of municipal landfill leachates the typical concentration ranged from 10 to 1000 mgL^{-1}. The results of this study nearly agree with those reported by Vadillo et al., (1999) on the urban solid waste leachate of the Marbella landfill (Southern Spain) were determined with the average value of 419.2 mgL^{-1}.

Sample from well water number one Table (4.18) during Nov. 2008 is the only recorded sulfate concentration 33 mgL^{-1} in the permissible range 30 mgL^{-1} according to Langmuir (1997) others are contaminated with sulfate, because they range between (43 – 181 mgL^{-1}).

Table (4.18): Sulfate (SO_4^{2-}) concentration values (mgL^{-1}) represented as (mean ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	± SD
Tanjaro River									
2P	69.3	69.5		53.0	100.7			73.1	19.94
3P	64.0	74.0		80.1	85.9			76.0	9.36
4P	68.0	75.8		81.5	86.7			78.0	8.02
5P	68.0	78.0		84.9	87.0			79.5	8.56
6P	67.9	72.0		67.5	122.0			82.4	26.51
Mean	67.4	73.8		73.4	96.5			77.8	12.79
± SD	2.01	3.29		13.17	15.54			8.50	6.85
2R		72.8	43.5	42.1	41.0			49.9	15.33
3R		77.9	33.1	81.9	41.2			58.5	24.96
5R		79.4	45.9	69.9	43.5			59.7	17.75
6R		74.1	31.7	78.8	52.7			59.3	21.64
Mean		76.1	38.6	68.2	44.6			56.8	18.09
± SD		3.11	7.19	18.11	5.52			8.48	6.63
Tanjaro Landfill Leachate									
B			819.6	359	275	334	143	386.1	256.3
C			999.7	497	321	498	131	489.3	323.0
D			1105	249	230	561	367	502.4	361.7
Mean			974.8	368.3	275.3	464.3	213.7	459.3	303.3
± SD			144.3	124.2	45.50	117.1	132.9	112.8	38.98
Well Water									
Number One	60.0	59.0	80.5	50.3	33.0	43.8	43.0	52.8	15.45
Number Two	110	120.0	54.6	95.8	118	47.3	47.9	84.8	33.61
Number Three	57.5	50.7	134	181.0	48.4	157.4	160.5	112.8	58.35
Mean	75.8	76.6	89.7	109.0	66.5	82.8	83.8	83.5	13.47
± SD	29.62	37.84	40.49	66.35	45.29	64.59	66.47	50.09	15.42

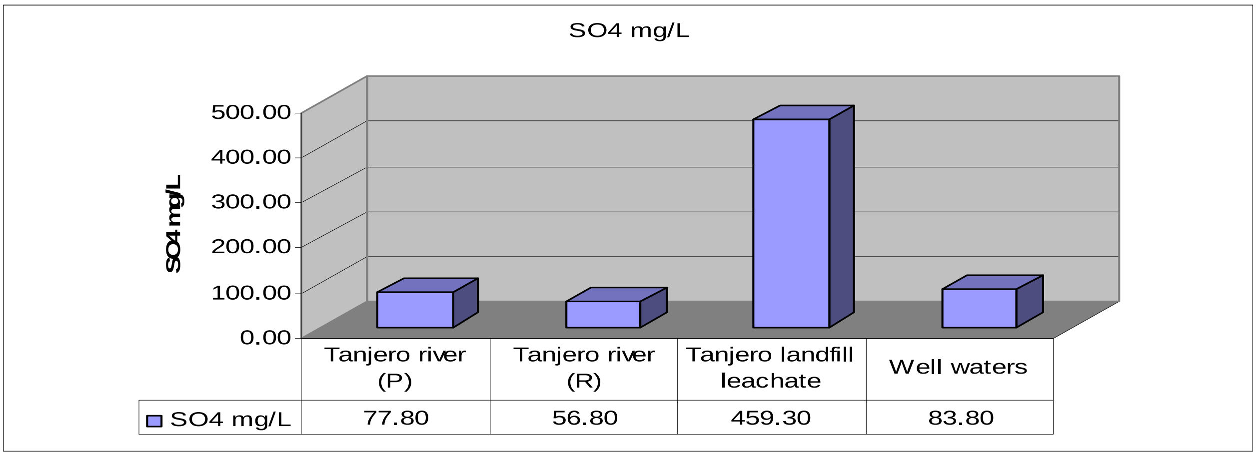


Figure (4.15): Demonstrates the average mean $SO4^{2-}$ concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water

High sulfate concentration in nearly all well water samples reflect the effect of Tanjaro landfill site which is close to wells′ water which is regarded to be the main source of well waters pollution, domestic uses of detergents and cleaners represent the other sources of sulfate in wells water.

The values of this study agree with those reported by Mustafa (2006) on groundwater in Tanjaro area during wet season with the mean value of 86.6 mgL^{-1} while lower than those obtained by Muhammad (2004) in Sarchnar spring/ Sulaimani the values ranged from 24 to 524 mgL^{-1} ,the values also were lower than those obtained by Nabi (2005) in some well waters in Arbil city which ranged from 50 to 520 mgL^{-1}, on well water in Halabja Sulaimani recorded from 85 to 733.5 mgL^{-1}, Muhammed (2008).

4.3.3 Phosphate (PO_4^{-3}):

The results in Table (4.19) shows the values of phosphate (PO_4^{-3}) in Tanjaro River standing condition which varied between 4.3 mgL^{-1} and 19.3 mgL^{-1} with the average mean value 8.8 mgL^{-1} whereas those of running condition ranged between 2.5 mgL^{-1} and 17.9 mgL^{-1} with the average mean value 8.2 mgL^{-1}. It is noted that there is a sharp increase in the concentration of phosphate at location 6P and 5R for both standing and running condition respectively. Phosphate was found in the present study at a significant high level along the Tanjaro River, due to the inputs from sewage works, since sewage effluent is a major source of phosphate. The untreated (raw) sewage effluent is directly discharged into Tanjaro River. These findings appear to be characteristic of municipal sewage point source discharges, as stated by Saad and Antoine (1978 and 1982) sewage disposal in the canal or river lead to increase phosphate content. This agrees with findings reported by Neal et al., (2000) who indicated that concentrations of soluble reactive phosphorus and total phosphorus increase considerably just downstream of the sewage works along the river Kennet U.K. as a result of a point source input.

Location (6P) shows a higher phosphate concentration this could be related to an increase in anthropogenic activity, receiving a large amount of drainage from agricultural lands close to this location and from direct effect of Sulaimani sewage effluents on Tanjaro River and its tributaries. On the other hand location 5R is adjacent to Tanjaro landfill site, high phosphate concentration related to receiving of a large amount of leachate from Tanjaro landfill site during heavy rainfall. The average mean phosphate concentration value Fig (4.16) in both standing and running conditions in Tanjaro river wastewater samples were within the permissible limits of typical ranges in the sewage effluents 5-50 mgL^{-1} according to Pescod, (1992) while exceeds the MEPA, (1992) standard of phosphate 3 mgL^{-1} for direct discharge of sewage, appendix (8). The result of this study was higher than those in previous studies Nizar (2008) on Tanjaro River the values ranged from 0.04 to 10.21 mgL^{-1} , Yahya (2008) on Erbil wastewater ranged from 0.42 to1.3 mgL^{-1}, Mustafa (2006) on Sulaimani sewage ranged from 4.67 to 6.77 mgL^{-1} and Tanjaro River from 0.34 to 1.23 mgL^{-1}, Ali (2003) on sewage wastewater within Erbil city from 17.91 to 100.4 µg/L. On the other hand, results were lower than those recorded by Khwakaram (2009) on untreated raw wastewater from Kostae cham with the mean concentration value higher than 16 mgL^{-1}. According to Kiely (1997) report, the high phosphate concentration in the wastewater may be attributed to many sources including, detergents, fertilizers, human excreta and food residues. Lind, (1979) and Hammer (1986) concluded that the minimum concentration values of phosphate refer to the capacity of the aquatic plant to absorb and store their need of phosphate for their growth while the removal mechanisms for phosphorus include chemical adsorption, precipitation and biological transformation (Sakadevan and Bavor 1998).

The concentration values of phosphate (PO_4^{-3}) in Tanjaro landfill leachate varied between ND (not detected) and 86.6 mgL^{-1} with the average mean value of 27 mgL^{-1} . The results showed that these concentrations are greater than the permissible limits which were recommended by Lee and Jones (1991b).

Concentration of phosphate in wells waters ranged between 0.1 and 0.35 mgL^{-1} with the average mean value of 0.2 mgL^{-1}. The results of this study showed that concentration of phosphate in well water especially adjacent to landfill site and in the village are higher than the permissible limits recommended by Langmuir, (1997) for ground water quality. This result was similar to the previous study by Mustafa (2006) on groundwater in Tanjaro area and its basin. While the results were higher than those obtained by Muhammed (2008) on Halabja well water 0.05 – 4.29 mgL^{-1} and lower than those recorded by Muhammed (2004) on Sarchnar, spring 0.06 to 9.97 µg/L, Nabi (2005) on some well water within Erbil city (ND to 1.14 µg/L). Phosphate concentrations in groundwater will reflect the effect of urban wastewater, sewage disposal, detergents used for washing, intensive agricultural activities and due to the Tanjaro landfill site adjacent to well waters through leachate migration which contains harmful metals and substances downward into groundwater.

Table (4. 19): Phosphate (PO_4^{3-}) concentration values (mgL^{-1}) represent as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	5.2	4.3	U	13.4	5.1			7.0	4.86
3P	5.5	5.9	U	18.8	6.5			9.2	6.92
4P	6.4	5.0	U	17.5	6.0			8.7	6.41
5P	4.5	8.0	U	19.0	7.0			9.6	7.03
6P	4.7	6.8	U	19.3	6.5			9.3	7.16
Mean	5.3	6.0		17.6	6.2			8.8	5.90
± S.D	0.75	1.46		2.45	0.72			1.34	0.81
2R	U	5.0	3.3	10.2	9.0			6.9	4.17
3R	U	4.3	2.5	16.3	9.6			8.2	6.49
5R	U	4.2	3.8	17.9	10.9			9.2	7.08
6R	U	5.3	4.0	15.5	9.2			8.5	5.87
Mean		4.7	3.4	15.0	9.7			8.2	5.27
± S.D		0.54	0.67	3.34	0.85			1.35	1.33
Tanjaro landfill leachate									
B	U	U	67.5	ND	0.5	13.3	ND	27.1	25.13
C	U	U	86.6	ND	ND	0.2	ND	43.4	32.72
D	U	U	67.5	ND	ND	ND	ND	67.5	25.51
Mean			73.9		0.5	6.7		27.0	40.68
± S. D			11.03			9.32		10.17	1.21
Well Waters									
Number One	0.3	0.32	0.15	0.30	0.21	0.35	0.30	0.3	0.07
Number Two	0.2	0.27	0.10	0.15	0.17	0.15	0.16	0.2	0.05
Number Three	0.3	0.3	0.25	0.29	0.30	0.30	0.29	0.3	0.02
Mean	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.04
± S. D	0.05	0.03	0.08	0.08	0.07	0.10	0.08	0.07	0.03

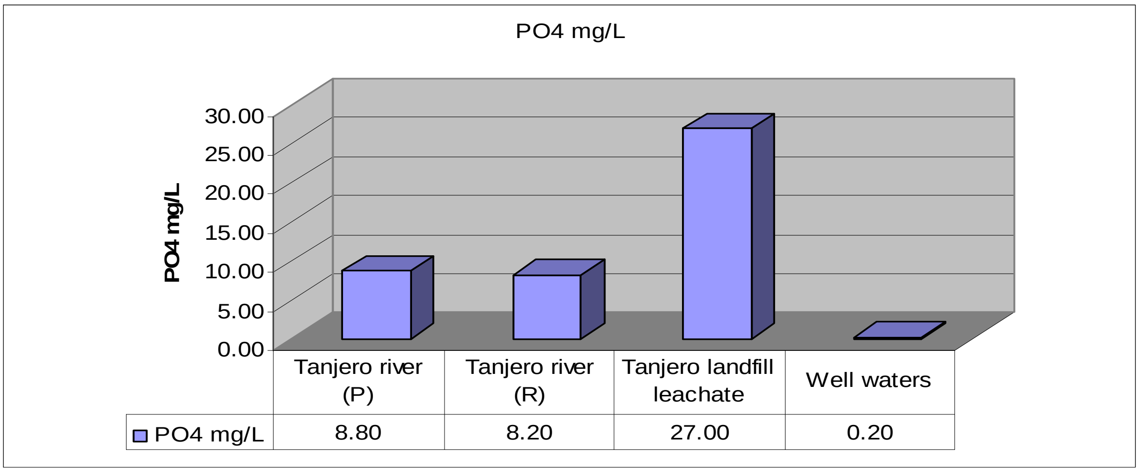


Figure (4.16): Demonstrates the average mean PO_4^{3-} concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

4.3.4 Bicarbonate (HCO_3^-) and Carbonate ($CO3^{2-}$):

There are different sources of bicarbonates in water among them, carbon- dioxide in atmosphere, carbonate rocks and from weathering of silicate minerals (Langmuir, 1997; Davis and Dewiest, 1966). The concentration of bicarbonates as a result of land application of waste water generally increases Gohil, (1989). Bicarbonates are generally present in the wastewater in relatively large quantities. These ions have a marked influence on the growth of crops and other vegetation supported on the land treatment sites. Decomposition of sulfate represents other sources of carbonate and bicarbonate in water Appelo and postma, (1999). The effect of bicarbonates in soil system is best judged by the concept of RSC {Residual sodium Carbonate} Eaton, (1950). Since Ca^{+2} and Mg^{+2} concentrations are governed by the presence of bicarbonate and carbonate ions. Residues sodium carbonate (RSC) criteria have been used for suitability of water for irrigation.

Bicarbonate (HCO_3^-) concentration, carbonate (CO_3^{2-}) concentration of Tanjaro river, Tanjaro landfill leachate and wells water (groundwater) are displayed in Tables (4.20), and (4.21) respectively.

Table (4.20): Demonstrates the mini. maxi. and mean concentration values of bicarbonate HCO_3^- (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

Sample location	Min. (mgL^{-1})	Maxi. (mgL^{-1})	Mean (mgL^{-1})
Tanjaro river			
Standing	646.8	746	688
Running	531	760	700
Tanjaro landfill leachate	343	4518	1388
Well water	167.5	651	281

It is observed that samples from all different locations taken during different period of time have a relatively high level of HCO_3^- concentration ranged from 688, 700, 1388 and 281 as average mean concentration values of HCO_3^- in Tanjaro river standing, running, Tanjaro landfill leachate and well water respectively. The high level concentration of bicarbonate may be due to land application of wastewater generally increases bicarbonates Gohil (1989). The amount of HCO_3^- introduced to the groundwater system through the degradation of organic matter can be very large. In general, the organic waste material is ultimately reduced to CO_2, CH_4 and H_2O (Baedecker and Apgar 1984; Christensen 1994; Ehriq 1983). Langmuir (1997) reported that waste of cements cause an increase of HCO_3^-.

Table (4.21): Demonstrates the mini. maxi. and mean concentration values of carbonate CO_3^{-2} (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

Sample location	Min. (mgL^{-1})	Maxi. (mgL^{-1})	Mean (mgL^{-1})
Tanjaro river			
Standing	0.14	9.9	2.5
-----------------------	---------------	-----------------	-----------------
Running	0.6	14.2	2.1
Tanjaro landfill leachate	125	283	189
Well water	0.03	10.3	4.3

4.4: Nitrogen Compounds:

4.4.1: Nitrate Nitrogen (NO_3^-)

According to Dowdesweel, (1984), nitrate is reduced biochemically to nitrite (NO_2^-) under anaerobic conditions by denitrification, while the nitrite ion is oxidized to nitrate quickly. Nitrate is an important nutrient for aquatic plants. The balance of nitrate in a water system is strongly depending upon processes such as nitrification, nitrate reduction, denitrification and eutrophication, (Golterman 1975, Tebbutt, 2006; Brown 1989; House et al., 1994; and Mackenzie 2003).

The current MCLG (Maximum contaminant level goals) for nitrate in Drinking water is 10 mgL^{-1} and that for nitrite 1 mgL^{-1} , both are measured as nitrogen EPA (1991). The high nitrate values in ground water are probably due to the application of fertilizers. Fresh groundwater is usually low of nitrate Valiela, (1983), but agricultural and urban contributions may produce very high groundwater nitrate values Hernandez- et al (1993), in addition to agrochemicals and animal wastes, sewage disposal represents other source of nitrate pollution (Yuce et al., 2006, and Rao et al., 1996). However, the occurrence of high concentrations of nitrate in groundwater may indicate the presence of another contamination, such as pathogenic organisms.

The primary adverse health effect associated with human exposure to nitrate or nitrites, is methemoglobinemia. Nitrate contamination is also responsible for several other diseases such as cancer and birth defect Spalding and Exner (1993).

Nitrate concentration of Tanjaro River, and well waters samples were displayed in Table (4.22). Almost all nitrate concentration values in Tanjaro River were higher than 50 mgL^{-1} except location 2R (46.8 mgL^{-1}) during Nov. 2007. The Value 50 mgL^{-1} is the value set by the WHO, (2001) in their guidelines appendix (6). The value 40 mgL^{-1} set by Russian standards in their guide lines for aquatic life Chapman and Kimstach, (1996). The minimum and maximum values for nitrate concentration were recorded for standing, and running conditions for Tanjaro River which ranged from 68 to 223.6 mgL^{-1} and from 46.8 to 1758 mgL^{-1} during October and Nov. 2007 and 2008 respectively. This clearly illustrates the impact of agricultural practices in these areas, sewage disposal, high nitrate concentration in sewage effluents of Sulaimani city as a consequences of domestic sewage that is discarded from households, cleaning products are synthetic detergents, and due to the presence of landfill site close to Tanjaro River. The average values for nitrate concentration for this study exceeds those data obtained by Nizar (2008) on Tanjaro River the concentration values of nitrate ranged between 10.1 and 100 mgL^{-1} during June 2007. Khwakaram (2009) reported the mean values of nitrate concentrations for raw waste water samples of Kostay cham 30.73 and 32.76 mgL^{-1}. Mustafa (2006) for Tanjaro sewage water, locations were located behind Quaradakh bridge the value ranged from 39.4 to 67.6 mgL^{-1}, Yahya (2008) for Erbil wastewater from 0.48 to 9210 ($\mu g\ NO_3.NL^{-1)}$.

Nitrate concentration in well waters ranged from 19.8 to 51.2 mgL^{-1} with the mean value of 39.5 mgL^{-1} , these results are similar to those detected by Mustafa (2006) for well waters located close to Tanjaro river, the mean concentration values for nitrate ranged from 37.7 to 42.1 mgL^{-1} for wet and dry seasons respectively.

The values were greater than those detected by Muhammed (2008) on Halabja well water the average mean nitrate concentration values ranged from 0.83 to 8.40 mgL^{-1}.

Table: (4.22): Demonstrates the mini. maxi. and mean values of Nitrate (NO^-_3) in Tanjaro River, and well waters:

Sample location	Min. mgL^{-1}	Maxi. mgL^{-1}	Mean mgL^{-1}
Tanjaro River			
Standing	68	223.6	110.8
----------	-----------	-------------	--------------
Running	46.8	1758	523.9
Well water	19.8	51.2	39.5

High nitrate concentration values in well water results from.

- Leaking of sewage wastewater.
- It is noted that high nitrate concentration was more in well number one close to landfill site.
- Manure which is high in nitrate is used as fertilizer hence large amounts of nitrates find their way into ground water.
- The influence of water recharge from Tanjaro River to ground water.

4.4.2: Nitrite Nitrogen (NO_2^-)

The nitrite concentration value in Tanjaro River standing condition ranged from 0.04 to 1.1 mgL^{-1} with the mean value of 0.2 and from 0.07 to 0.23 mgL^{-1} with the mean value of 0.16 mgL^{-1} for running condition as shown in Table (4.23) and Fig (4.17). All Tanjaro river samples exceed the permissible values according to WHO, (2006) and EU, (2004), moreover the concentration values of nitrite (NO_2^-) in Tanjaro river samples exceed the permissible values for Fisheries and Aquatic life Chapman and Kimstach, (1996) Appendix (11).

The maximum value of nitrite concentration was 0.23 mgL^{-1} recorded during May 2008 Table (4.23), this may be due to the decrease in temperature, which influenced ammonification and denitrification rate's speed. These findings are similar to those reported by Khwakaram (2009) for raw (untreated) wastewater samples of Kostae cham, the mean value of nitrite concentration for raw wastewater were 0.103 and 0.117mg L^{-1} in

2007 and 2008. Mustafa (2006) for Tanjaro sewage water were 0.163 – 0.27 mgL^{-1} and was less than those obtained by Yahya (2008) for Erbil wastewater channel which ranged from 23.3 to 1672 µg NO_2-$N.L^{-1}$, while exceed results detected by Kamees (1979) in sewage effluents of Sulaimani city with maximum value of 0.067 mgL^{-1} and Shekha (1994) for main sewage channel of Erbil city with the maximum value of 0.086 mgL^{-1} . Pollution of Tanjaro River and its tributaries by nitrite (NO_2^-) results from:

- Sewage disposal, Elhatip and Güllü (2005), Güllbahar and Elhatip (2005); Hem (1985).
- Pollution comes from fertilizers used in agricultural activities Yuce et al., (2006).
- Possibly, pollution comes from Tanjaro landfill leachate, especially during seasonal pollution due to leachate run off coming from Tanjaro landfill site.

The nitrite (NO_2^-) concentration values for Tanjaro landfill leachate ranged from 0.1-1.2 mgL^{-1} with the average mean value of 0.72 mgL^{-1} , the minimum concentration nitrite value was recorded during may 2008 Table (4.23) due to the dilution effect of rainfall, nitrite (NO_2^-) concentration in Tanjaro landfill leachate is less than that of Kahrizak landfill leachate in Tehran 1.53 $mg.L^{-1}$ Torbian et al., (2004). An increase in nitrite concentration values in landfill leachate can be linked to the impact input of raw leachate from this site (landfill) and also due to the absence of dissolved oxygen possibility due to pollution by organic and inorganic matters which finally cause toxic conditions.

The nitrite (NO_2^{2-}) concentration values for well water ranged from 0.03 to 0.05 mgL^{-1} with the mean average value of 0.04 mgL^{-1} , these findings are similar to those reported by Muhammed (2008) on well waters in Halabja/ Sulaimani with the mean value of 0.05 mg $NO_2.N.L^{-1}$, Mustafa (2006) reported for ground water in Tanjaro area close to Tanjaro river, a mean concentration values for nitrite NO_2^-which was ranged from 0.07 to 0.08 mgL^{-1} for wet and dry season respectively. Well waters number 1,2 and 3 showed nitrite NO_2^{2-} concentration values within acceptable limits according to WHO (2006), EU, (2004),appendix (4).

Table (4.23): Nitrite (NO^{-2}) concentration values (mgL^{-1}) represented as (mean, ± S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	0.06	0.04	U	0.07	0.08			0.06	0.03	
3P	0.05	0.09	U	0.22	0.10			0.12	0.08	
4P	0.09	0.08	U	0.20	0.09			0.12	0.07	
5P	0.09	1.10	U	0.90	0.10			0.55	0.52	
6P	0.09	U	U	0.19	0.10			0.13	0.08	
Mean	0.07	0.32		0.32	0.09			0.20	0.14	
± S.D	0.02	0.52		0.33	0.01			0.22	0.25	
2R	U	0.07	0.07	0.23	0.2			0.14	0.10	
3R	U	0.11	0.11	0.18	0.2			0.15	0.08	
5R	U	0.16	0.18	0.20	0.2			0.19	0.08	
6R	U	0.20	0.19	0.09	0.1			0.15	0.08	
Mean		0.1	0.1	0.2	0.2			0.16	0.02	
± S.D		0.06	0.06	0.06	0.05			0.06	0.00	
Tanjaro landfill leachate										
B	U	U	1.13	0.4	0.75	0.6	0.5	0.68	0.40	
C	U	U	0.10	0.6	0.70	0.61	0.6	0.53	0.33	
D	U	U	1.21	0.9	0.98	0.89	0.8	0.97	0.49	
Mean			0.8	0.6	0.8	0.7	0.7	0.72	0.08	
± S. D			0.62	0.25	0.15	0.16	0.18	0.27	0.20	
Well Waters										
Number One	0.04	0.05	0.03	0.05	0.05	0.04	0.03	0.04	0.01	
Number Two	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.00	
Number Three	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.00	
Mean	0.03	0.04	0.036	0.04	0.04	0.04	0.03	0.04	0.00	
± S. D	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.04	0.00	

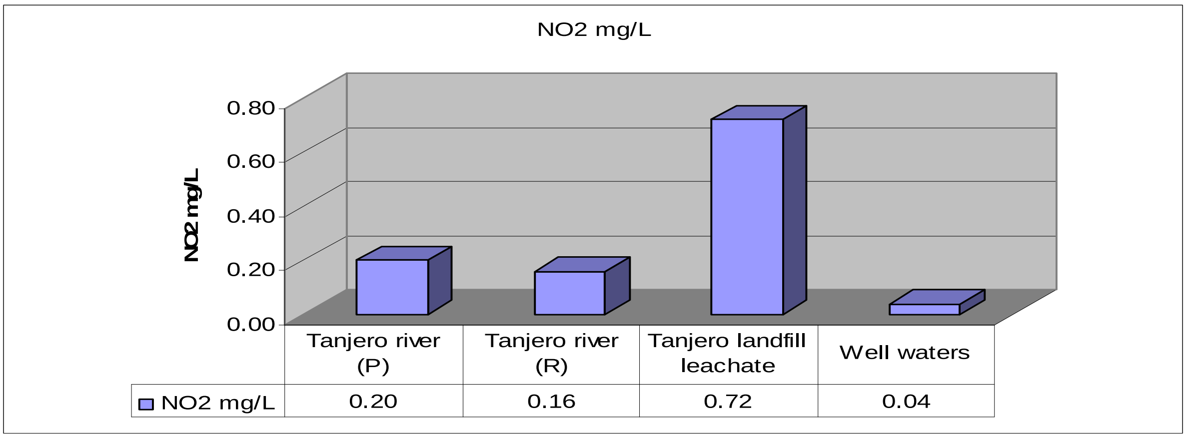


Figure (4.17): Demonstrates the average mean NO^{2-} concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

4.4.3 Ammonium (NH_4^+):

According to different standards of water quality, natural levels of ammonium concentration level in groundwater and surface water are usually below 0.2 mgL^1. According to WHO (2006), its existence in water is an indicator of possible pollution of sewage and animal waste by bacteria.

Results of NH_4-N concentration in Tanjaro River ranged from 0.92 to 0.94 mgL^{-1} with the mean value of 0.93 mgL^{-1} for standing condition and from 0.80 to 1.75 mgL^{-1} with the mean value of 1.1 mgL^{-1} for running condition Table (4.24). The results of this investigation were higher than that obtained by Yahya (2008) for Erbil wastewater 4.2-24.9 µg/L NH_4-N.L^{-1}, whereas it was less than the data obtained by Mustafa (2006) in Tanjaro River 69-73 mg NH_4. N.L^{-1}.

Table (4.24): Demonstrates the minimum, maximum and mean values of Ammonium in Tanjaro River, Tanjaro landfill leachate and well water.

Sample location	Min. (mgL^{-1})	Maxi. (mgL^{-1})	Mean (mgL^{-1})
Tanjaro River			
Standing	0.92	0.94	0.93
	------------------------	------	----------------
Running	0.80	1.74	1.10
Tanjaro landfill leachate	0.18	0.22	0.20
Well waters	0.27	0.34	0.30

High concentrations of ammonium (NH_4^+) in Tanjaro River samples are probably due to:

- Sulaimani city sewage and industrial waste discharge into Tanjaro River, results agree with the data of Elhatip et al, (2005) who referred to the high concentration of ammonium concentration in Mamasin dam watershed in Turkey due to sewage discharge.
- Due to agricultural activities.
- Leachate from Tanjaro landfill site close to Tanjaro River.

Concentrations of ammonium in Tanjaro landfill leachate samples ranged from 0.18 to 0.22 mg.NH_4.NL$^-$, with the mean value of 0.20 mgL^{-1} , Table (4.24).
Upadhyay (2004) reported that the decline in ammonium concentration level with an increase in oxidizable nitrogen form indicated that nitrification took place. The results of this study was lower than that of Jorstad et al., (2004) at Sydney, Australia for landfill leachate contaminated aquifer, for leachate impact on groundwater during July 2001 and February 2002 ranged from 0.1 to 54.2 with mean value of 15.5 mgL^{-1} and from 0.3 to 34.5 with the mean value of 18.3 mgL^{-1} respectively.

Ammonium concentration values in well water samples ranged from 0.27 to 0.34 with the average mean value of 0.3 mg.NH_4.NL$^-$ this exceeded the permissible value in natural waters (Langmuir, 1997, McKenzie et al., 2001, Hem 1985 and Hamil and Bill 1986), which should not be more than 0.2 mgL^{-1}. High concentrations of ammonium in well water indicate pollution of well waters. The source of pollution may be related with municipal dumps, leachate arises primarily from rainfall and other precipitation as moisture percolates through the landfill. It reaches contaminants from the solid wastes and transports them to the groundwater in the vicinity of the landfill.

4.5: Heavy metals:

Heavy metals are natural components in soil. Many different definitions have been proposed some based on density, some on atomic number or atomic weight and some on chemical properties or toxicity. Lasat et al., (1998) stated that heavy metals are conventionally defined as elements with metallic properties (ductility, conductivity, stability, etc) and atomic number >20. The most common heavy metal contaminants are: Cd, Cr, Cu, Hg, Pb, and Zn. Toxic metals are an alternative term for heavy metals.

4.5.1 Lead (Pb):

The concentration of lead (Pb) in Tanjaro River, Tanjaro lanfill leachate and well waters are shown in Table (4.25) and Fig (4.18). In general it is observed that samples from all different locations taken during different period of time have a relatively high level of lead concentration. For Tanjaro river standing condition the value of (Pb) concentration ranged from 0.245 mgL^{-1} as minimum to 0.59 mgL^{-1} as maximum, with the mean value of 0.42 mgL^{-1} , while for running condition ranged 0.09, 0.49 and 0.35 mgL^{-1} for minimum, maximum and mean values respectively. This very high concentration level of (Pb) content in the majority of Tanjaro river samples illustrated the impact of the pollution from municipal solid waste which were dumped and from municipal wastewater from Sulaimani city. Municipal sewage effluent is considered to be one of the main contributors to surface, ground water, soil pollution. However the average mean concentration values of (Pb) for both condition, ranged from 0.35 to 0.42 mgL^{-1} fig (4.18) are well above the limit of Canadian standard of 0.001- 0.007 and Russian standard of 0.1 mgL^{-1} according to Chapman and Kimstach (1996) ,appendix (11). Tanjaro River can only be used for unrestricted agricultural irrigation appendix (12).

Results obtained from this study were higher than lead concentrations of Wadi Hanifah stream water which is between 0.5 to 125.3 µg/L Al- Othman (2002). Lead concentration in Tanjaro river samples also exceeded the level of Pb in the effluent Alaro River in Ibadan, Nigeria which is receiving industrial effluent as a point source.

Sayo (2005) estimated the sources of heavy metals from the effluents in Alaro River could probably be from the metal work, construction, engineering and agrochemical industries.

The concentration values of lead for Tanjaro landfill leachate ranged from 0.16 mgL^{-1}as minimum concentration value for location D during May 2008 due to the dilution effect of heavy rainfall during that period of time to 1.23 mgL^{-1} as maximum concentration value for location C during March 2008 with an overall mean value of 0.46 mgL^{-1} , Table (4.25) and Fig (4.18). The mean maximum value for lead (Pb) concentration in Tanjaro landfill leachate was 1.23 mgL^{-1} nearly similar to the result obtained by Torabian et al., (2004) of Tehran solid waste leachate 1.5 mgL^{-1}. While the concentration of (Pb) in Tanjaro landfill leachate exceeded the standard concentration ranges for components of Municipal landfill leachate according to Lee and Jones (1991b), appendix (9).

The concentration value for well waters ranged from 0.16 mgL^{-1} as minimum, 0.38 mgL^{-1} as maximum with the mean value of 0.28 mgL^{-1}, Mason (1996) reported that the natural waters seldom contain more than 5µg/L, despite the fact that much higher values have been reported. Lead concentration values in all well water samples exceeded those that are recommended by WHO (2006), EU (2006), Canadian standard (2006), IQS (2001) which is equal to 0.01 mgL^{-1} while for surface water its equal to 0.003 mgL^{-1} from different references (Langmuir 19770, WHO 2006, EU 2004, and Manharawi and Hafiz 1997) .

This very high concentration level of lead in well waters illustrated the impact of Tanjaro landfill leachate penetrated soil profile towards groundwater. Sadiq and Alam (1997) reported that the high levels of lead in drinking water consist mainly of corrosion products from lead service pipes, solders and household plumbing.

Table (4.25): Lead (Pb) Concentration Values (mgL^{-1}) represent as (mean, ± S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	0.51	0.29	0.33	0.45	0.25			0.37	0.11	
3P	0.45	0.49	0.52	0.41	0.40			0.45	0.05	
4P	0.44	0.38	0.42	0.40	0.41			0.41	0.02	
5P	0.27	0.44	0.48	0.45	0.45			0.42	0.08	
6P	0.43	U	0.53	0.59	0.25			0.45	0.24	
Mean	0.42	0.41	0.46	0.46	0.35			0.42	0.05	
± S.D	0.09	0.09	0.08	0.08	0.10			0.09	0.01	
2R	U	0.39	0.24	0.38	0.09			0.28	0.17	
3R	U	0.35	0.36	0.40	0.29			0.35	0.16	
5R	U	0.39	0.48	0.48	0.09			0.36	0.23	
6R	U	0.37	0.49	0.47	0.25			0.39	0.20	
Mean		0.37	0.39	0.43	0.18			0.35	0.11	
± S.D		0.02	0.12	0.05	0.10			0.07	0.04	
Tanjaro landfill leachate										
B	U	U	0.48	0.8	0.75	0.29	0.25	0.51	0.33	
C	U	U	1.23	0.36	0.30	0.26	0.26	0.48	0.42	
D	U	U	0.78	0.16	0.56	0.17	0.18	0.37	0.29	
Mean			0.83	0.44	0.53	0.24	0.23	0.46	0.25	
± S. D			0.38	0.33	0.23	0.06	0.04	0.21	0.15	
Well Waters										
Number One	0.35	0.35	0.28	0.32	0.16	0.29	0.26	0.29	0.07	
Number Two	0.34	0.33	0.3	0.38	0.32	0.25	0.31	0.32	0.04	
Number Three	0.24	0.25	0.21	0.21	0.22	0.29	0.25	0.24	0.03	
Mean	0.31	0.31	0.26	0.30	0.22	0.27	0.27	0.28	0.03	
± S. D	0.06	0.05	0.05	0.09	0.08	0.02	0.03	0.05	0.02	

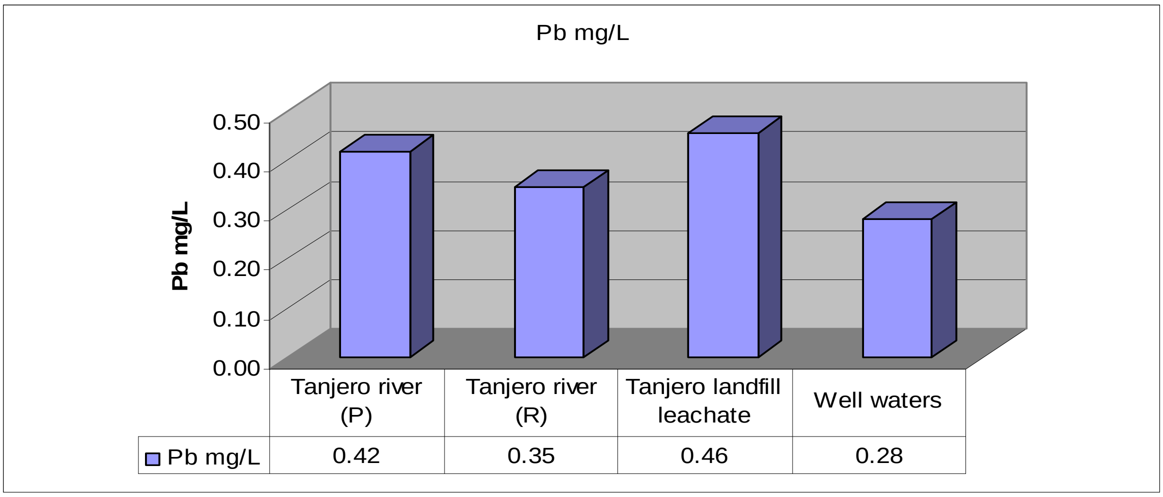


Figure (4.18): Demonstrates the average mean Pb concentration (mgL^{-1}) values in Tanjaro River, Tanjaro landfill leachate and well water.

4.5.2: Mercury (Hg):

Several towns and villages are contaminating Tanjaro River by thousands liters of wastewater every day. Among the inorganic contaminants of Tanjaro river water, heavy metals are getting importance for their non-degradable nature and often accumulate through tropic level causing a deleterious biological effect Jain (1978).

Mercury (Hg) concentration values Table (4.26) and Fig (4.19) for Tanjaro River standing condition samples ranged from non- detectable or at very low concentration to 1.22 and 0.59 mgL^{-1} as minimum, maximum and average mean values respectively. The maximum values 1.22 mgL^{-1} were recorded at location 2P during May. 2008, this is due to washing down landfill pollutants. While for running condition the values ranged from non- detected to maximum value 0.77 mgL^{-1} at location 2R during May, 2008, with the mean value of 0.34 mgL^{-1} .

Amma (2002) estimated that high concentrations of heavy metals in wastewater related to anthropogenic activities like segregation factories (gravel, sand, silt,…etc) oil purification factories, ultimate disposal of untreated waste effluents containing toxic metals. According to Abbasi (1998) the indiscriminate use of heavy metal containing fertilizers and pesticide in Agriculture resulted in deterioration of water quality for rivers rendering serious environmental problems posing threat on human beings.

The mean values of both standing and running conditions in Tanjaro river wastewater were 0.59 and 0.34 mgL^{-1} respectively even greater than the maximum value for mercury in sediments according to FFTC, (2006) which is equal to 0.3 mgL^{-1}.

The Mercury concentration values for Tanjaro landfill leachate Table (4.26) ranged from 0.001 to 83.3 mgL^{-1} with an overall mean of 12.1 mgL^{-1}. The increase of concentration values of mercury in Tanjaro landfill leachate is due to washout of pollutants from different kinds of wastes dumped in an open area in Tanjaro landfill site and accumulation of heavy metals in runoffs that carries them towards the leachate, pools. According to report by Manohar et al., (2002) and Patterson, (1985), environmental contamination due to mercury is caused by several industries, petrochemical, mining, painting and also agricultural sources such as fertilizers and fungicidal spray. Lee et al., (2005) studied the composition of the solid waste stream controls the composition of the leachate produced at a municipal solid waste landfill, the leachate has a high probability of containing potentially significant concentrations of hazardous chemicals arising from household and commercial use of these chemicals and through illegal dumping.

However, recent studies suggest that anthropologenic sources (Human causes) contribute the majority of mercury releases among those sources, according to (EPA 2007, USGS 2007, Clifton 2007 and Kitameera 1974) report 3% of Hg comes from waste disposal including municipal and hazardous waste, crematoria and sewage sludge incineration and (1,1%) from mercury production mainly from batteries. Mercury containing products contribute to the mercury emission at Municipal, hazardous waste and medical waste incinerators, and leachate from landfill. As long as mercury is used in industrial processes facilities will generate wastes that contain mercury and consumer products will contribute mercury upon disposal. As rainwater permeates through waste deposits at Tanjaro landfill site, it is inferred that various components dissolve as ions in pore water from wastes during the permeating process.

The concentrations of mercury in well waters close to Tanjaro landfill site were analysed. The results are shown in Table (4.26), the values of mercury concentrations in well waters close to Tanjaro landfill site ranged from 0.002 to 1.39 with an overall mean of 0.29 mgL^{-1} . The maximum concentration values 1.39, 0.54, 0.57 and 0.59 mgL^{-1} were recorded at location well water number one adjacent to Tanjaro landfill site during 9th. May 2008, 13th. March 2008, Nov. and Dec. 2007 respectively, the concentrations of mercury were not within the safe limit for drinking except in well water number three (House No. 14 in the village) with the concentration mercury value 0.0022 mgL^{-1} during 27th Nov. 2007. According to WHO (1996 and 2006), IQS (2001), Canadian standard (2006) the maximum recommended levels of mercury for water quality is 0.001 mgL^{-1} . While for EPA (2004) is 0.002 mgL^{-1} , appendix (4). In 1974 congress passed the drinking water Act, this law requires EPA to determine safe levels of chemicals in drinking water which do or may cause health problems. These non-enforceable levels, based solely on possible health risks and exposure are called Maximum Contaminant Level Goals (MCLG) for mercury has been set at (2PPb) according to EPA (2004), because EPA believes this level of protection would not cause any of the potential, health problems. Cry, et al., (2002) studied that mercury and its compounds are accumulative toxics and in small quantities are hazardous to human health.

Table (4.26): Mercury (Hg) Concentration Values (mgL^{-1}) represented as (mean, ± S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	0.2	0.25	0.53	1.22	ND			0.55	0.48	
3P	0.1	0.15	0.75	0.81	0.8			0.52	0.36	
4P	0.1	0.20	0.25	0.28	ND			0.21	0.12	
5P	0.7	0.85	0.90	0.90	0.9			0.86	0.07	
6P	0.5	U	0.7	0.72	ND			0.64	0.36	
Mean	0.33	0.36	0.62	0.78	0.85			0.6	0.2	
± S.D	0.29	0.33	0.25	0.34	0.07			0.25	0.11	
2R	U	0.5	ND	0.77	0.008			0.44	0.36	
3R	U	0.3	0.21	0.72	ND			0.41	0.30	
5R	U	0.6	0.45	0.50	ND			0.51	0.28	
6R	U	0.5	0.10	0.45	ND			0.35	0.25	
Mean		0.5	0.25	0.61	0.0			0.34	0.26	
± S.D		0.12	0.18	0.16				0.15	0.03	
Tanjaro landfill leachate										
B	U	U	83.3	1.15	0.12	0.100	0.07	16.95	31.40	
C	U	U	46.1	1.25	0.02	0.001	0.01	9.48	17.35	
D	U	U	47.7	1.53	0.15	0.003	0.05	9.89	17.93	
Mean			59.0	1.30	0.10	0.030	0.04	12.10	26.24	
± S. D			21.03	0.20	0.07	0.06	0.03	4.28	9.37	
Well Waters										
Number One	0.59	0.57	0.54	1.39	0.034	0.036	0.03	0.46	0.49	
Number Two	0.47	0.45	0.42	1.20	0.020	0.028	0.02	0.37	0.42	
Number Three	0.08	0.08	0.01	0.01	0.002	0.010	0.01	0.03	0.04	
Mean	0.38	0.36	0.32	0.86	0.02	0.024	0.06	0.29	0.31	
± S. D	0.27	0.26	0.28	0.75	0.02	0.01	0.01	0.23	0.26	

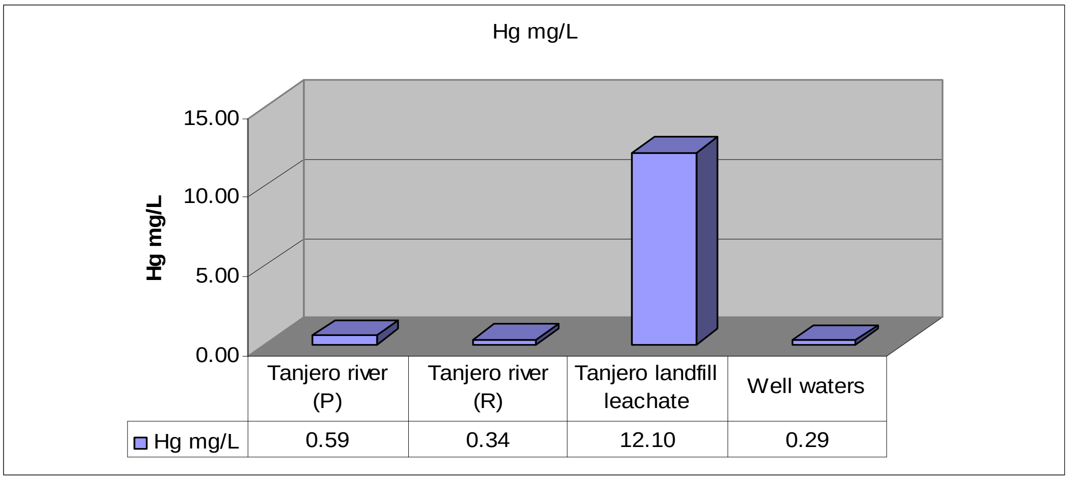


Figure (4.19): Demonstrates the average mean Hg concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water

4.5.3: Zinc (Zn):

The results of this study showed that zinc concentration values Table (4.27) and Fig (4.20) for Tanjaro river standing condition ranged (non-detected, 0.12 and 0.05 mgL^{-1} as minimum, maximum and mean values respectively recorded at location 4P during 13th. Nov. 2007 and maximum value recorded at location 2P during 27th. Oct. 2008. While for running condition ranged (non-detected, 0.076, and 0.042 mgL^{-1}) as minimum, maximum and mean values. Very low or non detected concentration values recorded at different locations due to high rainfall, runoff, most of the standing (pond) locations converted to running condition locations, because of the dilution effect of rainfall the concentration of zinc declined to very low or non detected values.

Results for zinc concentration values for Tanjaro river were lower than those obtained by Khwakaram (2009) on raw wastewater at Kostae cham 0.882 and 0.938 mgL^{1}during 2007 and 2008 respectively and also lower than results obtained by Mustafa (2006) on Tanjaro river (surface water and sewage wastewater with the mean values 27.2 mgL^{-1} and 0.99 mgL^{-1} respectively.

The results agreed with Al- Othman (2002) on the stream water along Wadi Hanifah 0.05 – 0.11 mgL^{-1}. None of the samples exceeded the maximum contaminant levels of 4000 µg/L and 1000 µg/L set by USAPA, Saudi Arabian standards for Irrigation (1986) and Al-Dhowalia (1986) and Saudi MEPA standards for direct discharge (1992). The results agreed with sewage wastewater standards according to ESC (1996) for sewage effluents 5 mgL^{-1}, and MEPA (1992) standard of direct discharge 10 mgL^{-1}, appendix (8). However the results for this study were lower than those obtained by Nabizadeh (2005) on samples collected from drainage channels through Tehran city, with the average concentration of Zinc was 0.638 mgL^{-1}. while Kar et al., (2008) studied surface water collected from river Ganga in west Bengal during 2004- 2005 with the average concentration of zinc ranged 0.012 – 0.37 mgL^{-1} . Krishna (2005) reported, high level of zinc in environment means zinc pollution, the main sources are, smelting, application of sewage sludge to land, using levels of agrochemicals such as fertilizer, pesticides in agriculture practices, and other anthropogenic process.

For Tanjaro landfill leachate the concentration of zinc values are displayed in table (4.27). The concentration value varies between 0.044 and 2.93 mgL^{-1} with an average value of 0.75 mgL^{-1}.

Table (4.27): Zinc (Zn) Concentration Values (mgL^{-1}) represented as (mean, ± S.D) during the studied period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	0.007	0.02	0.04	0.09	0.12			0.06	0.05	
3P	0.019	0.02	0.04	0.02	ND			0.02	0.01	
4P	0.029	ND	ND	ND	ND			0.03	0.01	
5P	0.021	0.04	ND	ND	ND			0.03	0.02	
6P	0.030	U	0.08	0.08	0.05			0.06	0.03	
Mean	0.021	0.03	0.05	0.06	0.09			0.05	0.03	
± S.D	0.01	0.01	0.02	0.04	0.05			0.03	0.02	
2R	U	0.02	0.01	ND	0.07			0.03	0.03	
3R	U	0.04	ND	0.04	0.08			0.05	0.03	
5R	U	ND	ND	ND	0.04			0.04	0.02	
6R	U	0.03	ND	ND	0.05			0.04	0.02	
Mean		0.03	0.01	0.04	0.06			0.04	0.02	
± S.D		0.01			0.02			0.01	0.01	
Tanjaro landfill leachate										
B	U	U	1.06	0.58	0.59	0.59	0.14	0.59	0.39	
C	U	U	2.93	0.69	0.19	0.04	0.05	0.78	1.07	
D	U	U	2.69	0.17	1.21	0.11	0.25	0.89	1.00	
Mean			2.22	0.48	0.66	0.25	0.14	0.75	0.85	
± S. D			1.02	0.27	0.51	0.30	0.10	0.44	0.35	
Well Waters										
Number One	0.21	0.20	0.11	0.13	0.05	0.155	0.15	0.14	0.05	
Number Two	0.17	0.19	0.10	0.09	0.15	0.195	0.18	0.15	0.04	
Number Three	0.40	0.42	0.35	0.39	0.45	0.155	0.15	0.33	0.13	
Mean	0.26	0.27	0.18	0.20	0.21	0.17	0.16	0.21	0.04	
± S. D	0.12	0.13	0.14	0.16	0.21	0.02	0.02	0.12	0.07	

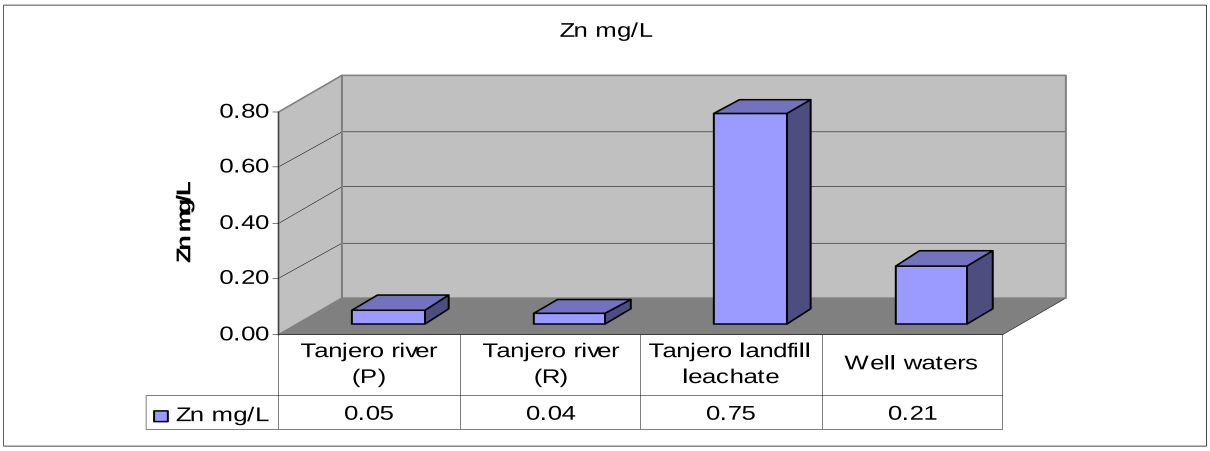


Figure (4.20): Demonstrates the average mean (Zn) concentration (mgL^{-1}) values in Tanjaro River, Tanjaro landfill leachate and well water.

These results were less than those obtained by Torbian et al., (2004) on Tehran solid waste leachate (Raw leachate) 5.665 mgL^{-1}, and lower than those obtained by Godson, et al., (2004) on Harcourt, Nigeria solid waste leachates 3 mgL^{-1}. According to Lee and Jones (1991 b), typical concentration range for zinc 0.5– 30 mgL^{-1}, appendix (9), the value of the lower allowable 0.5 mgL^{-1} is greater than the minimum concentration value of zinc obtained during this study, while the maximum allowable concentration (MAC) set by Lee and Jones (1991b), 30 mgL^{-1} is higher than the maximum concentration value of zinc obtained during this study

Table (4.27) shows, Zinc concentration values for well waters varies between 0.09 – 0.45 with the average mean value of 0.21 mgL^{-1}, values exceeded the recommended value in groundwater (0.05ppm) according to WHO (2006), appendix (6). Results from this study are lower than those obtained by Mustafa (2006) on groundwater during wet and dry seasons with the average value 31.8 – 24.1 mgL^{-1} respectively. While, the minimum value nearly similar to those obtained by Al-Othman (2002) on wadi Hanifah groundwater with the minimum value of 0.0018, but exceeded the maximum value 0.055 mgL^{-1}. Leachate from Tanjaro landfill may be responsible for Zinc pollution in wells water.

4.5.6: Copper: (Cu)

Results for Tanjaro River standing condition shown in Table (4.28) and Fig (4.21) concentration values ranged from 0.05 to 0.07 and 0.06 mgL^{-1} as mean value. While for running condition cupper concentration values ranged from 0.05 to 0.07 and 0.06 mgL^{-1} as mean value. The mean concentration values for both running and standing conditions were similar. All collected samples from Tanjaro river exceeds the maximum allowable concentrations for Fisheries and Aquatic life recommended by Canadian standard of 0.002-0.004 mgL^{-1} and Russian standard of 0.001 mgL^{-1}, according to Chapman and Kimstach (1996), appendix (11). The values obtained were well below the 400 µg/L set by SAS (2000), as well as bellow 500 µg/L EPA (2000) prescribed standards for irrigation water. The values obtained were well below the 200, 400 and 200 µg/L for Saudi MEPA (1992) standards for direct discharge, Saudi Arabia standards for irrigation (1986) and Al-Dhowalia (1986), and Irrigation water quality criteria according to FAO, (1985) and PEA (1981) respectively, appendix (12). Effluents from urban areas, sewage and industrial wastes from Sulaimani city were regarded as the main source of Tanjaro river pollution. It is noted that Tanjaro river water contained high level of copper due to surface drainage

from the runoff through Tanjaro landfill site, because waters in Tanjaro river can become heavily polluted depending on the proximity to point sources (Sulaimani sewage).
De Fillipis (1994) concluded that, sources of trace element are either natural (geologic and weathering processes) or man made. Scoullos (1983), and Alloway et al, (1997) reported that India waters can become significantly polluted through industrial discharge and sewage. Goncalves et al.,(1992); Lee et al, (2005) estimated that spatial distribution of the total concentrations of copper and zinc in sediments resulting from the increase in urbanization and industrial activities, Borovec (1996) concluded that material contamination of the bottom sediments in the Elbe River is a consequence of discharge of untreated sewer water.

Concentration values for cupper in Tanjaro River were less than values obtained by Khwakaram (2009) on untreated wastewater in Kostae cham ranged from 0.617 to 0.638 mgL^{-1} during (2007) and (2008) respectively. While Nazar (2008) estimated the concentration values for cupper in Tanjaro wastewater during Jan. 2008 ranged from 0.11 to 0.51 mgL^{-1}. The values did not agree with results obtained by Mustafa (2006) on Tanjaro surface water, groundwater (wet season), ground water (dry season) and sewage wastewater (0.53, 0.62, 0.66, 0.43 mgL^{-1}) respectively. The results agreed with those obtained by Nabizadeh et al., (2005) on urban runoff across drainage channel through Tehran city, the average concentration value was 0.035 mgL^{-1}, and the results obtained by Kar, et al., (2008) on Ganga river of India, the mean concentration value was detected in 20 and 36 samples (0.003 – 0.032 mgL^{-1}) respectively. The results exceeded the values obtained by Sayo, (2005) on Alaro river upstream which is receiving industrial effluent as a point source of pollution, the concentration value for cupper 0.005 mgL^{-1} agree with those obtained for down stream 0.092 mgL^{-1} , on the other hand the results of this study nearly similar to those obtained by Al- Othman (2002), on Wadi Hanifah stream water, the majority of copper values ranged 3.1 to 7 µg/L ,this is due to the effects of aeration, vegetation, purification by sun light and sediment interaction all affect the existences of heavy metals along Tanjaro river.

The concentration values for copper of Tanjaro landfill leachate Table (4.28) ranged from 0.06 to 0.34 and 0.15 mgL^{-1} as mean values. Minimum values were recorded for locations C (0.06) and D (0.06 mgL^{-1}) during 17th. Feb. 2009, due to dilution effects of rainfall during Feb. 2009. The level of copper in Tanjaro landfill leachate exceeded the effluent guideline for Saudi MEPA (1992) standards appendix (12) for direct discharge

Table (4.28): Copper (Cu) Concentration Values (mgL^{-1}) represented as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	0.067	0.07	0.06	0.07	0.05			0.06	0.01
3P	0.069	0.06	0.06	0.07	0.07			0.07	0.01
4P	0.067	0.07	0.07	0.07	0.07			0.07	0.00
5P	0.070	0.07	0.06	0.07	0.07			0.07	0.00
6P	0.058	U	0.06	0.05	0.05			0.06	0.02
Mean	0.066	0.07	0.06	0.06	0.06			0.06	0.00
± S.D	0.00	0.01	0.00	0.01	0.01			0.01	0.00
2R	U	0.07	0.07	0.06	0.05			0.06	0.03
3R	U	0.07	0.07	0.06	0.05			0.06	0.03
5R	U	0.06	0.07	0.07	0.05			0.06	0.03
6R	U	0.07	0.07	0.06	0.05			0.06	0.03
Mean		0.07	0.07	0.06	0.05			0.06	0.01
± S.D		0.01	0.01	0.01	0.01			0.01	0.01
Tanjaro landfill leachate									
B	U	U	0. 23	0.27	0.13	0.09	0.09	0.15	0.10
C	U	U	0.31	0.08	0.12	0.06	0.06	0.13	0.11
D	U	U	0.34	0.16	0.16	0.06	0.06	0.16	0.12
Mean			0.29	0.17	0.14	0.07	0.07	0.15	0.10
± S. D			0.02	0.10	0.02	0.02	0.02	0.03	0.03
Well Waters									
Number One	0.06	0.06	0.07	0.07	0.051	0.057		0.06	0.01
Number Two	0.05	0.05	0.06	0.06	0.051	0.057		0.05	0.00
Number Three	0.05	0.05	0.05	0.05	0.053	0.056		0.05	0.00
Mean	0.05	0.05	0.06	0.06	0.05	0.056		0.06	0.00
± S. D	0.01	0.01	0.01	0.01	0.00	0.00		0.01	0.00

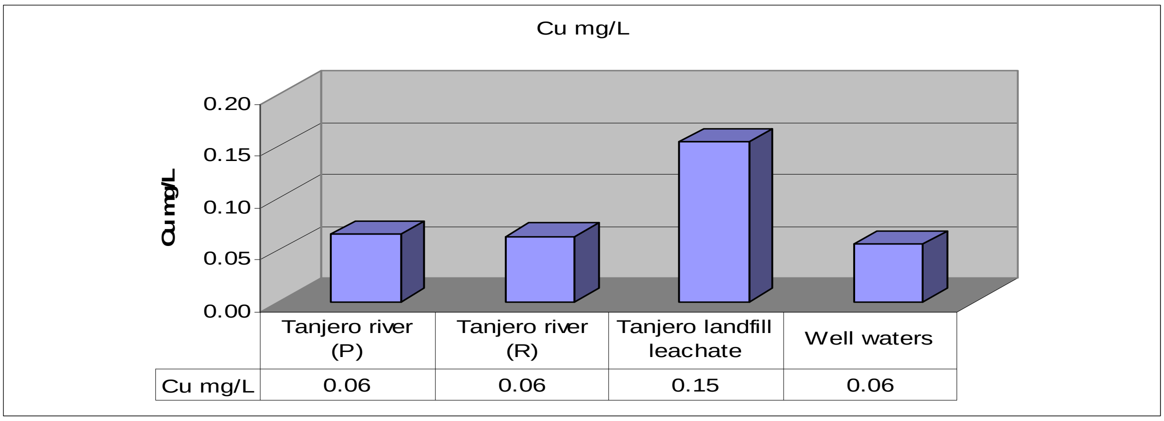


Figure (4.21): Demonstrates the average mean (Cu) concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water except samples collected during Feb. 2009 (0.06 mgL^{-1}) due to the dilution effect of rainfall. The values obtained for copper in leachate samples were similar to those obtained by Torbian et al., (2004) on solid waste leachate of Tehran 0.34 mgL^{-1} for raw leachate, while the values were within the permissible limits of recommended by Lee and Jones, (1991 b) for components of Municipal landfill leachate "typical" concentration range 0.02 - 1 mgL^{-1} , appendix (9).

Cupper (Cu) concentration values for well waters ranged 0.05, 0.07 and 0.06 mgL^{-1} for the minimum, maximum and mean values respectively, the highest value 0.07 mgL^{-1} were recorded for location well water number 1 adjacent to Tanjaro landfill site during March, May 2008 while lower values 0.05, 0.057 mgL^{-1} were recorded for location well water numbers 3 and 2 during Nov. 2008 and Feb. 2009 respectively Table (4.28). All ground water samples from well number 1,2 and 3 (especially well No. one with the value of 0.07 mgL^{-1}) exceeded recommended levels according to Crompton (1997) appendix(6), the maximum recommended levels of water quality for groundwater and surface water are 0.003 and 0.007 mgL^{-1} respectively.

Waters in wells located close to Tanjaro landfill site can become heavily polluted depending on the leachate movement down ward towards ground water and also due to the leakage of sewage wastewater to groundwater. According to Meybeck et al, (1989) the influences of human activities are reflected by elevated contents of Cr, Cd, Pb, Hg and Cu.

4.5.5 Manganese (Mn):

Table (4.29) and Fig (4.22) show the values of the manganese (Mn) concentration of Tanjaro river standing condition ranged 0.01, 1.78 and 0.15 mgL^{-1} as minimum, maximum and mean concentration values. The maximum value recorded at 6P (1.78 mgL^{-}) during Nov. 2008, this location is adjacent to the factories and active gravel, and sand open cast mine along site Tanjaro river. These values were less than those obtained by Khwakaram (2009) on Kostae cham wastewater which recorded 1.617 and 1.867 mgL^{-1} during 2007 and 2008 respectively. This may be due to the high level of inorganic material in raw wastewater Berry et al., (1980). The results of this study also were less than those obtained by Nizar (2008) on Tanjaro River, the Mn concentration level in the study area ranged from 0.08 to 3.9 mgL^{-1}. This is due to the direct discharge from different sewage effluents to Tanjaro River and its tributaries. While for running condition Table (4.29), the minimum concentration value was 0.01 mgL^{-1} for Tanjaro river and its tributaries which is within the recommended value 0.01 mgL^{-1} according to water Quality Assessments Chapman and Kimstach (1996) for fisheries and aquatic life appendix (11), while the maximum concentration value for both standing and running condition ranged from 1.78 to 0.51 mgL^{-1} respectively in Tanjaro river this exceeded the previous recommended standard values the levels were above the 200 µg/L for Saudi Arabian standards MEPA (1992) as well as 200 µg/L FAO (1985) for irrigation use.

These results were also higher than those obtained by Al- Othman (2002) on water stream along Wadi Hanifah were the manganese concentration values recorded at various locations ranged between 1.9 to 173.6 µg/L and those recorded by Kar et al., (2008) on surface water samples collected from river Gana west Bengal during 2004-2005 which ranged from 0.025- 2.72 mgL^{-1}.

Tanjaro landfill leachate samples showed the Mn concentration values Table (4.29) varied between 0.15, 23.3 and 4.75 mgL^{-1} as minimum, maximum and mean values. The results of this study is less than those obtained by vadillo et al., (1999), on the urban solid waste leachate of the Marbella landfill (Spain), the mean average concentration value of Mn 189.2 mgL^{-1} . While Kazuo (2002), on Landfill sites consisting mainly of solid wastes in Japan, the recorded values for Mn concentration in landfill leachate > 20 mgL^{-1} . The results of this study were less than the recommended standard values according to Lee and Jones (1991b), appendix (9). The typical concentration values of Mn ranged 30 to 500 mgL^{-1} for municipal landfill leachates. High concentration of various ions in leachate were due to, rain water penetrates through waste deposits at landfill sites, various components dissolve as ion in pore water from wastes during the permeating process Kazuo (2002).

In the well waters close to Tanjaro landfill dumps site, Mn concentration values, range 0.001, 0.05 and 0.01 mgL^{-1} as minimum, maximum and mean values respectively. The high values 0.05, 0.04 and 0.03 were recorded at location, well water number one adjacent to Tanjaro landfill site. The Mn concentration values were within the recommended value according to WHO (2006) 0.01 mgL^{-1} , IQS(2001) 0.1 mgL^{-1} and EPA (2004) 0.05 mgL^{-1}, appendix(6). Bocangra (2000) reported that concentrations of Mn and Fe are not considered as good indicators since these metals can appear for natural reasons. Results of this study were less than those obtained by Lee et al., (2005) on mine area in Korea where the mean average Mn concentration value was 1662 µg/L, concentration of Mn was beyond the Korean drinking water standards 300 µg/L, and less than those obtained by Kazuo (2002) on groundwater from well near landfill in Japan, Table (4.29): Manganese (Mn) Concentration Values (mgL^{-1}) represented as (mean ± S.D) during the study period

Location	Date of Sampling									
	2007		2008			2009				
	Oct	Nov.	March	May	Nov.	Feb	April			
	27	13	19	9	27	17	7	Mean	S.D. ±	
Tanjaro River										
2P	0.014	0.03	0.01	0.02	1.28			0.27	0.56	
3P	0.014	0.01	0.01	0.01	0.01			0.01	0.00	
4P	0.014	0.02	0.01	0.01	0.02			0.01	0.01	
5P	0.068	0.01	0.01	0.01	0.01			0.02	0.03	
6P	0.192	U	0.09	0.01	1.78			0.52	0.77	
Mean	0.06	0.014	0.03	0.01	0.62			0.15	0.26	
± S.D	0.08	0.01	0.04	0.00	0.85			0.20	0.37	
2R	U	0.02	0.02	0.01	0.07			0.03	0.03	
3R	U	0.01	0.01	0.01	0.28			0.08	0.12	
5R	U	0.07	0.21	0.32	0.47			0.27	0.19	
6R	U	0.01	0.40	0.35	0.51			0.32	0.23	
Mean		0.02	0.16	0.17	0.33			0.17	0.12	
± S.D		0.03	0.18	0.19	0.20			0.15	0.08	
Tanjaro landfill leachate										
B	U	U	11.9	1.5	1.8	1.8	0.75	3.55	4.20	
C	U	U	21.4	1.9	0.9	0.9	0.15	5.05	7.88	
D	U	U	23.3	1.4	1.7	0.5	1.32	5.64	8.52	
Mean			18.9	1.6	1.5	1.1	0.7	4.75	7.90	
± S. D			6.11	0.28	0.48	0.67	0.59	1.62	2.51	
Well Waters										
Number One	0.04	0.04	0.01	0.05	0.001	0.031	0.02	0.03	0.02	
Number Two	0.01	0.01	0.01	0.01	0.001	0.02	0.02	0.01	0.01	
Number Three	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.00	0.00	
Mean	0.017	0.017	0.007	0.02	0.001	0.017	0.014	0.01	0.01	
± S. D	0.02	0.02	0.01	0.03	0.00	0.01	0.01	0.01	0.01	

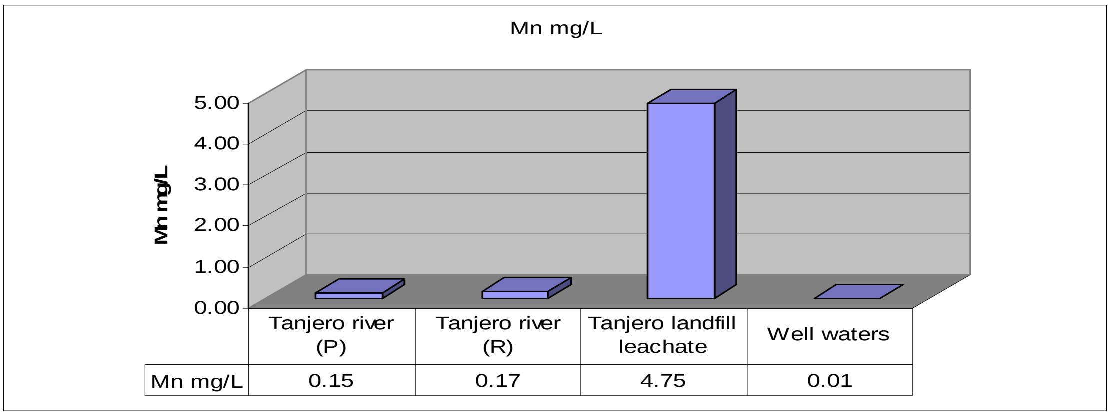


Figure (4.22): Demonstrates the average mean (Mn) concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

were Mn concentration value was 9 mgL^{-1}. The results of this study were nearly similar to those obtained by Al- Othman (2002) on Wadi Hanifah groundwater at different locations which ranged between 0.3, 67.3 and 10.3 μg/L as min., maxi, and mean values.

4.5.6 Chromium (Cr) :

During the present investigation, chromium concentration values Table (4.30) and Fig (4.23) for Tanjaro river (standing condition) ranged from non-detectable at locations 3P and 6P during May 2008 ,due to the dilution effects of rainfall, because both run offs water and sewage wastewater flow out to the Tanjaro river via the same channel. The maximum Cr concentration value was 0.44 mgL^{-1} at location 2P (close to Tanjaro landfill site) during Nov. 2008, with the mean value of 0.16 mgL^{-1} . While for running condition the values were ranged from 0.076 mgL^{-1} as minimum concentration value (at location 6R close to Qaradagh Bridge, 500m west of Tanjaro landfill site) to 0.41 mgL^{-1} at location 3R, Nov. 2008, with the mean value of 0.22 mgL^{-1}. Tanjaro river samples during the investigation showed pollution by Cr which exceed permissible value 0.02 – 0.002 mgL^{-1} and 0.02 – 0.005 mgL^{-1} , which is recommended by both Canadian and Russian guideline value for allowable concentrations of selected water quality variables for different uses (fisheries and Aquatic life) according to Chapmen and Kimstoch, (1996), appendix (11). Nizar (2008) estimated the minimum observed value of Cr as 0.02 mgL^{-1} during July 2007 and the maximum value was 3.3 mgL^{1} during Nov. 2007 for Tanjaro River.

Kar et al., (2008) concluded that the maximum mean concentration of Cr was 0.020 mgL^{-1} for surface water samples collected from river Ganga in west Bengal during 2004. The highest value 0.44 mgL^{-1},Table (4.30) of Cr in Tanjaro River for standing condition was due to the impact of the discharge of sewage wastewater from Sulaimani city, industrial discharge from 60 factories located on Tanjaro River and finally may be due to the location of Tanjaro landfill site close to the Tanjaro River.

Chromium concentration in Tanjaro landfill leachate ranged from 0.27mgL^{1} to 2mgL^{-1} and 0.7 mgL^{-1} as mean values. Chromium Cr concentration in landfill leachate samples exceeds, the concentration ranges for components of Municipal landfill leachate, typical concentration range 0.05 – 1 mgL^{-1} and the average 0.9 mgL^{-1} according to Lee and Jones (1991 b), appendix (9). The increase of concentration values of Cr for Tanjaro landfill leachate is because of washing out and accumulation of heavy metals in run-offs that carries them towards the leachate pond which located close to landfill site .

Chromium Cr concentration values for well waters ranged from 0.09 mgL^{-1} for well number 2 during May 2008 to 0.43 mgL^{-1} for the same well water during Nov. 2007 Table (4.30) as minimum and maximum values respectively with the mean value of 0.24 mgL^{-1} . The Cr content of the well waters was higher at the location close to the landfill site than the other sites. Natural waters, usually contain much lower levels than those obtained during this study, the maximum recommended levels and standards of water quality is 0.05 mgL^{-1} by WHO (2006) EUDWS (2005), IQS (2005), Canadian (2005) and 0.01 mgL^{-1} by (EPA 2004) respectively. There are some external effects which cause high concentration of Cr in well waters such as pollution due to the percolation of leachate movement down towards the ground water; according to Priestley (2002) pollution of groundwater may result from leakage of leachate.

Table (4.30): Chromium (Cr) concentration values (mgL^{-1}) represented as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	0.17	0.050	0.28	0.10	0.45			0.21	0.16
3P	0.05	0.144	0.19	ND	0.22			0.15	0.09
4P	0.12	0.122	0.12	0.11	0.20			0.14	0.04
5P	0.17	0.183	0.18	0.18	0.21			0.18	0.02
6P	0.05	U	0.09	ND	0.33			0.16	0.14
Mean	0.11	0.124	0.17	0.13	0.28			0.16	0.07
± S.D	0.06	0.06	0.07	0.04	0.11			0.07	0.02
2R	U	0.19	0.204	0.2	0.33			0.23	0.12
3R	U	0.08	0.206	0.2	0.41			0.23	0.15
5R	U	0.12	0.195	0.2	0.39			0.22	0.14
6R	U	0.08	0.317	0.1	0.37			0.22	0.16
Mean		0.12	0.230	0.2	0.37			0.22	0.11
± S.D		0.05	0.06	0.05	0.03			0.05	0.01
Tanjaro landfill leachate									
B	U	U	0.79	1.4	0.07	0.4	0.4	0.61	0.51
C	U	U	1.32	0.3	0.53	0.4	0.3	0.56	0.45
D	U	U	1.29	2.0	0.65	0.3	0.3	0.91	0.74
Mean			1.13	1.2	0.40	0.4	0.3	0.70	0.45
± S. D			0.30	0.86	0.31	0.04	0.07	0.32	0.33
Well Waters									
Number One	0.27	0.16	0.19	0.30	0.27	0.25	0.25	0.24	0.05
Number Two	0.39	0.43	0.10	0.09	0.25	0.23	0.22	0.24	0.13
Number Three	0.39	0.32	0.22	0.32	0.19	0.15	0.14	0.25	0.10
Mean	0.35	0.30	0.17	0.24	0.24	0.21	0.20	0.24	0.06
± S. D	0.07	0.14	0.06	0.13	0.04	0.05	0.06	0.08	0.04

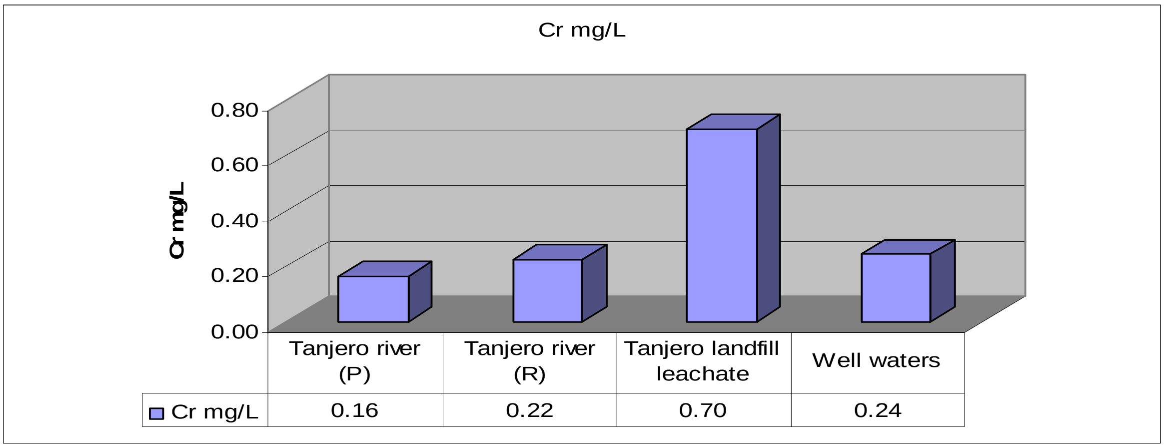


Figure (4.23): Demonstrates the average mean (Cr) concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water

4.5.7 Cadmium (Cd):

Cadmium (Cd) concentration values for this study Table (4.31) and Fig (4.24) ranged from 0.042 to 0.11 mgL^{-1} and as mean values 0.08 mgL^{-1} for Tanjaro river standing condition. While for running condition it ranged from 0.022 to 0.1, and 0.08 mgL^{1} as mean value. Cadmium concentration values in Tanjaro river for both standing and running condition samples exceeds the recommended value 0.003 mgL^{-1} according to WHO (2006), EU (2004), IQS (1996), appendix (11), and also exceeds the maximum allowable concentrations of selected water quality for fisheries and Aquatic life, according to Chapman and Kimstach (1996), appendix (11). This may be resulted from fresh inputs of raw sewage runoff from Sulaimani outlets and drainage from residential areas this gives rise to high pollution.

According to WHO (2006), cadmium is released to environment in wastewater and the diffuse pollution is caused by contamination from fertilizers and local air pollution. Alloway (1997), (Moore and Ramamoorthy, 1984), indicated that the level of cadmium in sediments is equal to 2 mg/kg, when cadmium compounds do bind to the sediments of rivers, they can be easily bioaccumulated or redissolved when sediments are disturbed, such as during flooding. Its tendency to accumulate in aquatic life is great in some species, low in others.

Cadmium concentration values for Tanjaro landfill leachate ranged from 0.017 mgL^{-1} to 0.43 mgL^{-1} and 0.12 mgL^{-1} as mean value. Higher concentration of cadmium in leachate is due to the composition of solid wastes which dumped daily in landfill site, which contains variety of industrial products, including electroplating, pigments, plastic stabilizers and batteries which were rich in Cd in their composition. Cadmium concentration value in Tanjaro landfill leachate exceeds the recommended value 0.001 – 0.1 mgL^{-1} as typical concentration range for components of municipal landfill leachate according to Lee and Jones (1991 b), appendix (9).

While for well waters, the cadmium concentration values ranged from 0.02 to 0.1 and 0.05 mgL^{-1} as mean value the high level of cadmium concentration in ground water samples indicate a high degree of contamination. The cadmium concentration values for well water exceeding the permissible level 0.003 and 0.005 mgL^{-1} according to WHO (2006), IQS (2001) and EUDWS (2005), EPA (2004), Canadian (2005), appendix (4).

Table (4.31): Cadmium (Cd) concentration values (mgL^{-1}) represented as (mean, ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	0.07	0.10	0.10	0.10	0.04			0.08	0.03
3P	0.07	0.10	0.08	0.09	0.09			0.09	0.01
4P	0.09	0.07	0.08	0.08	0.09			0.08	0.01
5P	0.11	0.09	0.08	0.09	0.09			0.09	0.01
6P	0.09	U	0.09	0.08	0.05			0.08	0.04
Mean	0.09	0.09	0.09	0.09	0.07			0.08	0.01
± S.D	0.02	0.01	0.01	0.01	0.03			0.01	0.01
2R	U	0.033	0.10	0.1	0.09			0.08	0.05
3R	U	0.022	0.08	0.1	0.09			0.07	0.04
5R	U	0.028	0.10	0.1	0.09			0.08	0.04
6R	U	0.039	0.09	0.1	0.10			0.08	0.04
Mean		0.03	0.09	0.1	0.09			0.08	0.03
± S.D		0.01	0.01	0.01	0.01			0.01	0.00
Tanjaro landfill leachate									
B	U	U	0.2	0.15	0.05	0.039	0.039	0.09	0.08
C	U	U	0.2	0.02	0.05	0.041	0.035	0.07	0.07
D	U	U	0.2	0.17	0.09	0.08	0.430	0.19	0.15
Mean			0.2	0.10	0.06	0.05	0.168	0.12	0.06
± S. D			0.00	0.08	0.02	0.02	0.23	0.07	0.09
Well Waters									
Number One	0.10	0.10	0.10	0.10	0.025	0.033	0.03	0.07	0.04
Number Two	0.09	0.09	0.09	0.09	0.031	0.037	0.03	0.07	0.03
Number Three	0.02	0.02	0.02	0.02	0.042	0.040	0.04	0.03	0.01
Mean	0.07	0.07	0.07	0.07	0.032	0.036	0.03	0.05	0.02
± S. D	0.04	0.04	0.04	0.04	0.01	0.00	0.01	0.03	0.02

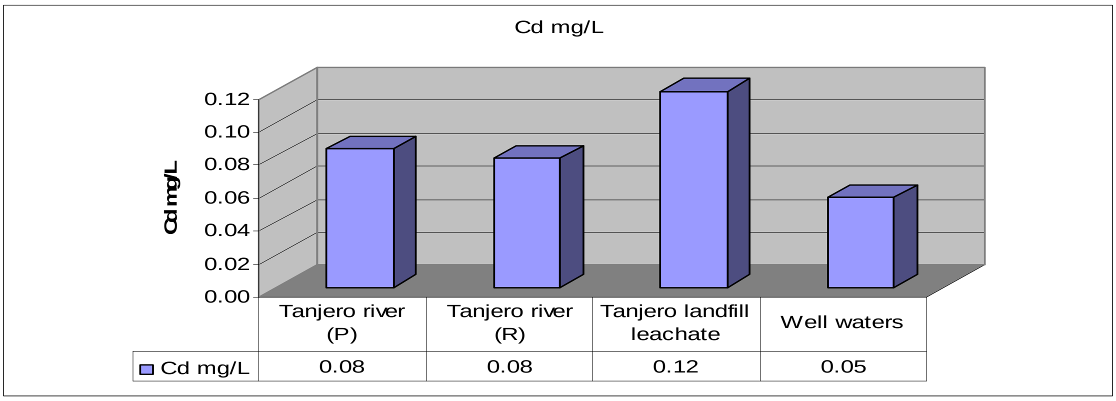


Figure (4.24): Demonstrates the average mean (Cd) concentration values (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water.

Pollution of groundwater in Tanjaro landfill area may result from leakage of leachate from landfill towards groundwater. In particular, cadmium can be released into drinking water from the corrosion of some galvanized plumbing and water main pipe materials. Some cadmium compounds are able to leach through soil to ground water. According to EPA (2004) the (MCLG) Maximum Contaminant Level Goals for cadmium has set at 5 ppb parts per billion because EPA believes this level of protection would not cause any of the potential health problems.

4.5.8 Iron: (Fe):

Results of the present study showed in Table (4.32) and Fig (4.25) for standing condition, the concentration values for iron (Fe) ranged from 0.025 to 0.125, with the mean value of 0.05 mgL^{-1}. The minimum value 0.025 mgL^{-1} recorded at location 2P during March 2008, almost all standing condition locations except 2P were converted to running condition locations due to heavy rainfall and runoff. While for running condition the values ranged between 0.025, 0.124 and 0.06 $mgL^{-1}$for minimum, maximum and mean values respectively. The minimum values were recorded at locations 2R, 3R during March 2008, while the maximum values were recorded at 5R (0.108 mgL^{-1}) and 6R (0.124 mgL^{-1}) locations, adjacent to Tanjaro landfill site and active gravel and sand open cast mining. The results obtained for Tanjaro river were relatively lower than those obtained by Khwakaram (2009) on Kostae cham, were the mean values of iron concentration in raw wastewater ranged from 1.011 to 1.147 mgL^{-1} , but the values were nearly similar to those obtained by Hussain (2005) on Dohuk wastewater and Othman (2006) on Erbil wastewater, while Nizar (2008) on Tanjaro wastewater obtained the value of iron concentration ranged from 2.13 to 2.55 mgL^{-1}. The results obtained for Tanjaro river were relatively lower than those obtained by Al- Othman (2002) on stream water samples along Wadi Hanifah with levels ranged between 0.507 and 6.041 mgL^{-1}. Tanjaro River had concentrations level of iron below, Saudi Arabian standards for irrigation (Ministry of Agriculture and water (1986), Al- Dhowalia (1986), FAO (1985), and USEPA (1981).

Golterman et al., (1978), estimated that iron is present in the wide variety of industrial wastewater including milling, chemical industrial wastewater, dye manufacture metal processing, textile mills, mining operations and petroleum refining.

Shah et al., (2005) reported that the highest concentrations of most of the heavy metals like (Fe) may be due to the discharge of heavy metal loaded industrial wastewater, and because none of the above factories and operations are available in Tanjaro river locations, this reason becomes the only explanation for low iron concentration of Tanjaro river.

The iron concentration in the Tanjaro landfill leachate at the study area Table (4.32) were ranged from 0.07 to 5.7 mgL^{-1} with the mean value of 2.40 mgL^{-1} , results were lower than the typical concentration range of iron in municipal landfill leachate which according to Lee and Jones (1991 b) is from 10 to 100 mgL^{-1} appendix (9). Results obtained were lower than those obtained by Torabian et al., (2004) on Tehran solid waste leachate (raw leachate) 41.88 mgL^{-1}. Bocangera et al., (2001) on leachate from landfills at Mardel Plata (Argentina) which is ranged from 0.54 to 5.2 mgL^{-1} this was nearly similar to the results obtained from this study.

The mean average concentrations of iron in well waters ranged between 0.026 to 0.65 mgL^{-1} , with the mean value 0.12 mgL^{-1} . The maximum value was recorded at well number one 0.65 adjacent to Tanjaro landfill site during Nov.2008. The mean average concentrations of iron in well waters were below the detection limit recommended by WHO (2006), and EPA (2004) level of 0.3 mgL^{-1} for potable uses, while the mean value concentrations of iron in well water adjacent to Tanjaro landfill site was 0.65 mgL^{-1} this concentration is above the permissible limits of recommended by WHO (2006), EPA (2004) and EUDWS (2005) appendix (4). These results disagree with those reported by Lee et al., (2005) on the ground water in the Korea mine area which ranged from 160-2280 µg/L with the mean iron concentration level of 661 µg/L. The results also disagree with those obtained by Al-Othman (2002), on ground water in Wadi Hanifah with the mean average value of 821.5 µg/L.

The high iron concentration levels for most of the well waters located in the studied area may be due to the discharge of heavy metal loaded industrial wastewater, Tanjaro landfill leachate infiltrated downward mixed with groundwater, and from municipal wastes. According to Diagomanlin et al., (2004), and Berry et al., (1980) the source of heavy metal (iron) in groundwater include raw household wastewater which may contain metals such as pharmaceutical, paint, battery and also vegetable matter and human excreta. These high concentrations can be attributed to the existence of the corroding, rusty iron pipes used for drawing water from these wells. Sadiq and Alam (1997) reported that the corrosion product of foundations was mixed with groundwater, hence increasing the levels of some trace elements.

Table (4.32): Iron (Fe) Concentration Values (mgL^{-1}) represented as (mean ± S.D) during the study period

Location	Date of Sampling								
	2007		2008			2009			
	Oct	Nov.	March	May	Nov.	Feb	April		
	27	13	19	9	27	17	7	Mean	S.D. ±
Tanjaro River									
2P	0.079	0.026	0.025	0.03	0.17			0.07	0.06
3P	0.028	0.027	U	0.03	0.03			0.03	0.01
4P	0.028	0.027	U	0.03	0.03			0.03	0.01
5P	0.028	0.028	U	0.07	0.09			0.05	0.03
6P	0.088	U	U	0.09	0.13			0.10	0.06
Mean	0.050	0.027	0.025	0.05	0.09			0.05	0.03
± S.D	0.03	0.03		0.03	0.06			0.03	0.03
2R	U	0.026	0.026	0.03	0.098			0.05	0.04
3R	U	0.027	0.025	0.03	0.109			0.05	0.04
5R	U	0.028	0.025	0.03	0.108			0.05	0.04
6R	U	0.040	0.080	0.09	0.124			0.08	0.05
Mean		0.03	0.039	0.04	0.11			0.06	0.04
± S.D		0.01	0.03	0.03	0.01			0.02	0.01
Tanjaro landfill leachate									
B	U	U	4.9	5.7	0.49	0.07	0.07	2.25	2.54
C	U	U	4.8	5.6	0.48	0.07	0.07	2.21	2.49
D	U	U	5.5	5.6	0.46	0.91	1.29	2.75	2.49
Mean			5.1	5.6	0.47	0.35	0.48	2.40	2.70
± S. D			0.38	0.06	0.02	0.48	0.70	0.33	0.29
Well Waters									
Number One	0.60	0.65	0.03	0.03	0.07	0.079	0.09	0.22	0.28
Number Two	0.09	0.09	0.03	0.03	0.07	0.077	0.08	0.07	0.03
Number Three	0.08	0.08	0.026	0.03	0.07	0.076	0.08	0.06	0.02
Mean	0.25	0.27	0.028	0.03	0.07	0.077	0.08	0.12	0.11
± S. D	0.30	0.33	0.039	0.00	0.00	0.065	0.01	0.09	0.15

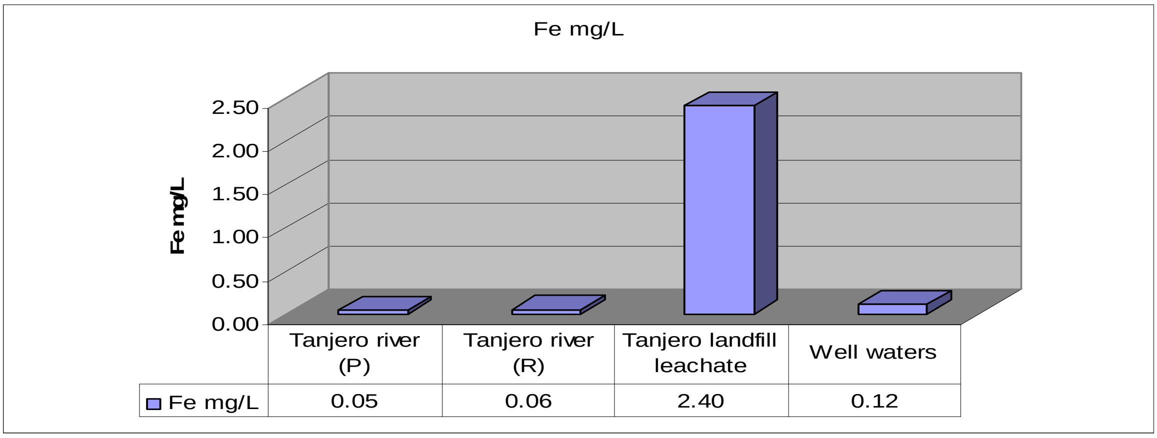


Fig (4.25): Demonstrates the average mean (Fe) concentration value (mgL^{-1}) in Tanjaro River, Tanjaro landfill leachate and well water

4.5.9: Aluminum (Al):

The aluminum concentration levels in the Tanjaro River Table (4.33) ranged between non detected to 0.02 mgL^{-1} with the mean value of 0.015 mgL^{-1} for standing condition while for running condition the value ranged from non-detected to 0.02 mgL^{-1} with the mean value of 0.012 mgL^{-1} respectively. Aluminum concentration levels of Tanjaro river were lower than the acceptable levels recommended by Saudi Arabia standards for irrigation Ministry of Agriculture and water (1986) and Al- Dhowalia (1986), 5000µg/L, appendix (12), and lower than permissible limits recommended by FAO (1985), and USEPA (1981) for irrigation water quality criteria 1000µg/L. The results of this study were lower than those obtained by Al- Othman (2002) on stream water samples along the Wadi Hanifah Saudi Arabia ranged from 0.04 to 1.399 mgL^{-1}.

Table (4.33): Demonstrates minimum, maximum and mean values of Aluminum (Al^{+3}) in Tanjaro river, Tanjaro landfill leachate and well water:

Sample location	Min. (mgL^{-1})	Maxi. (mgL^{-1})	Mean (mgL^{-1})
Tanjaro River			
Standing	ND	0.02	0.015
Running	ND	0.02	0.012
Tanjaro landfill leachate	ND	0.8	0.36
Well water	ND	0.003	0.003

While aluminum concentration values for Tanjaro landfill leachate ranged between non detected to 0.8 mgL^{-1} with mean value 0.36 mgL^{-1} , this value is considerably higher than the acceptable level recommended by Saudi standards for direct discharge, MEPA (1992), FAO (1985),and USPEA (1981) for irrigation water quality criteria.

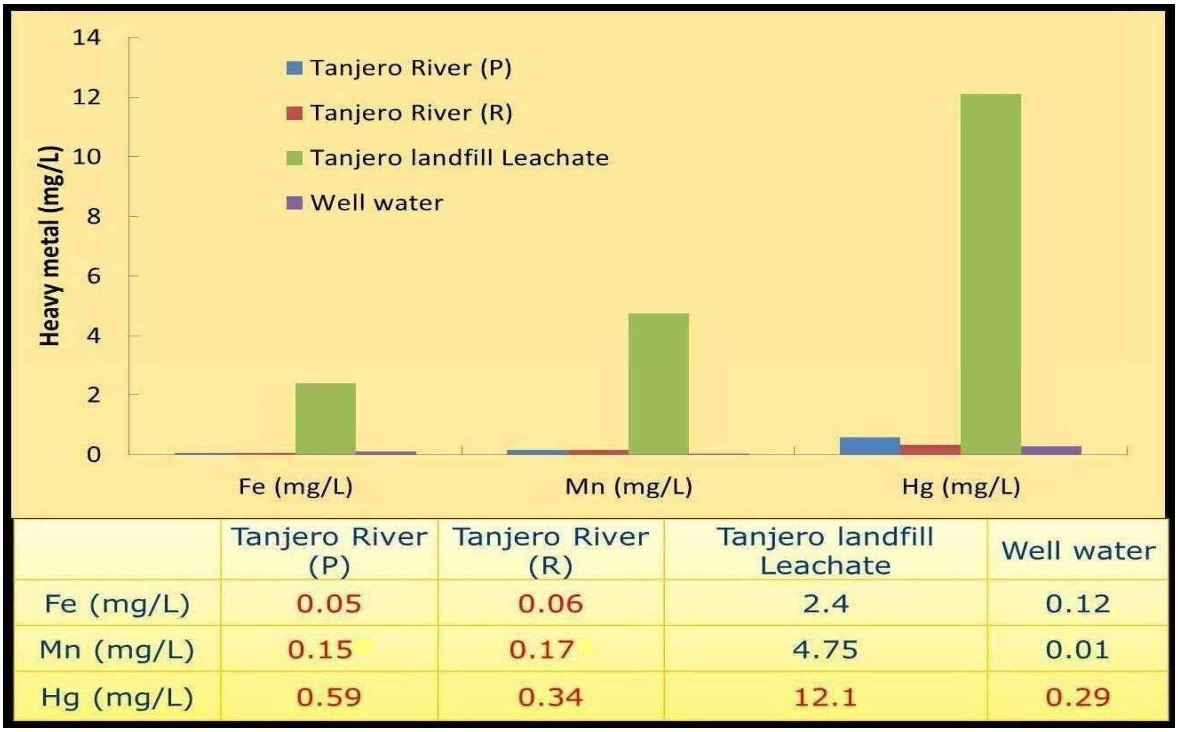
For well water, the values ranged from non -detected to 0.003 mgL^{-1} , aluminum concentration values were much lower than the acceptable levels recommended by WHO 2000 µg/L. Results of this study were lower than those obtained by Al-Othamn (2002) on wells waters of Wadi Hanifah which ranged from 261.3 to 1.3 and 29.9 µg/L as mean values. According to Lee et al., (2005) aluminum concentration values at zinc mine area in Korea were from 0.050 to 4.68 mgL^{-1} with the mean value of 1.204 mgL^{-1} , the aluminum concentration values were above the Korean guideline for drinking water (0.2 mgL^{-1}).

4.5.10: Assessment of heavy metals in the studied area:

Results of heavy metals Fig (4.26A) and Fig (4.26B) indicated that the relative dominance of the heavy metals in Tanjaro landfill leachate was observed in the following sequence:
Hg > Mn > Fe > Zn > Cr > Pb > Cd while in Tanjaro river was Hg > Pb > Cr > Mn > Cd > Cu > Fe > Zn and in wells water was Hg > Pb > Cr > Zn > Fe > Cu > Cd > Mn.

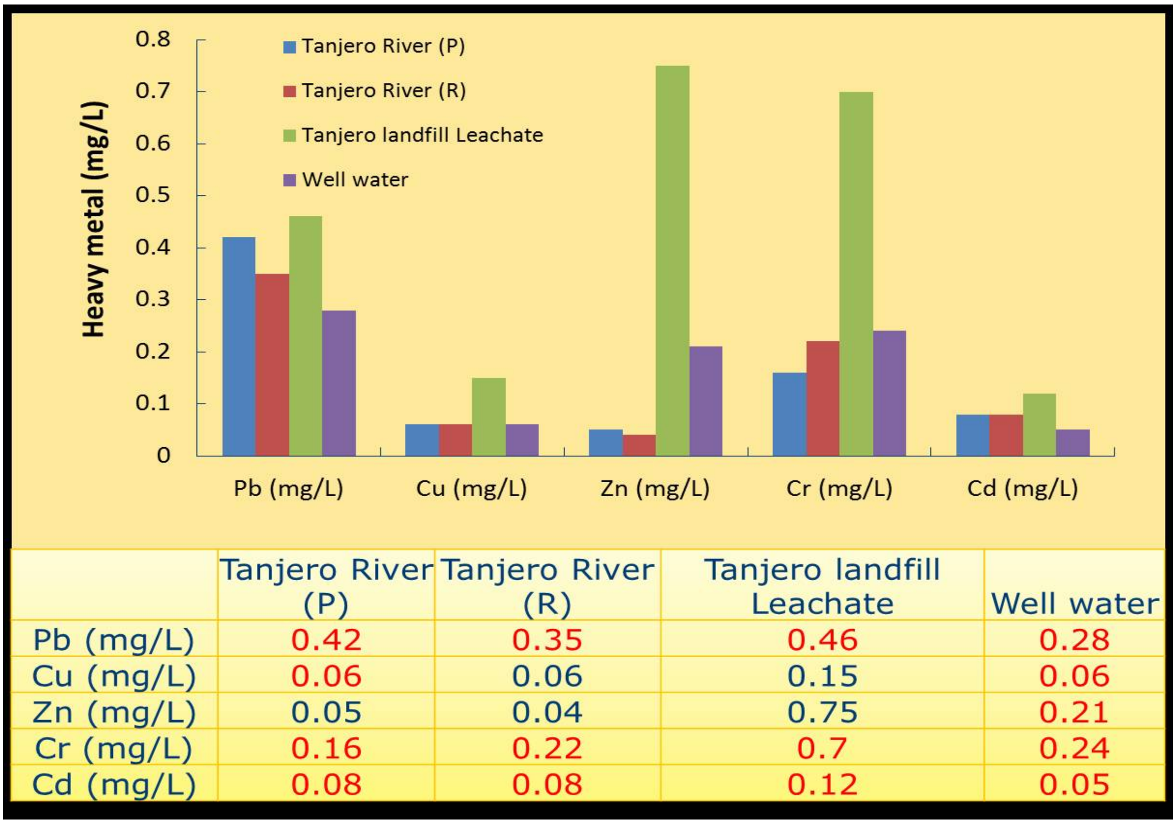
- Data comparison showed that heavy metals concentration increases from Tanjaro landfill site to Tanjaro river and wells´ water.
- The average mean concentration value of mercury (Hg) in Tanjaro landfill leachate was 12.1 mgL^{-1} which indicated that mercury had the highest mean average concentration value.
- The increase concentration of heavy metals is due to the composition of dumped solid wastes.
- It should be noted that seasonal rain on the site washes the pollutants from it runoff is flowing through the dumping site and the accumulation of heavy metals is carried by the runoff, towards the pond of leachate.
- Comparing the concentrations of heavy metals in leachate with corresponding samples from Tanjaro river and wells water is the subject on which an assessment can be made about the effect of landfill site on Tanjaro river, wells´ waters, soil, ambient air quality and peoples health in the whole area.

Fig (4.26A): Demonstrates the average mean concentration values (mgL^{-1}) of heavy metals in the study area.



	Tanjero River (P)	Tanjero River (R)	Tanjero landfill Leachate	Well water
Fe (mg/L)	0.05	0.06	2.4	0.12
Mn (mg/L)	0.15	0.17	4.75	0.01
Hg (mg/L)	0.59	0.34	12.1	0.29

Fig (4.26B): Demonstrates the average mean concentration values (mgL^{-1}) of heavy metals in the study area.



	Tanjero River (P)	Tanjero River (R)	Tanjero landfill Leachate	Well water
Pb (mg/L)	0.42	0.35	0.46	0.28
Cu (mg/L)	0.06	0.06	0.15	0.06
Zn (mg/L)	0.05	0.04	0.75	0.21
Cr (mg/L)	0.16	0.22	0.7	0.24
Cd (mg/L)	0.08	0.08	0.12	0.05

4.6: Ambient Air Quality Assessment:

Everyone agrees that pollution is a global problem. Air pollution is a problem that everyone should be concerned about with the growing number of automobiles; exhaust emissions from vehicles are adversely affecting the air quality in cities. Air pollution is some thing to be concerned with. Eklund et al., (1998) estimated that, air pollution involves the release of gases, finely dissolved solids or liquid aerosols into the atmosphere at rates that exceed the capacity of the atmosphere to dissipate them or to dispose of them through incorporation into solid or liquid layers of the biosphere.

According to Krishnamurthy et al., (1987), the major causes of air pollution are:

- Some of the highly polluting industries are metal smelting, cement factories, dyes, fertilizers, steel, leather, pesticides, petrochemicals, paper and refineries.
- Power generation plants.
- Dust storms in deserts.
- Smoke from forest and grass fires.
- Smoke from open damp sites, due to incineration processes.
- Automobiles are the major cause of air pollution.

Daniel, (2002) reported that air pollution posing serious problems for the health of the people, serious health problems are caused by the presence of flying ash in the air, since flying ash production is only going to get worse. Flying ash is responsible for air pollution and wastage of land that could be used to grow crops. Small scale industries located in residential areas are also major causes of pollution and related health risks.

Giri et al., (2007) estimated that the respirable particle matter concentration (RPM_{10}) in urban areas has been a chronic cause concerns and principle reason for increased morbidity rate among resident population. Folinsbee (1992) concluded that (RPM_{10}) particles penetrate deep into lungs and pose significant health risks. While Pope et al., (1991) reported that (RPM_{10}) is often associated with asthma and chronic cardiovascular and respiratory health problems. Muhammad (2008) studied that Tasluja cement factory has significant health impacts on the residents around the factory. According to World Bank statement (2007), for ambient air quality, there are four gaseous pollutants which are:

CO: Carbon monoxide.
NO_2: Nitrogen dioxide
SO_2: Sulphur dioxide.
HC: Hydrocarbons (Methane and non- methane).

While suspended particulate matters (SPM) and respirable particulate matters of ten micron dimension (RPM_{10}) are other two most concerned parameters. (RPM_{10}) defined as particulate matter with aerodynamic diameter less than 10 µm. The size is important because it is this that determines where in the human respiratory trace a particle deposits when inhaled.

Gill et al., (2006), reported that there are a number of important natural sources of particulate in the air with forest fires and volcanic eruptions being two sources which can cause extreme pollution episodes and can be very adverse to human health.

Airborne Particles Expert Group (APEG) (1998) reported that, sea spray and the erosion of soil and rocks by wind are important sources of primary (RPM_{10}) in many localities there are also biological sources with considerable numbers of pollen grains, fungal spores and their fragments contributing to the total loading of airborne particles. Manmade airborne particles result mainly from combustion processes are other sources of primary (RPM_{10}), working of soil and rock and from industrial processes the attrition of road surface by motor vehicles.

The study area is mainly close to residential, with suburban locations. There is major active gravel sand open cast mining activities within the concession area, there are local illegal factories and Tanjaro landfill site regarded as the main source of air pollution in the area. Five locations were selected within the study area for ambient air quality measurements. Gaseous pollutants including SO_2. NO_x, CO and HC (Hydrocarbon) were analysed directly in the field using a portable gas analyser dragger- Multiwarn/ Germany.

Results from this study Table (4.34) represents the measured levels of particulate, (RPM_{10}), SPM, Sulphur dioxide (SO_2), Nitrogen oxides (NO_x) Carbon monoxide (CO) and Hydrocarbons (HC) and compares these levels with the guidelines prescribed by the world Bank (WB) Ambient Air Quality Norms (2007), Table (4.34), the recorded levels of (RPM_{10}), (SPM), (SO_2), (NO_X), (CO) and (HC) were higher than the concentration objectives given by the world Bank (WB) Ambient Air Quality Norms. The results obtained from this study are higher than those obtained by Muhammad (2008) on the Tasluja cement plant and mining site, Sulaimani, the measured mean concentration levels of SO_2 , CO, NO_x, Methane, Non Methane, SPM and RPM_{10} were 17.8, 59.98, 26.8, 0.41, 0.12, 171.8 and 89.01 $\mu g/m^3$ respectively. The mean concentration values of RPM_{10} and NO_x at the monitoring sites did exceed the values obtained by Giri et al., (2007) who estimated that the mortality rate attributed to excess the respirable particle matter RPM_{10} and NO_x 87.59 and 12.3$\mu g/cm^3$ respectively in Kathamandu valley/ Nepal.

Table (4.34) Gaseous pollutants and particulate matter recorded for different locations within the Tanjaro Landfill Area

S.N.	Location	Concentration ($\mu g/m^3$)						
		SPM	RPM10	SO2	NOx	CO	Hydrocarbon	
							Methane	Non-methane
1	NTL1	82	155	138	175	13.5	1.08	0.28
2	ETL2	78	172	152	168	16.1	1.06	0.27
3	CTL3	95	172	115	161	10.5	2.09	0.42
4	WTL4	71	164	138	173	17.0	1.06	0.39
5	STL5	84	173	163	141	15.2	1.07	0.27
World Bank Norms		70	150	125	150	100	0.10	0.15

4.7: Assessment of Bacterial contamination:

Bacteriological characteristics of Tanjaro River and leachate from Tanjaro landfill site, samples collected at various locations were analysed for the presence of coliform bacteria and fecal coliform counts.

Tables (4.35) and (4.36) indicate the highest total bacterial count in Tanjaro River observed in locations where water is standing 2P and 3P. Table(4.36) shows the mean total bacterial count which was found at 2P location (standing waste water) is equal to (30×10^9), CFU.ml^{-1} while for running waste water 2R at the same location equal to (0.98×10^9). CFU.ml^{-1} .Table (4.36) same phenomenon repeated at 2P, 2R and 3P, 3R during 27th Oct. 2007 with (600×10^9), (50×10^9) and (404×10^9), (51×10^9) CFU.ml^{-1} respectively.

Table (4.37) shows densities of different microorganisms analysed in Tanjaro River and leachate from Tanjaro landfill area. In this investigation, the mean value of total bacterial counts were found to be (21.8×10^9), (344.6×10^9) and (4.36×10^9) CFU.ml^{-1} for running, standing water in Tanjaro River and Tanjaro Landfill leachate respectively. Higher bacterial count and the exist (positive) of the thermotolerant faecal coliform in all analysed samples gives a rise to faecal pollution according to WHO (2006), Al-Marharawi and Hafiz (1997) and Bartam and Balance (1996), appendix (6), due to the fact that Tajaro River may be an important water source of nutrients´ ions such as phosphate and nitrate compounds, these constituents are regarded as essential microorganisms nutrients.

At locations where Tanjaro River is standing the total bacterial count and total coliform is at the highest level. All tested samples from different locations were contaminated and they did not meet with the standards for irrigation according to WHO (2006), EU (2004) and IQS (2000).

The higher means coliform number for Tanjaro River as compared with Landfill leachate Table (4.37) was due to:

- Tanjaro River wastewater is contaminated by domestic waste, which will be one of the main sources of nutrients for coliforms.
- Leachates from landfill contain high levels of toxic elements.
- Dissolved oxygen is low in landfill leachate samples as it appears from Table (4.10) and Fig (4.9) which is (0.6, 2.7 and 0.3) for three locations in landfill site compared with (2.6, 4.16 and 5.39) for Tanjaro River respectively.

Mutlak et al., (1985) recorded the total coliform in Baghdad sewage water was 4×10^3 $CFU.ml^{-1}$ and for bacterial counts 45×10^9 $CFU.ml^{-1}$ meanwhile, Nasser et al., (2004) reported 2.88×10^7 $CFU.ml^{-1}$ in Alkiesh river/ Syria, they attributed the reason to the increased pollution discharge into river, elevation of water temperature and low water velocity leading to the increase of various microbial densities. Shekha (2008) on Erbil city wastewater recorded that the mean value of total bacteria counts was found to be 4.1×10^7 $CFU.ml^{-1}$, while coliform mean numbers of Erbil waste water samples were 12.04×10^3 $CFU.ml^{-1}$ with no detection of fecal coliform. While Aziz et al., (2001) and Trajani (2006) found that faecal coliform in Erbil wastewater was 13.5×10^5 $CFU.ml^{-1}$ and more than 16 $CFU.ml^{-1}$ respectively.

Table (4.35): Bacterial count (MPN / ml) analysis of Tanjaro River:

Location - number dated (27/10/2007)	Total bacterial count $\times10^9$ CFU/ml	Total coliform	Faecal coliform
2P	600	> 2400	T.N.T.C
2R	50	34	T.N.T.C
3P	404	2400	T.N.T.C
3R	51	350	T.N.T.C
6R	25	>2400	T.N.T.C

T.N.T= Too Number to count, CFU= Colony Forming Units

Table (4.36): Bacterial count (MPN / ml) analysis of Tanjaro River and landfill leachate.

Location-number dated (13/11/2007)	Total bacterial count $\times 10^9$ CFU/ml	Total coliform	Faecal coliform
B	11.48	63	T.N.T.C
C	0.59	1600	T.N.T.C
D	1.01	33	T.N.T.C
2P	30.00	>2400	T.N.T.C
2R	0.98	1600	T.N.T.C
3R	2.96	>2400	T.N.T.C
5R	0.86	>2400	T.N.T.C

(B, C, D) Tanjaro landfill leachate locations, (2P, 2R, 3R, 5R) Tanjaro River waste water locations.

Table (4.37): Bacterial count (MPN/ ml) analysis of Tanjaro River and Tanjaro Landfill leachate represent as Mean with Minimum and maximum values.

Location	Total bacterial count $\times 10^9$ CFU/ml	Total coliform	Faecal coliform
Running wastewater	21.8 0.86-51	1217 34-2400	T.N.T.C
Standing wastewater	344.6 30-600	2400 2400	T.N.T.C
Tanjaro landfill leachate	4.36 0.59-11.48	816.5 33-1600	T.N.T.C

4.8: Physio-chemical properties of soil:

Soil has a significant impact on the amount of recharge that can infiltrate into the ground, and hence on the ability of contaminant to move vertically towards groundwater. The hydraulic conductivity of soil is important because it controls the rate of groundwater movement in the saturation zone, thereby controlling the degree and fate of contaminants. The presence of fine textured materials such as silt and clay can decrease relative soil permeability and restrict contaminant migration. Veeresh et al., (2003) reported that environmental risk potential from metal contamination is associated with the disposal of sewage which depends on part of the metal sorption characteristic of the soil. Center for Ecology and Hydrology (CEH), (2002) concluded that one of the causes for soil contamination is due to the presence of heavy metals which mostly come from sewage, further more the pathogens reach soil from the same source. Kamees, (1979) reported that soils in Sulaimani governorate area are classified as alkaline soils; they are strongly calcic with $CaCO_3$ % reach 30%. Rashid (1993) reported that $CaCO_3$ % in the North part of Iraq ranged (Kurdistan Region) from 3.8% for Halabja to 65% for Akra from the same reference % sand content ranging from 1.18% for Bakrajo to 84.92% for Aski- Kalak, while % silt content ranged from 3.79 for Aski- Kalak to 73.7 for Kala Diza.

Suliaman, (1978) estimated that, mineralogical soils of the area are composed of Monmorillonite, chlorite, Vermiculite, mica and Kaolinite, from the same reference majority of soils in the area are classified as Mollisols and Vertisols. Rashid (1993) reported that organic matter content in north part of Iraq (Kurdistan Region) ranged between 0.17% for Qaradag to 2.39% for Akra.

The results of various laboratory tests are presented in Table (4.38) giving some physical and chemical properties of soil from Tanjaro landfill sit.

Table (4.38): Some physical and chemical properties of soil samples from study area.

Data for physical properties							
Location	Soil depth cm	Particle size distribution			Textural name	Bulk density mg/cm^3	Water content %
		Sand %	Silt %	Clay %			
Surface landfill	0 - 30	15	29	56	Clay	1.56	0.038
Sub- surface landfill	30 - 50	11	28	61	Clay	1.57	0.030
Surface soil	0 – 30	15	28	57	Clay	1.25	0.23
Sub- surface soil	30 - 50	20	26	48	Clay	1.30	0.19

Data for some chemical properties

Location	Soil depth cm	pH	EC µs/cm	$CaCO_3$ %	Si O_2 %	Al_2O_3 %	Fe_2O_3 %
Surface landfill	0 - 30	8.6	30800	33	28.8	7.27	4.26
Sub- surface landfill	30 – 50	8.3	34100	51	45.2	10.5	6.22
Soil surface	0 – 30	7.8	398	25	42.8	11.0	5.57
Sub- surface soil	30 – 50	7.7	375	45	40.6	10.7	5.90

CHAPTER FIVE Conclusions and Recommendations

5.1: Conclusions:

1. Results obtained from this study indicate that Sulaimani Municipal sewage effluents, municipal solid waste, leachate from Tanjaro landfill site as well as discharge from networks are all considered being the main contributors to the pollution of the studied area.

2. Heavy metals and some (cations and anions) have higher concentration values in Tanjaro River, therefore pollution in Tanjaro River and its tributaries is the major source of pollution in Darbandikhan Lake.

3. Anthropogenic activities, ultimate disposal of untreated waste effluents, farming activities and Tanjaro landfill location are all causing serious environmental problems and posing threat to inhabitants living close to the study area.

4. High levels of nutrients in Tanjaro River and its tributaries lead to eutrophication and outbreak of growth of algae which could deplete the dissolved oxygen (DO) levels.

5. Facilities to treat wastewater do not exist in any city in Kurdistan region.

6. Bacteriological analysis indicated that Tanjaro River is highly contaminated by coliform and fecal coliform bacteria groups.

7. Tanjaro landfill site is currently used for dumping disposals without any environmental consideration.

8. Tanjaro landfill site has potential to harbor birds, insects, vermin and scavengers.

9. Several adverse impacts from Tanjaro landfill site are recorded including, contribution to the greenhouse gases, odour, noise, dust, windblown litters, insects, birds and vermin.

10. Wastes in Tanjaro are often deliberately incinerated by torching.

11. The Ambient Air quality at the site indicated that current investigation exceeded the recommended standards.

12. From interviews carried out with the local people living close to Tanjaro landfill site, they complained from poor water quality, smoke, odour, insects…etc., and they were suffering from eye and skin itching, inflammation of eye, nose, throat , complains about miscarriages and birth defects.

5.2: Recommendations:

1. A sophisticated and regulated system (Sanitary landfill) should be introduced instead of open dumping areas in Kurdistan Region and especially in Sulaimani city.

2. Segregation of solid waste from (houses, hospitals, factories…etc.) is essential, and different categories should be treated separately.

3. The municipalities should use the information in this study to highlight where we need to make environmental improvements.

4. Construction of a buffer zone is essential to minimize the negative effects of landfill.

5. Kurdistan Region Government (KRG) should set up permanent air monitoring station networks. Continuous air monitoring should be carried out to control air pollution.

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6. The private sector should involve more effectively in solid waste management.

7. Our goal is to ensure a safe and sustainable water supply and proper sewage disposal of Sulaimani Governorate by building powerful sewage treatment plants.

8. There should be a system for treatment of hospital wastewater.

9. The water quality of Tanjaro River should be improved by introducing tougher legislations for the discharge of wastewater.

10. It is preferable to have a separate drainage system for runoff water in Sulaimani Governorate areas that are developed with sewer system.

11. Further researches are required to manage landfill and sewage treatment to protect the environment of the area.

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Appendix (1): Shows the population of Sulaimani Governorate

Expectation of population growth 2005			Expectation of population growth 2004			Expectation of population growth 2003			Number of population on July 2002			Zone	Sub- District	District
Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male			
30829	16291	14538	29931	15817	14114	29059	15356	13703	28213	14909	13304	Total population in Bazyan		
5173	2562	2611	5022	2488	2534	4876	2415	2461	4734	2345	2389	Bazyan Village		
36002	18854	17148	34953	18305	16649	33935	17772	16164	32947	17254	15693	Total		
1530	785	745	1485	762	724	1442	740	702	1400	718	682	Hazar	Karadagh	
10318	5122	5196	10017	4972	5045	9725	4828	4898	9442	4687	4755	Village		
11847	5906	5941	11502	5734	5768	11167	5567	5600	10842	5405	5437	Total		
14310	7161	7150	13894	6952	6941	13489	6750	6739	13096	6553	6543	Hazar	Tanjero	
9337	4618	4719	9065	4483	4582	8801	4353	4449	8545	4226	4319	Village		
23648	11779	11869	22959	11435	11523	22290	11102	11188	21641	10779	10862	Total		
699963	351821	348142	679575	341574	338002	659782	331625	328157	640565	321966	318599	Hazar	Total of Sulaimani District	
33080	16461	16619	32117	15981	16135	31181	15516	15665	30273	15064	15209	Village		
733043	368282	364761	711692	357555	354137	690963	347141	343822	670838	337030	333808	Total		
33583	16833	16749	32605	16343	16261	31655	15867	15788	30733	15405	15328	Hazar	Sharazoor Center	Sharazoor
0	0	0	0	0	0	0	0	0	0	0	0	Village		
33583	16833	16749	32605	16343	16261	31655	15867	15788	30733	15405	15328	Total		
33090	16489	16601	32126	16009	16117	31190	15543	15648	30282	15090	15192	Hazar	Said Sadik	
19392	9655	9736	18827	9374	9453	18278	9101	9177	17746	8836	8910	Village		
52481	26145	26337	50953	25383	25570	49469	24644	24825	48028	23926	24102	Total		

Source: Directorate of Statistics/ Sulaimani Governorate (2009).

Appendix (1): Shows the population of Sulaimani Governorate

Expectation of population growth 2008			Expectation of population growth 2007			Expectation of population growth 2006			Area (Zone)	Sub- District	District
Total	Female	Male	Total	Female	Male	Total	Female	Male			
33688	17802	15886	32707	17284	15423	31754	16780	14974	Total population in Bazyan		
5653	2800	2853	5488	2718	2770	5328	2639	2689	Bazyan Village		
39340	20602	18738	38195	20002	18192	37082	19420	17663	Total		
1672	857	814	1623	832	791	1576	808	768	Urban	Karadagh	
11274	5597	5678	10946	5434	5512	10627	5275	5352	Village		
12946	6454	6492	12569	6266	6303	12203	6083	6119	Total		
15637	7825	7813	15182	7597	7585	14740	7375	7364	Urban	Tanjero	
10203	5046	5157	9906	4899	5007	9617	4756	4861	Village		
25840	12871	12970	25088	12496	12592	24357	12132	12225	Total		
764868	384444	380424	742590	373247	369344	720962	362376	358586	Urban	Total of Sulaimani District	
36148	17987	18160	35095	17463	17631	34073	16955	17118	Village		
801016	402431	398584	777685	390710	386975	755034	379330	375704	Total		
36697	18394	18302	35628	17859	17769	34590	17338	17252	Urban	Sharazoor Center	Sharazoor
0	0	0	0	0	0	0	0	0	Village		
36697	18394	18302	35628	17859	17769	34590	17338	17252	Total		
36158	18018	18140	35105	17493	17612	34083	16984	17099	Urban	Said Sadik	
21190	10551	10639	20572	10243	10329	19973	9945	10028	Village		
57348	28569	28779	55678	27737	27941	54056	26929	27127	Total		

Source: Directorate of Statistics/ Sulaimani Governorate (2009).

Appendix (1): Shows the population of Sulaimani Governorate

Expectation of population growth 2005			Expectation of population growth 2004			Expectation of population growth 2003			Number of population on July 2002			Zone	Sub- District	District
Total	Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male			
621896	311802	310094	603783	302720	301062	586197	293903	292293	569123	285343	283780	Hazar	Sulaimani city	Sulaimani
0	0	0	0	0	0	0	0	0	0	0	0	Village		
621896	311802	310094	603783	302720	301062	586197	293903	292293	569123	285343	283780	Total		
14178	7127	7051	13765	6919	6846	13364	6718	6647	12975	6522	6453	Hazar	Sarchinar (Bakrajo)	
6097	3071	3027	5920	2981	2939	5747	2894	2853	5580	2810	2770	Municipality	Rapareen	
4405	2207	2197	4276	2143	2133	4152	2081	2071	4031	2020	2011	Municipality	Tasluja	
2180	1094	1086	2116	1062	1055	2055	1031	1024	1995	1001	994	With services	Maasker Salam	
1559	783	776	1514	761	753	1470	739	731	1427	717	710	With services	Topkhana	
2754	1382	1371	2673	1342	1331	2596	1303	1293	2520	1265	1255	With services	Azadi Campus	
224	118	106	217	115	103	211	111	100	205	108	97	With services	Tasluja Cement	
31397	15782	15615	30483	15323	15160	29595	14876	14719	28733	14443	14290	Total population of Sarchinar Hazar		
8252	4159	4093	8012	4038	3974	7779	3920	3858	7552	3806	3746	Sarchinar Village		
39650	19941	19708	38495	19360	19134	37374	18796	18577	36285	18249	18036	Total		
13159	7414	5744	12775	7198	5577	12403	6989	5415	12042	6785	5257	Hazar	Bazyan	
3542	1779	1763	3438	1725	1711	3338	1677	1661	3241	1628	1613	Municipality	Allaii	
2996	1520	1476	2909	1476	1433	2824	1433	1392	2742	1391	1351	Municipality	Tainal	
3537	1776	1761	3434	1724	1710	3334	1674	1660	3237	1625	1612	Municipality	Gopala	
7596	3803	3793	7374	3692	3682	7160	3584	3575	6951	3480	3471	Municipality	Bainjan	

Source: Directorate of Statistics/ Sulaimani Governorate (2009).

Appendix (1): Shows the population of Sulaimani Governorate

Expectation of population growth 2008			Expectation of population growth 2007			Expectation of population growth 2006			Zone	Sub- District	District
Total	Female	Male	Total	Female	Male	Total	Female	Male			
679563	340714	338848	659770	330791	328979	640553	321156	319397	Hazar	Sulaimani city	Sulaimani
0	0	0	0	0	0	0	0	0	Village		
679563	340714	338848	659970	330791	328979	640553	321156	319397	Total		
15493	7788	7705	15042	7561	7481	14603	7341	7263	Hazar	Sarchinar (Bakrajo)	
6663	3355	3308	6469	3258	3211	6280	3163	3118	Municipality	Rapareen	
4813	2412	2401	4673	2342	2331	4537	2274	2263	Municipality	Tasluja	
2382	1195	1187	2313	1160	1152	2245	1127	1119	With services	Maasker Salam	
1704	856	848	1654	831	823	1606	807	799	With services	Topkhana	
3009	1510	1499	2921	1466	1455	2836	1424	1413	With services	Azadi Campus	
245	129	116	238	125	112	231	122	109	With services	Tasluja Cement	
34309	17246	17063	33309	16743	16566	32339	162256	16084	Total population of Sarchinar Hazar		
9017	4545	4473	8755	4412	4343	8500	4284	4216	Sarchinar Village		
43326	21790	21536	42064	21156	20909	40839	20539	20300	Total		
14379	8102	6277	13960	7866	6094	13553	7637	5917	Hazar	Bazyan	
3870	1944	1926	3757	1887	1870	3648	1832	1815	Municipality	Allaii	
3274	1661	1613	3179	1613	1566	3086	1566	1521	Municipality	Tainal	
3865	1940	1925	3753	1884	1869	3643	1829	1814	Municipality	Gopala	
8300	4155	4145	8058	4034	4024	7823	3917	3907	Municipality	Bainjan	

Source: Directorate of Statistics/ Sulaimani Governorate (2009).

Appendix (2) Information about water wells in Sulaimani city

No.	Name of water wells	Deep well (m)	Static water level (m)	Dynamic water level(m)	Discharge of well (L.sec^{-1})
1	Bakhtyari	130	10	15	5
2	Mamayara	115	10	25	3
3	Azadi(3)	130	32	56	8
4	Ashti	51	10	25	11
5	Kadamkher	170	12	27	10
6	Azadi(2)	135	10	30	7
7	Grde jameiya	120	24	65	10
8	Shakraka	175	32	74	9
9	Kani Kurda	85	10.1	15	4.5
10	Chwarbakh	48	5	19	6.5
11	Benaei	76	47.3	52	10
12	Haji Bag	56	4	22	8.5
13	Pak city(1)	60	8	20	7
14	Pak city(2)	60	8	20	7
15	Kerga(1)	58	17.7	18.8	4
16	Kerga(2)	64	30.4	36.4	4
17	Kerga(3)	63	27	43.5	3.8
18	Kerga(6)	69	4	6.57	5
19	Kalaken(1)	85	26.3	31.4	6
20	Kalaken(2)	100	25	50	4.6
21	Kalaken(3)	66	36	31.3	3.7
22	Kalaken(4)	85	26	54	3.4
23	Kalaken(5)	50	19	27	4
24	Raparen (1)	85	19	54.2	2.8
25	Raparen (2)	75	13	41	3.6
26	Raparen (3)	56	5	36	4
27	Kareze Ail Jolla	181	27	101	1.3
28	Kareze Ail Jolla	101	25	27	5.3
29	Zargata	86	54	61	4.2
30	Shekh Fathoallah	150	35	55	5

Source: Directorate Water, sewage/Sulaimani governorate 2009

Appendix (3) Number of private water wells in new quarters of sulaimani

No.	Name of the quarter	Number of wells
1	Kani speak	3746
2	Kallaken	659
3	Homara kwer	438
4	Chwar bakh	241
5	Kazenawa (Ibrahem Ahmad)	939
6	Kerga	540
7	Karatogan	210
8	Zeirenok	27
9	Zargata	96
	Total	5896

Source: Directorate Water, sewage/Sulaimani governorate (2009)

Appendix (4): Maximum recommended levels and standards of water quality

Parameter mg/L	WHO,06[1]	IQS,01[2]	EUDWS,05[3]	EPA,04[4]	Canada,05[5]	Surface Water[6]
Aluminium (Al)	0.2	0.2	0.2	0.05-0.2	0.1	
Ammonium (NH3)	1.5	N/A	0.5	N/A	N/A	0.2
Alkalinity	N/A	N/A	N/A	N/A	N/A	200
Bicarbonate(HCO3)	N/A	N/A	N/A	N/A	N/A	58
BOD	N/A	N/A	N/A	N/A	N/A	Zero
Calcium (Ca)	75	50	N/A	N/A	N/A	15
Chloride (CI)	250	250	250	250	250	7.8
COD	N/A	N/A	N/A	N/A	N/A	4
Dissolved Oxygen (DO)	N/A	N/A	N/A	N/A	N/A	10
Fluoride (F)	1.5	1	1.5	2	1.5	N/A
Hardness	500	500	150-500	N/A	N/A	N/A
Hydrogen Sulfide (H_2S)	0.05	N/A	Zero	N/A	≤0.05	N/A
Magnesium (Mg)	100	50	30-50	N/A	N/A	4.1
Nitrate (NO3)	50	50	50	10	45	0-18
Nitrite (NO2)	3-3.3	3	0.5	1	3.2	0.005
Pesticide (Total)	N/A	N/A	0.0005	N/A	N/A	N/A
Phosphate (PO4)	0.4	N/A	0.4	N/A	N/A	0.1
Potassium (K)	10-12	N/A	10-12	N/A	N/A	2.3
Sodium (Na)	200-250	200	200	N/A	≤200	6.3
Sulfate(SO4)	250	250	250	250	≤500	11.2
Total Dissolved Solids (TDS)	1000	1000	300	500	500	N/A
Arsenic	0.1	0.1	0.01	0.01	0.025	0.098
Cadmium (Cd)	0.003	0.003	0.005	0.005	0.005	0.005
Chromium (Cr)	0.05	0.05	0.05	0.1	0.05	N/A
Copper (CU)	2	1	2	1.3	1	0.06
Iron (Fe)	0.3	N/A	0.2	0.3	N/A	N/A
Lead (Pb)	0.01	0.01	0.01	Zero	0.01	0.003
Manganese (Mn)	0.4	0.1	0.05	0.05	≤0.05	N/A
Mercury (Hg)	0.001	0.001	0.001	0.002	0.001	N/A
Nickel (Ni)	0.02	0.02	0.02	N/A	N/A	N/A
Zinc (Zn)	1.1-3	3	3	5	5	0.01

Note/concentration of all parameters is in mg.L^{-1}

1- WHO, 2006: World health organization, Guidelines for Drinking- water Quality .3rd ed., Vol.1.
2- IQS, 2001: Iraqi Drinking water Standard.
3- EUDWS, 2005: EU's Drinking water Standard.
4- USEPA, 2004: United state Environmental Protection Agency, Drinking water Standard.
5- Canada, 2006: Guidelines for Canadian Drinking water Quality.
6- From different references (Langmuir,1997;WHO,2006 European Standards (EU),2004; Manharawi and Hafiz,1997; Mckenzie,2001; hem,1985; Hamil and bill,1986; Grompton,1997; Swedish EPA,2000 and Environmental and Health Protection office of Sulaimani,2006).

Appendix (5): Physical parameters

Parameter mg/L	WHO,06[1]	IQS,01[2]	EUDWS,05[3]	USEPA,2004[4]	Canada,05[5]
Color (TCU)[6]	15	10	N/A	15	15
Conductivity µs/cm	250	N/A	250	N/A	N/A
pH	6.5-9.5	6.5-8.5	6.5-9.5	6.5-8.5	6.5-8.5
Temperature (C^0)	N/A	N/A	13-35	N/A	15C
Turbidity (NTU)	5	5	10	0.5-1	1
Odor	N/A	Should be acceptable	N/A	N/A	Inoffensive
Taste	N/A	Should be acceptable	N/A	N/A	Inoffensive

1- WHO, 2006: World health organization, Guidelines for Drinking- water Quality .3rd ed., Vol.1.
2- IQS, 2001: Iraqi Drinking water Standard.
3- EUDWS, 2005: EU's Drinking water Standard.
4- USEPA, 2004: United state Environmental Protection Agency, Drinking water Standard.
5- Canada, 2006: Guidelines for Canadian Drinking water Quality.
6- TCU (True Color Unit).
7- NTU (Nephelometric Turbidity Unit).

Appendix (6): Maximum recommended levels and standards of water quality

Variables	WHO,2006	IQS,1996	Canada ,2005	EU, 2004	Surface water	Ground water
TDS	1000	1000	500	300	---------	---------
pH	6.5-9.5	6.5-8.5	6.5-8.5	6.5-9.5	---------	---------
NO_3	50	50	45	25-50	0-18	0.1-10
NO_2	3-3.3	3	---------	0.1	0.005	---------
PO_4	0.4	---------	---------	0.4	0.1	0.1
HCO_3	---------	---------	---------	---------	58	<200
CL	45-250	250	250	250	7.8	20
SO_4	250	250	500	250	3.7	30
Ca	75	50	---------	100-200	15	50
Mg	100	50	---------	30-50	4.1	7
Na	200-250	200	200	200	6.3	30
K	10-12	---------	---------	10-12	2.3	3
NH_4	---------	---------	---------	0.05-0.5	0.2	0.2
NH_3	1.5	---------	---------	---------	0.2	0.2
H_2S	0.05	---------	0.05	0	---------	---------
Hardness	500	500	---------	150-500	---------	---------
Temperature (C^0)	---------	---------	15	13-35	---------	---------
Turbidity(NTU)	5	---------	---------	1-10	---------	---------
Cd	0.003	0.003	0.005	0.003	0.001	---------
Cu	2	1	1	2	0.007	0.003
Ni	0.02	0.02	---------	0.02	0.0003	
Pb	0.01	0.01	0.01	0.01	0.003	
Zn	1.1-3	3	5	3	0.01	0.05
T.coliform (Cell/100ml)	0	5	---------	0	---------	---------
F.coliform (Cell/100ml)	0	0	---------	0	---------	---------

*Source: Langmuir 1997;WHO,2006; European Standards(EU),2004; Manharawi and Hafiz,1997; Mckenzie,2001; Hemil and Bill,1986; Crompton,1997/***&**** from IQS,2000 (---)= not found.*

Appendix (7): Guidelines for interpretation of water quality for irrigation.

Potential irrigation problem	Units	Degree of restriction of use		
		None	Slight to moderate	Severe
Salinity				
ECw[1]	dS/m	<0.7	0.7-3.0	>3.0
or				
TDS	Mg.L^{-1}	<450	450-2000	>2000
Infiltration				
SAR[2] = 0-3 and ECw		>0.7	0.7-0.2	<0.2
3-6		>1.2	1.2-0.3	<0.3
6-12		>1.9	1.9-0.5	<0.5
12-20		>2.9	2.9-1.3	<1.3
20-40		>5.0	5.0-2.9	<2.9
Specific ion toxicity				
Sodium (Na)				
Surface irrigation	SAR	<3	3-9	>9
Sprinkler irrigation	Mg.L^{-1}	<70	>70	
Chloride (Cl)				
Surface irrigation	Mg.L^{-1}	<140	140-350	>350
Sprinkler irrigation	Mg.L^{-1}	<100	<100	
Boron (B)	Mg.L^{-1}	<0.7	0.7-3.0	>3.0
Miscellaneous effects				
Nitrogen (NO_3-N)[3]	Mg.L^{-1}	<5	5-30	>30
Bicarbonate (HCO_3)	Mg.L^{-1}	<90	90-500	500
pH	unit		Normal range 6.5-8.4	

Source: FAO (1985)

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[1] **Ecw means electrical conductivity in deciSiemens per meter at 25°C.**

[2] **SAR means sodium adsorption ratio**

[3] **NO_3- means nitrate nitrogen reported in terms of elemental nitrogen**

Appendix (8): Sewage Wastewater Standards and typical values

Variables	Sewage Effluents (1)	Standard of Direct Discharge (2)	Typical Domestic Wastewater (3)	Sewage of Arbil City (4)
TDS(ppm)	3500	--------	500	--------
TSS(ppm)	150	--------	200	---------
NO_2(ppm)	------	---------	-------	0.0004-0.086
NH_3(ppm)	40	1	---------	0.49
PO_4(ppm)	-------	3	5-50	0.0015-0.113
K(ppm)	------	---------	----------	4-20
T.H(ppm)	------	---------	-----------	207-432
CL(ppm)	1000	----------	50	--------
SO_4(ppm)	600	---------	-----------	---------
H2S(ppm)	1	----------	-----------	---------
BOD(mg/l)	80	25	100	---------
COD(mg/l)	150	150	-----------	---------
PH	6-10	6-9	----------	---------
Temp (C^{0})	≤3	----------	-----------	---------
EC(µS/cm)	-----	-----------	----------	430-946
Alkal (ppm)	------	-----------	200	112-505
Cd(ppm)	0.1	0.2	----------	----------
Cu(ppm)	1	2	----------	----------
Ni(ppm)	1	2	----------	----------
Pb(ppm)	0.5	1	-----------	----------
Zn (ppm)	5	10	---------	---------

(1) Esc, 1996; (2) MEP, 1992; (3) Pescod, 1992; (4) Shekha, 1994 ;(---) = not found

Appendix (9): Concentration Ranges for Components of Municipal landfill leachate.

parameter	Typical Concentration Range	Average
Biochemical Oxygen Demand	1000 – 30000	10500
Chemical Oxygen Demand	1000 – 50000	15000
TOC	700 – 10000	3500
Total Volatile acids (as acetic acid)	70 – 28000	-------
Total Kjeldah1 Nitrogen (as N)	10 - 500	500
Nitrate (as N)	0.1 - 10	4
Ammonia (as N)	100 – 400	300
Total Phosphate(PO4)	0.5 – 50	30
Orthophosphate (PO4)	1.0 – 60	22
Total alkalinity (as CaCO3)	500 – 10000	3600
Total hardness (as CaCO3)	500 – 10,000	4200
Total solids	3000 – 50000	16000
Total Dissolved Solids	1000 – 20000	11000
Specific conductance (mhos/cm)	2000 – 8000	6700
pH	5 - 7.5	6.3
Calcium	100 – 3000	1000
Magnesium	30 – 500	700
Sodium	200 – 1500	700
Chloride	100 – 2500	980
Sulphate	10 – 1000	380
Chromium (total)	0.05 - 1	0.9
Cadmium	0.001 – 0.1	0.05
Copper	0.02 – 1	0.5
Lead	0.1 – 1	0.5
Nickel	0.1 – 1	1.2
Iron	10 – 1000	430
Zinc	0.5 – 30	21
Methane gas %	60%	-------
Carbon dioxide %	40%	-------

Source: Lee and Jones, 1991b

All units in mg.L^{-1} unless otherwise noted

Appendix (10): Guidelines for interpretation of Water Quality for Irrigation.

Parameter	Degree of Restriction of use		
	Slight to Non Severe	Moderate	Severe
Salinity , EC_w (dS m^{-1})	<0.7	0.7-3.0	>3.0
Total dissolved Solids, TDS	<450	450-2000	>2000
Total suspended solids, TSS	<50	50-100	>100
Bicarbonate, (HCO_3)	<90	90-500	>500
Chloride (Cl_2), total residual	<1.0	1.0-5.0	>5.0
Chloride (Cl^-),sensitive crops	<140	140-350	>350
Chloride (Cl^-), sprinklers	<100	100	>100
Boron (B)	<0.7	0.7-3.0	>3.0
Hydrogen Sulfide (H_2S)	<0.5	0.5-2.0	>2.0
Iron (Fe), drip irrigation	<0.1	0.1-1.5	>1.5
Manganese (Mn), drip irrigation	<0.1	0.1-1.5	>1.5
Nitrogen (N), total	<5	5-30	>30
Sodium (Na^+), sensitive crops	<100	100	>100
Sodium (Na^+),sprinklers	<70	70	70
Sodium Absorption Ratio SAR	<3.0.0	3.0-9.0	>9.0
Residual Sodium Carbonate RSC	<0	0-2.5	>2.5
Hardness (Grain/gallon)	<200	200-300	>300
Oil and grease	<5.0	5.0	>5.0

Sources: (Ayers and Westcot, 1985).

All units in mg.L^{-1} unless otherwise noted

Appendix (12): Recommended maximum chemical compositions in effluent for direct discharge and for irrigation water set by MEPA (Saudi Arabia), USEPA and Saudi Arabian tentative water quality for unrestricted agricultural irrigation.

parameter	Saudi MEPA Standards for Direct Discharge[1]	Saudi Arabian Standards[2] for Irrigation	Irrigation Water Quality Criteria[3]
pH	6-9	6.0-8.4	6.5-8.4
Total Dissolved Solids	U	1500	<2000
Alkalinity	U	U	NA
Biochemical Oxygen Demand	25	10-20	NA
Chemical Oxygen Demand	150	U	NA
Total Nitrogen	5	U	<30
Ammonia Nitrogen	1	NA	NA
Nitrate Nitrogen	U	U	<30
Total Phosphate	3	NA	NA
Bicarbonate	U	90-500	500
Chloride	U	<350	<350
Calcium	U	U	NA
Magnesium	U	U	NA
Aluminium (µg/ L)	U	5000	1000
Arsenic (µg/ L)	100	100	100
Cadmium (µg/ L)	20	10	10-50
Chromium (µg/ L)	100	100	100
Cobalt (µg/ L)	U	50	50
Copper (µg/ L)	200	400	200
Iron (µg/ L)	U	5000	5000
Lead (µg/ L)	100	1000	5000
Manganese (µg/ L)	U	200	200
Molybdenum (µg/ L)	U	10	10
Nickel (µg/ L)	200	200	200
Zinc (µg/ L)	1000	4000	2000

All units in milligrams per litre unless otherwise noted as micrograms per litre (µg/L).
U: unavailable. NA: not applicable.
[1] ***MEPA (Saudi Arabia, 1992) Performance Standards for Direct Discharge.***
[2] ***Ministry of Agriculture and Water, 1986 and Al-Dhowalia, 1986.*** [3] ***from FAO, 1985 and USPEA, 1981.***

Appendix (11): Examples of maximum allowable concentrations of selected water qualify variables for different uses.

Use	Drinking Water					Fisheries and Aquatic Life		
Variable	WHO^1	EU	Canada	USA	Russia	EU	Canada^1	Russia
Total dissolved solids (mg l^{-1})	1,000		500	500	1,000			
PH	<8.0	6.5^1.5^1	6.5-8.5	6.5-8.5	6.0-9.0	6.0-9.0	6.5-9.0	
Nitrate as N (mg l^1)								
Nitrate (mg l^{-1})	50	50			45			40
Nitrite (mg l^{-1})	3(P)	0.1			3.0	0.01-0.03	0.06	0.08
Phosphorus (mg l^{-1})		5.0						
BOD (mg l^{-1} 0_2)					3.0	3.0-6.0		3
Chloride (mg l^{-1})	250	25^1	250	250	350			300
Trace Elements								
Aluminium (mg l^{-1})	0.2	0.2			0.5		0.005-0.1^2	
Arsenic (mg l^{-1})	0.01(P)	0.05	0.05	0.05	0.01		0.05	
Barium (mg l^{-1})	0.7	0.1^1	1.0	2.0	0.7			
Cadmium (mg l^{-1})	0.003	0.005	0.005	0.005	0.003		0.0002-0.0018^3	0.005
Chromium (mg l^{-1})	0.05(P)	0.05	0.05	0.1	0.05		0.02-0.002	0.02-0.005
Cobalt (mg l^{-1})					0.1			0.01
Copper (mg l^{-1})	2(P)	0.1^1-3.0^1	1.0	1	2.0	0.005-0.112^3	0.002-0.004^3	0.001
Iron (mg l^{-1})	0.3	0.2	0.3	0.3	0.3		0.3	0.1
Lead (mg l^{-1})	0.01	0.05	0.05	0.015	0.01		0.001-0.007^3	0.1
Manganese (mg l^{-1})	0.5(P)	0.05	0.05	0.05	0.5			0.01
Zinc (mg l^{-1})	3	0.1^1-5.0^1	5.0	5	5.0	0.03-2.0^3	0.03	0.01
Faecal coliforms (No. per 100 ml)	0	0	0		0			
Total coliforms (No. per 100 ml)	0		10^{13}	1	0.3			

P	Provisional value
1	Guideline value
2	Depending on pH
3	Depending on hardness

Sources: Reprinted from Water Quality Assessments
(Chapman and Kimstach, 1996).

Appendix (13) : Correlation coefficint of different physico- chemical parameters during the studied period

	Temp	pH	EC	Color	TDS	TSS	TNU	Do	BoD	TH	K	Mg	Na	NO_2	SO_4	PO_4	Cl	Fe	Mn	Zn	Cu	Cd	Cr	pb	Hg
Temp	1																								
pH	0.98*	1																							
EC	-0.5	0.30	1																						
Color	-0.52	0.28	0.99**	1																					
TDS	-0.95*	0.28	0.99**	0.99**	1																				
TSS	-0.98*	0.28	0.99**	0.99**	0.99**	1																			
TNU	0.98*	-0.18	0.44	0.46	0.47	0.47	1																		
DO	-0.96*	-0.68	-0.90	-0.88	-0.88	-0.88	-0.99	1																	
BOD	0.99**	0.97*	-0.70	-0.68	0.96*	0.98*	0.95*	-0.99**	1																
TH	0.95*	0.95*	0.99**	0.99**	0.99**	0.99**	0.55	-0.99**	0.99**	1															
K	0.23	-0.70	0.20	0.21	0.21	0.21	-0.9	0.12	0.50	0.99**	1														
Mg	-0.51	0.30	0.99**	0.99**	0.99**	0.99**	0.44	-0.89	-0.70	0.99**	0.22	1													
Na	-0.51	0.29	0.99**	0.99**	0.99**	0.99**	0.44	-0.89	-0.69	0.99**	0.20	0.99**	1												
NO_2	-0.56	0.16	0.98*	0.99**	0.99**	0.99**	0.51	-0.82	-0.60	0.19	0.99**	0.99**	0.98*	1											
SO_4	-0.59	0.76	0.33	0.32	0.33	0.33	0.43	-0.55	-0.81	0.36	0.32	0.32	0.34	-0.84	1										
PO_4	-0.56	0.16	0.98*	0.99**	0.99**	0.99**	0.51	0.95*	-0.60	0.99**	0.99**	0.99**	0.98*	0.30	0.25	1									
Cl	-0.52	0.28	0.99**	0.99**	0.99**	0.99**	0.45	-0.88	-0.68	0.99**	0.21	0.99**	0.99**	0.99**	0.32	0.99**	1								
Fe	-0.52	0.28	0.99**	0.99**	0.99**	0.99**	0.45	-0.88	-0.68	0.98*	0.19	0.99**	0.99**	0.98*	0.34	0.98*	0.99**	1							
Mn	-0.51	0.32	0.99**	0.99**	0.99**	0.99**	0.43	-0.90	-0.71	0.99**	0.22	0.99**	0.99**	0.99**	0.32	0.99**	0.99**	0.99**	1						
Zn	-0.54	0.21	0.99**	0.99**	0.99**	0.99**	0.48	-0.82	-0.63	0.94	0.07	0.97*	0.97*	0.93	0.41	0.93	0.96*	0.96*	0.97*	1					
Cu	-0.32	-0.45	0.68	0.70	0.70	0.70	0.40	-0.32	0.02	0.99**	0.27	0.99**	0.99**	0.99**	0.28	0.99**	0.99**	0.99**	0.99**	0.53	1				
Cd	-0.57	-0.19	0.99**	0.88	0.88	0.88	0.60	-0.57	-0.28	0.90	0.53	0.87	0.87	0.96*	-0.006	0.93	0.88	0.88	0.86	0.91	0.93	1			
Cr	-0.55	0.41	0.99**	0.98*	0.98*	0.98*	0.45	-0.93	-0.78	0.98*	0.07	0.99**	0.98*	0.96*	0.45	0.96*	0.98*	0.98*	0.99**	0.97*	0.59	0.81	1		
pb	-0.53	0.27	0.99**	0.99**	0.99**	0.99**	0.46	-0.88	-0.68	0.70	0.80	0.68	0.69	0.77	-0.36	0.77	0.70	0.70	0.67	0.96*	0.99**	0.88	0.98*	1	
Hg	-0.39	0.49	0.97*	0.96*	0.96*	0.96*	0.29	0.97*	-0.81	0.99**	0.23	0.99**	0.99**	0.99**	0.31	0.99**	0.99**	0.99**	0.99**	0.99**	0.70	0.74	0.98*	0.99**	1

(**) Indicates correlation is positively highly significant at the 0.001 level (P< 0.001)

(*) Indicates correlation is positively significant at the 0.005 level (P<0.005)

(-) negatively correlated

خلاصة البحث

أجريت هذه الدراسة في تا نجرو في موقع لرمي القمامة يبلغ مساحته (180) دونماً من الأراضي ويقع جنوبي مدينة السليمانية بـ (10) كيلومترات. وفق إحصائية أجريت عام 2009 يبلغ عدد سكان مدينة السليمانية قرابة (700.000) سبعمائة ألف نسمة ويرمون يومياً ما يقارب (1000) طن من القمامة الصلبة (solid waste). تم جمع المعلومات على أساس الفصول والأشهر حيث أخذت عينات من ماء نهر تا نجرو والمياه الآسنة في موقع رمي القمامة ومياه الآبار القريبة من موقع رمي القمامة وعينات من التربة كذلك. وللتحاليل المختبرية اخذت العينات بصورة مباشرة من أماكن مختلفة بهدف إجراء التحليلات الفيزيوكيميائية والبايولوجية. ولقياس نوعية هواء المنطقة التي أجريت فيها الدراسة أستخدم كلا تحليلي الغاز والفلتر لجمع العينات وتسجيل المعلومات وفي الوقت نفسه أجريت تجارب مختلفة لتشخيص التلوث المايكروبايولوجي. وكل عينة أُجريت عليها تحاليل الآيونات الموجبة $(Ca^{2+}, Na^{+}, K^{+}, Mg^{2+})$ والآيونات السالبة $(NO^{-}_{2}, NO^{-}_{3}, Cl^{-}, PO^{-3}_{4})$ والعناصر الثقيلة.

قيمة معدل درجة حموضة (درجة تفاعل) (pH) كانت مابين 7.8 ، 7.9 ، 8.1 و 8.2 في نهر تا نجرو في حالتي الركود والجريان والمياه الآسنة في موقع رمي القمامة ومياه الآبار القريبة على التوالي، المعلومات المجموعة في الموقع الذي أجريت فيه الدراسة أظهرت العينات متوسطةالقلوية إلى عالية القلوية.

قيم (التوصيل الكهربائى) الـ (EC) مختلفة مابين 876,4 ، 781,9 ، 24117,8 و 1125 µs/cm لكل من الماء الجاري والماء الراكد لنهر تا نجرو والماء الآسن لموقع رمي القمامة ومياه الآبار على التوالي. القيم العليا للـ EC لوحظت في موقع رمي القمامة وهذا يشير إلى إنتاج مقدار كبير من الملح والمواد الذائبة في المياه الآسنة في موقع رمي القمامة. قيم الـ EC كانت عالية في أغلب عينات ماء تا نجرو وهذا يظهر تأثير مصادر التدفق من المناطق السكنية والزراعية حين تصب كمية كبيرة من مياه شبكات الصرف والمجاري من مصادر مختلفة في نهر تا نجرو.هناك فروقات معنوية واضحة فى التوصيل الكهربائى و بعض صفات الأخرى مثل (Turbidity) العكارة و (TSS) (المجموع الكلي للمواد العالقة) بين مواقع مختلفة خلال فترات زمنية مختلفة.

تركيز العسرة الكلية (Total hardness) المسجلة كانت مابين 224,7 ، 233,8 ، 281,2 و 90,2 ملغم $CaCO_3$/ ليتر. أعتبر ماء نهر تا نجرو كماء ذو العسرة الكلية العالمية ، وعينات الماء الآسن كماء ذو عسرة عالية جداً. أكبر قيم للعسرة كانت في العينات التي أخذت من ماء الآبار القريبة من موقع رمي القمامة. عينات الماء المأخوذة من الآبار تقدر كمياه متوسطة العذوبة.

النتائج تظهر أن قيم معدل التركيز BOD كانت مابين 3.7، 2,4 ، 0,3 و 1,1 مغ/لتر على التوالي. قيمة أقل تركيز سجل في الماء الآسن كان 0,03 مغ/لتر وقيمة أعلى تركيز سجل كان 13,9 مغ/لتر في الماء الراكد في نهر تا نجرو في حين صنفت مياه الشرب المأخوذة من الآبار كمياه عذبة أو متوسطة العذوبة.

قيم معدل التركيز (DO) كانت مابين 4,43 ، 4,16 ، 0,59 و 2,65 مغ/لتر على التوالي. قيم أعلى تركيز حين إجراء الدراسة كانت متناسبة مع قيمة أقل عكارة في حين أن الـ (DO) كانت تزداد تدريجياً كلما ا تجهت نحو بحيرة دربندخان وهذا بسبب إعادة تغذية الماء بالأوكسجين (reareation) والتصفية الطبيعية للماء. تحول السولفايت إلى سولفايد الهيدروجين، وهذا غير محبذ في الماء الآسن ويؤدي إلى إنتاج رائحة (البيض الفاسد) بسبب نقص تركيز DO (0,6 مغ/لتر) في الماء الآسن.

مجاري مدينة السليمانية، معامل الحصى والرمل، مياه الأماكن المفتوحة، وغسل مكونات القمامة كلها مسببات رئيسية لزيادة التعكر و TDS و TSS في المنطقة التي أجريت فيها الدراسة. معدل أعلى للتعكر مسجل في ماء تا نجرو الجاري كان (703,6 NTU). وقيمة معدل أدنى تركيز TSS مسجلة في الماء الآسن كانت 5350,5 مغ/لتر بسبب طبيعة العوامل الملوثة لنفايات البلدية والمكونة من أنواع عديدة من الفضلات.

قيم التركيز TDS كانت عالية في أغلب أماكن نهر تا نجرو بقيمة معدل 827.8 و 1540 مغ/لتر في حالتي الركود والجريان في حين أنها كانت 31080 مغ/ لتر في الماء الآسن، وهذه القيمة العالية لمعدل الماء الآسن يعود إلى عدم السيطرة على الموقع كمنطقة مفتوحة لرمي القمامة.

قيم معدل تركيز الصوديوم (Na) كانت 53,6 ، 84,5 ، 5144,3 و 120,92 مغ/لتر والبوتاسيوم (K) كانت 29,4 ، 20,73 ، 1861,5 و 1,18 مغ/لتر والمغنيسيوم (Mg) كانت 22,6 ، 20,77 ، 354,2 و 17,3 مغ/لتر في نهر تا نجرو بمائه الجاري والراكد والماء الآسن ومياه الآبار على التوالي. القيم كانت أعلى من الدرجة المسموح بها وفق المعايير المقبولة. زيادة تركيز K, Mg, Na في المياه الجوفية ربما يعود لتأثير موقع الردم في تا نجرو وعملية استعمال المواد المعقمة والمنظفات. زيادة التراكيز

المذكورة أعلاه لنهر تا نجرو سببه امتزاج مياه مجاري مدينة السليمانية بطريقة مباشرة مع النهر وترسب ملوثات البيئة في موقع القمامة وكذلك النشاطات البشرية، بالإضافة الى هذا فإن النتائج تظهر بأن معدل تركيز البوتاسيوم كانت في الحدود المسموحة بها لمياه الشرب.

قيم تراكيز كل من Cl ، SO_4 ، PO_4 و NO_2 **كانت** 35.4 ، 24.48 ، 3459.4 و 17.42 **مغ/لتر للكلورايد ، و** 77.8، 56.8 ، 459.3 و 83.3 **مغ/ لتر للسولفات و** 8.8 ، 8.2 ، 27 و 0.2 **للفوسفات، و** 0.2 ، 0.16 ، 0.72 و 0.04 **مغ/لتر للنترات في نهر تا نجرو في حالة الجريان والركود وفي الماء الآسن ومياه الآبار على التوالي. تركيز** PO4 **في مياه الآبار كانت أعلى من النسبة المسموح بها. والنسبة العالية للسولفات كانت بسبب وجود نفايات صناعية في موقع رمي القمامة والتي تعتبر نقطة مصدر السولفات. وتُظهِر مياه الآبار بأن مقدار تركيز النترات هو في الحدود المسموح بها.**

قيمة معدل تركيز العناصر الثقيلة (Fe / Mn /Cd /Cr/ Zn/Cu /Pb /Hg) **كانت كالتالي :** (0.59 ، 0.34 ، 12.1 و 0.29 **مغ/ل لـ** Hg) **في حين أنها كانت لـ** Pb (0.42 ، 0.35 ، 0.46 و 0.28 **مغ/ل**) **ولـ** Cu (0.06 ، 0.06 ، 0.29 و 0.06 **مغ/ل**) **ولـ** Zn (0.05 ، 0.04 ، 0.75 و 0.12 **مغ/ل**) **ولـ** Cr (0.16 ، 0.22، 0.07 و 0.24 **مغ /ل**) **ولـ** Cd (0.08 ، 0.08 ، 0.12 و 0.05 **مغ/ل**) **ولـ** Mn (0.15 ، 0.17 ، 4.75 و 0.01 **مغ/ل**) **ولـ** Fe (0.05 ، 0.06 ، 2.4 و 0.12 **مغ/ل**) **في نهر تا نجرو في حالة الجريان وحالة الركود والماء الآسن ومياه الآبار على التوالي.**

النتائج تظهر بأن العينات المأخوذة من الماء الآسن في موقع رمي القمامة توجد فيها تراكيز عالية من العناصر الثقيلة (ماعدا الـ Mn وZn وFe**) والتي تخطّت القيم المقبولة والمسموح بها. بسبب تلك النفايات الصلبة التي ترمى يومياً والتي يوجد فيها نفايات صناعية ونفايات بلدية ونفايات سامة وخطرة ونفايات طبية، في حين أن قيم تراكيز الفلزات الثقيلة في نهر تا نجرو كانت أدنى.**

أكثرية العينات المدروسة المأخوذة من النهر تظهر التلوث بالعناصر الثقيلة (ماعدا الـ Zn و Cu وAl وFe**) والتي تخطّت قيمة المقادير المسموح بها. بسبب تأثير فضلات مجاري مدينة السليمانية وقرب موقع رمي القمامة من النهر والنشاطات البشرية.**

معدل العناصر الثقيلة كان عالياً إلى حد ما في مياه الآبار القريبة من موقع رمي القمامة. أكثرية النماذج والعينات المأخوذة من مياه الآبار تخطّت الحدود المسموح بها في مياه الشرب (ماعدا الـ Fe و Mn و Al**).**

الخواص البكتريولوجية تظهر بأن قيمة المعدل العام لعدد البكتريا ،التي وجدت كانت كالتالي: (21.8*10^9) **و** (334.6 * 10^9) **و** (4.36 * 10^9) CFU/ml **وللمجموع الكوليفورم كانت** (1217)، (2400) **و** (816.5) **وأعداد لا تحصى من الفيكل كوليفورم لنماذج المأخوذة لماء نهر تا نجرو في حالة الجريان وفي حالة الركود والماء الآسن في موقع رمي القمامة على التوالي.**

كثرة البكتريا ووجود (thermotolerant faecal coliform) **في العينات التي أجريت عليها التحاليل تظهر ارتفاع نسبة تلوث بالفيكل وفق المعايير. تظهر النتائج أيضاً وجود أعداد كثيرة من الكوليفورم ومجاميع البكتريا في نهر تا نجرو بالمقارنة مع موقع قمامة تا نجرو.**

نتيجة تحاليل نوعية الهواء المحيط بالموقع لمستويات الـ RPM_{10} وSPM وSO_2 و NO_X وCO وHC **كانت أعلى من التراكيز المقررة التي حددها البنك الدولي لنوعية الهواء في مثل تلك المناطق.**

الدلائل تظهر وجود مشاكل صحيّة وهذا يتبيّن من زيادة معدلات الشكاوى التي يتقدم بها السكان في المنطقة المحيطة بموقع مردم الفضلات وكثرة أعداد الحالات السرطانية في مدينة السليمانية وفقاً لتقرير مستشفى هيوا الخاص بأمراض السرطان، هذه كلها مؤشرات على النتائج المضرة لردم الفضلات في موقع تا نجرو.

حكومة إقليم كوردستان
وزارة التعليم العالي والبحث العلمي
جامعة السليمانية – كلية الزراعة

تأثير ردم النفايات في موقع تانجرو على بيئة السليمانية

أطروحة مقدمة إلى
كلية الزراعة – جامعة السليمانية
كجزء من متطلبات نيل درجة الدكتوراه فلسفة
في
تلوث البيئة
(الهواء ، التربة ، المياه الجوفية)

من قبل

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أ.م.د. محمد أمين عبدالعزيز البرزنجي
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مشرف

جمادى الأولى (1431) هـ   گولان (2709) ك   نيسان (2010) م

پوختەی لێکۆڵینەوەکە

ئەم لێکۆڵینەوەیە لە تانجەرۆ ئەنجامدراوە کە شوێنی رۆکردنی خاشاکە و رووبەرەکەی (180) دۆنم زەویە و بە دووری (10) کیلۆمەتر دەکەوێتە خوارووی شاری سلێمانییەوە. بە پێی ئامارێکی ساڵی 2009 دانیشتوانی شاری سلێمانی نزیکەی (700.000) حەوتسەد هەزار کەس دەبن و رۆژانە (1000) تۆن لە خاشاکی رەق (solid waste) دروست دەکەن. داتاکان لەسەر بنەمای وەرز و مانگ کۆکراونەتەوە لەوانەش نموونە لە ئاوی رووباری تانجەرۆ و چڵکاو و ئاوی ئەو بیرانەی کە نزیکن لە شوێنی فڕێدانی خۆڵەکە و هەروەها نمونەی خۆڵەکەش وەرگیراوە. بۆ شیکارە تاقیگەییەکانیش نموونە بە شێوەیەکی راستەوخۆ لە شوێنی جیاواز وەرگیراون بە مەبەستی شیکاری فیزیوکیمیایی وبایۆلۆجی. بۆ پێوانی چۆنیەتی هەوای ئەو ناوچەیە ی کە لێکۆڵینەوەکەی تیادا ئەنجامدراوە ، هەردوو لە شیکاری گازو فلتەر بۆ کۆکردنەوەی نمونەکان و تۆمارکردنی داتاکان بەکارهێنراون و لەهەمان کاتدا چەندین تاقیکردنەوەی جیاواز بۆ دەستنیشانکردنی پیسبوونی میکرۆبایۆلۆجی ئەنجامدراون.
هەرنموونەیەکیش شیکاری بۆ کراوە بۆ کاتیۆنە سەرەکیەکان (Ca^{2+} , Na^{+} , K^{+} , Mg^{2+}) و ئانیۆنەکان (NO^{-}_{2}, NO^{-}_{3}, Cl^{-}, PO^{-3}_{4}) و کانزا قورسەکان.

بەهای تێکڕای پەیتیی ترشەڵۆکی (pH) لە نێوان7.8، 7.9 ، 8.1 و 8.2 دایە لە ناو رووباری تانجەرۆ راوەستاو و خوڕ و چڵکاوی شوێن خاشاکی تانجەرۆ و ئاوی بیرەکانی نزیکی یەك لەدوای یەك (علی التوالي). داتا کۆکراوەکان لەو شوێنەی ئەم لێکۆڵینەوەیەی تیادا ئەنجامدراوە تفتی مامنەوەند بۆ بەهێزی پیشانداوە.

بەهاکانی گەیاندنی کارەبایی (EC) جیاوازن لە نێوان 876.4 ، 781.9 ، 24117.8 و 1125 μs/cm بۆ هەردوو ئاوی خوڕ و وەستاوی روباری تانجەرۆ و چڵکاوی شوێنی فڕێدانی خاشاکەکە و ئاوی بیرەکان یەك لە دوای یەك (علی التوالی). بەها بەرزەکانی EC لە شوێنی فڕێدانی خاشاکەکە تێبینی کراون ئەمەش ئاماژە بەوە دەدات کە بڕێکی زۆر لە خوێ و مادده تواوەکانی ناو چڵکاوەکە لە شوێن خاشاکی تانجەرۆدا بەرهەم هاتووە. بەهاکانی EC بەرز بوون لە زۆربەی نموونەکانی ئاوی تانجەرۆ ئەمەش کاریگەری سەرچاوەکانی (تدفق) لە ناوچەکانی نیشتەجێبوون و کشتوکاڵەوە دەردەخات کاتێك بڕێکی زۆر لە ئاوی تۆڕەکانی صرف وە زێراب (ئاوی پاشەڕۆ) لە چەند سەرچاوەیەکی جیاوازەوە دەرژێنە ناو روباری تانجەرۆوە.

کۆی گشتی ناسازی ئاو لە نێوان 224.7 ، 233.8 ، 281.2 و 90.2 تۆمارکرا وەکو ملغم CaCO3 /لیتر. روباری تانجەرۆ بە ئاوێکی ناساز (hard)دانراوە، نموونەکانی چڵکاوەکەش بە زۆر ناساز. زۆرترین بەهای کۆی ناسازی لە ئاوی بیرەکانی نزیك لە شوێنی رۆکردنی خاشاکەکەوە وەرگیراوە. نموونەی ئاوی وەرگیراو لە بیرەکانەوە بە شێوەیەکی مام ناوەندی بە ئاوی سازگار (سۆفت) دەژمێررێت. ئەنجامەکان ئەوە دەردەخەن کە بەهاکانی تێکڕای خەستی BOD لە نێوان 3.7 ، 2.4 ، 0.3 و 1.1 مغ/لیتر بوون یەك لەدوای یەك. بەهای کەمترین خەستی کە تۆمارکرا لە چڵکاوەکەدا 0.03 مغ/لیتر بوو وە بەهای بەرزترین خەستی 9ر13 مغ/لیتر تۆمارکرا لە ئاوی وەستاوی روباری تانجەرۆدا لە کاتێکدا ئاوی خواردنەوەی بیرەکان بە پاك یان پاکێکی مامناوەند پۆلێنکراوە.

بەهاکانی تێکڕای خەستی ئۆکسجینی تواوە (DO) لە نێوان 4.43 ، 4.16 ، 0.59 و 2.65 مغ/لیتر بوون (علی التوالی) . بەهاکانی زۆرترین چڕیش لە کاتی توێژینەوەکەدا هاوکات بوون لەگەڵ بەهای نزمی لێلبوون (عکر) لە کاتێکدا (DO) وردە وردە زیاد دەکات کاتێك بەرەو دەریاچەی دەربەندیخان دەروات ئەمەیش بەهۆی سەرلەنوێ پێدانەوەی ئۆکسجین بە ئاوەکە (reareation) و خۆپاککردنەوەوە. تەحویل بوونی سولفایت بۆ سولفایدی هایدرۆجین، کە ئەمەش زۆر نەویستراوە لە چڵکاودا دەبێتە دروست بوونی بۆنی (هێلکەی پیسبو) بە هۆی کەمیی DO (0.6 مغ/لیتر) .

زێرابی شاری سلێمانی (ئاوی پاشەڕۆ) ، کارگەکانی چەوو لم ، ئاوی شوێنە کراوەکان و شۆردنەوەی پێکهاتەی خاشاکەکە ئەمانە هەموو هۆکارە سەرەکییەکانی بەرزی (لێڵ بوون) و TDS و TSSن لەو ناوچەیەی کە لێکۆڵینەوەکەی تیا ئەنجامدراوە. تێکڕای بەرزترین لێڵی (تعکر) کە لە ئاوی خوڕی تانجەرۆدا تۆمارکراوە (NTU 703.6) ە . وە بەهای تێکڕای کەمترین خەستی TSS کە لە چڵکاوەکەدا تۆمارکراوە 5350.5 مغ / لیتر ئەویش بەهۆی سروشتی هۆکارە پیسکەرەکانی شارەوانی کە پێکهاتووە لە چەندین جۆر لە پاشماوە. بەهاکانی کۆی گشتی مادە تواوەکان TDS بەرز بوون لە زۆربەی شوێنەکانی روباری تانجەرۆ بە بەهای تێکرایی 827.8 و 1540 مغ/ لیتر بە هەردوو شێوازی خوڕ و وەستاو لە کاتێکدا لە چڵکاوەکەدا 31080 مغ/ لیتر بوو، ئەم بەها بەرزەی تێکڕای چڵکاوەش دەگەڕێتەوە بۆ کۆنترۆڵ نەکردنی ئەو شوێنە وەکو ناوچەیەکی کراوەی فڕێدانی خاشاك.

بەهاکانی تێکڕای خەستی سۆدیۆم (Na) 53.6 ، 84.5 ، 5144.3 و 120.92 مغ/لیتربوون و پۆتاسیۆم (K) 29.4 ، 20.73 ، 1861.5 و 1.18 مغ/لیتر بوون و مەگنیسیۆم (Mg) 22.6 ، 20.77 ، 354.2 و 17.3 مغ/لیتر لە ڕوباری تانجەرۆ بە خوڕی و بە وەستاوی و چڵکاوو ئاوی بیر یەك لەدوای یەك. بەهاکان لە ئاستی ڕێگە پێدراو بەرزتر بوون بە پێی ستانداردە پەسەندکراوەکان. زۆری خەستی K, Mg, Na لە ئاوی ژێرزەوی ڕەنگە بە هۆی کاریگەری شوێن خاشاکی تانجەرۆ و کرداری ماددە پاکژکەرەوەکان بێت. بەروباری تانجەرۆشەوە هۆکارەکەی تێکەڵبونی ئاوی پاشەڕۆ (زێرابی شاری سلێمانی) (سیاناوی شاری سلێمانی) بە شێوەیەکی ڕاستەوخۆ بە ڕوبارەکە و چۆڕانەوەی ژێنگە پیسکەرەکان لە شوێنی خاشاکەوە هەروەها چالاکییە مرۆییەکان ، سەرەڕای ئەمانە ش ، ئە نجامەکان ئەوە پیشان دەدەن کە بەهای تێکڕای خەستی پوتاسیۆم لە سنوری ڕێگە پێدراودا بووە بۆ ئاوی خواردنەوە.

بەهاکانی تێکڕای خەستی هەریەك لە Cl ، SO$_4$ ، PO$_4$ وە NO$_2$ 35.4 ، 24.48 ، 3459.4 وە 17.42 مغ/لیتر بوون بۆ کلۆراید ، وە 77.8 ، 56.8 ، 459.3 وە 83.8 مغ/ لیتر بۆ سولفات ، 8.8 ، 8.2 ، 27 وە 0.2 بۆ فۆسفات ، وە 0.2 ، 0.16 ، 0.72 وە 0.04 مغ/لیتر بۆ نیترات لە ڕوباری تانجەرۆ لەکاتی وەستان و خوڕی و لە چڵکاو و ئاوی بیر یەك لە دوایەك. خەستی PO$_4$ لە ئاوی بیردا بەرز تر بووە لە ڕێژەی ڕێگە پێدراو . ئەو ڕێژە زۆرەی سولفاتیش بە هۆی بوونی خاشاکی پیشەسازییەوە یە کە لە شوێنی خاشاکەکەدا بوونی هەیە وە بە خاڵی سەرچاوە (point source)ی سولفات دادەنرێت. ئاوی بیرەکانیش بڕی خەستی نیترات لە سنورێکی پەسەندکراودا پیشاندەدات.

بەهای تێکڕای خەستی کانزا قورسەکان (Fe / Mn /Cd /Cr/ Zn/Cu /Pb /Hg) بەم شێوەیە بوون : (0.59 ، 0.34 ، 12.1 وە 0.29 مغ/ل بۆ Hg) لە کاتێکدا بۆ Pb (0.42 ، 0.35 ، 0.46 وە 0.28 مغ/ل) وە بۆ Cu (0.06 ، 0.06 ، 0.15 وە 0.06 مغ/ل) وە بۆ Zn (0.05 ، 0.04 ، 0.75 وە 0.12 مغ/ل) وە بۆ Cr (0.16 ، 0.22، 0.07 وە 0.24 مغ/ل) بۆ Cd (0.08 ، 0.08 ، 0.12 وە 0.05 مغ/ل) بۆ Mn (0.15 ، 0.17 ، 4.75 وە 0.01 مغ/ل) وە بۆ Fe (0.05 ، 0.06 ، 2.4 وە 0.12 مغ /ل) لە ڕوباری تانجەرۆ بە وەستاوی و خوڕی و ئاوی بیرەکان یەك لە دوای یەك.

ئە نجامەکان ئەوە دەردەخەن کە نمونەکانی (عینات)ی ناو چڵکاوی شوێنی خاشاکەکە خەستی زۆری کانزا قورسەکانی تێدایە (جگە لە Mn وZn وFe) کە لە بەهای ڕێگە پێدراوی پەسەندکراو لایان داوە بە هۆی ئەو خاشاکە ڕەقەی کە ڕۆژانە فڕێدەدرێت کەچەندین پاشماوەی پیشەسازی و شارەوانی و سامناك و تەندروستی (طبي) تێدایە لە کاتێکدا کە بەهای خەستی کانزا قورسەکان لە ڕوباری تانجەرۆدا بەهایەکی نزمتری پیشانداوە. زۆربەی نموونە دیراسەت کراوەکان کە لە ڕوباری تانجەرۆوە وەرگیراون پیسبوون بە کانزای قورس دەردەخات (جگە لە Zn و Cu وAl وFe) کە لە بەهای بڕی ڕێگە پێدراو لایداوە بە هۆی کاریگەری ئاوەڕۆی شاری سلێمانی ونزیکی شوێنی ڕشتنی خاشاکەکە لە ڕوبارەکەوە و چالاکییە مرۆییەکان .

ئاستی کانزا قورسەکان تا ڕادەیەك بەرزە لە ئاوی بیرەکانی نزیك لە شوێنی خاشاکەکەوە. نزیکەی هەموو نمونەکانی لە ئاوی بیر وەرگیراون لە بەهای ئاستی ڕێگە پێدراو بۆ خواردنەوە تێپەڕیان کردووە جگە لە Fe وMn وAl.

خاسیەتە بەکتریۆلۆجیەکان ئەوە دەردەخەن کە بەهای تێکڕای گشتی ژمارەی بەکتریا ، کە دۆزراونەتەوە بەم شێوەیەیە بوون ($21.8*10^{9}$) وە ($344.6 * 10^{9}$) وە ($4.36*10^{9}$) CFU/ml , بەڵام بۆ کۆی گشتی کۆلیفۆرم(coliform) بریتییە لە (1217) ، (2400) وە (816.5) وە ژمارەیەکی زۆری فیکل کۆلیفۆرم (کەلە ژمارە نایەت) بۆ ئاوی ڕوباری تانجەرۆ بە وەستاوی و بە خوڕی و چڵکاوی شوێنی خاشاکەکە یەك لەدوای یەك.

زۆری بەکتریا و بوونی (thermotolerant faecal coliform) لە نموونە شیکارکراوەکاندا بەرزی ڕادەی پیسبوونی بە فیکل کۆلیفۆرم دەردەخات بە پێی ستانداردەکان. ئە نجامەکان هەروەها ژمارەیەکی زۆری کۆلیفۆرم و کۆی بەکتریا لە ڕوباری تانجەرۆ دەردەخەن بە بەراورد لە گەڵ شوێنی خاشاکی تانجەرۆ.

ئە نجامی چۆنیەتی هەوای نزیك بە شوێنەکە ئاستەکانی RPM$_{10}$ وSPM وSO$_2$ و NO$_X$ و CO وHC بەرزتر بوون لە خەستی دیاری کراو کە بانکی جیهانی بۆ شێوازەکانی چۆنیەتی هەوای ئەو ناوچانە دیاریکردووە.

بەڵگە بۆ دەرکەوتنی کێشەی تەندروستی بەدی دەکرێت لە بەرزبوونەوەی ئاستی ئەو گازندانەی کە دانیشتوانی دەوروبەری شوێن خاشاکەکە دەیکەن وە زۆربوونی ژمارەی حاڵەتەکانی شێر پە نجە لە شاری سلێمانی بە پێی ڕا پۆرتی نەخۆشخانەی هیوا کە تایبەتە بە نەخۆشیەکانی شێر پە نجە . ئەمانە هەمووی ئاماژەن بە دەرە نجامە زیانبەخشەکانی شوێن خاشاکی تانجەرۆ.

حکومەتی هەرێمی کوردستان
وەزارەتی خوێندنی باڵاو توێژینەوەی زانستی
زانکۆی سلێمانی – کۆلێجی کشتوکاڵ

کاریگەری وێستگەی خاشاکی تانجەرۆ لەسەر ژینگەی سلێمانی

تێزەیەکە
پێشکەش بە کۆلێجی کشتوکاڵ/ زانکۆی سلێمانی کراوە
وەك بەشێك لە پێویستییەکانی بەدەستهێنانی پلەی دکتۆرای فەلسەفە
لە
پیس بوونی ژینگە
(هەوا ، خاك ، ئاوی ژێرزەوی)

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