Assessment of treated wastewater Quality under different climate change Scenarios in Jordan

Prepared by IHP committee

Ministry of Water and Irrigation

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INTRODUCTION

The Kingdom of Jordan has faced the problem of water scarcity for many years, and reuse of treated wastewater in agriculture is necessary to overcome this problem. The volume of treated wastewater produced in 2005 reached 82 MCM per year, of which about 95% is reused for irrigation (Haddadin 2005). The reuse of treated wastewater in Jordan reached one of the highest levels in the world that about 80% of the treated effluent is discharged to Zarqa River from Kherbit As Samra where it is collected and stored downstream in King Talal Dam to be used for restricted irrigation in the central part of the Jordan Valley. The remaining 20% which is not located within the Zarqa river watershed is reused on-site. The treatment and reuse of this vital resource is well organized. Future plans aim at improving the quality of effluent and expanding its reuse in other areas in the upland.

Shatanawi, et al. (1994) indicated that, the initially high coliform population in wastewater decreased at first and after chlorination but increased again at irrigated site. Soil EC, was increased at surface soil 0-20 cm depth by using treated wastewater irrigation. In general the trace and heavy metals were increased in soil at different depths by the irrigation by treated wastewater.

Meteorological observation over the last few decades showed that throughout most of the Mediterranean there have been an increase in the frequency of high rainfall intensity and a decrease in the mean annual rainfall (Haim et al. 2001). Jordan suffers from water shortages due to low amount of annual rainfall and high evaporation rate as it is located in a semi arid region. More than 60% of its water resources are being used for agriculture, where treated wastewater is an important portion of this source especially during summer seasons where an increase demand on water exists.

Three climatic models can be found on the eastern flank of the Jordan valleys. They range from Mediterranean climatic conditions on the upper mountainous part (rain fall around 400mm/year) to arid environments in Jordan valley (<150 mm/year) and semiarid in between (Metrology Department, 2003). Water movement of fresh water in the unsaturated zone was investigated the Jordan valley by Jiries et al. 1991 and in the mountainous region (GLOWA, JR phase I). They found that evaporation from soil played a major role in amount and direction of water movement in the unsaturated zone.

The shift of climate in the eastern Mediterranean to warmer and drier conditions results in higher demand for irrigation water as well as a change in its quality. The expected shortage in water resources for irrigation will be substituted by higher use of treated wastewater which could be the main source of irrigation water in the country. However, the reuse of the treated wastewater for irrigation purposes is combined usually with adverse environmental impacts on the irrigated soil, crop type and quality, irrigation water and groundwater quality. Increasing of the evaporation might lead to increase the concentration of the chemical constituents of the irrigation water. On the other hand, increasing temperature and solar radiation intensity increase photo degradation of the organic constituents in both water and soil irrigated with wastewater.

Four of the United Nations (UN) organizations, which work in Jordan, namely UNDP, WHO-CEHA, FAO, and UNESCO, are implementing jointly the program titled "Adaptation to Climate Change to Sustain Jordan's MDG Achievements." The program is financed by the MDG Achievement Fund which is in turn financed by the Government of Spain, SIWI, and UNDP Jordan. Besides the Ministry of Water and Irrigation (MWI), national key partners include the Ministry of Health (MoH), Ministry of Agriculture (MoA), and Ministry of Education (MoE), Ministry of Environment (MoEnv), in addition to other institutions, societies, and nongovernmental organizations (NGOs).

The program addresses challenges caused by climate-related water scarcity, including access to improved water sources including wastewater. The wastewater treatment plant at Karak city serves as a pilot area and which can be applied to other locations in the country, in which the adaptive capacity of vulnerable communities is strengthened. The program started in 2008 and was expected to last for three years.

The program will help Jordan address the above key strategic issues through achieving:

1. Sustained access to improved water supply sources despite increased water scarcity induced by climate change and

2. Strengthened adaptive capacity for health protection and food security to climate change under water scarcity conditions.

These outcomes address identified wastewater quality and soil irrigated with wastewater to provide support to Jordan's national strategies and action plans for sustainable management of its natural resources; reducing poverty; and enhancing health indicators.

One of the main components of the program is the UNESCO component. Under this component, the IHP committee at the MWI to conduct a professional consulting service for the project titled "*Assessment of treated wastewater Quality under different climate change Scenarios in Jordan*

CURRENT CLIMATIC CONDITIONS

Jordan is located about 80 km east of the Mediterranean Sea between latitudes 29°11' and 33°22' north, and longitudes 34°19' and 39°18' east. The area of its land mass is about 88,778 km^2, while the area of its water bodies is approximately 482 km^2, including the Dead Sea and Gulf of Aqaba. Altitude ranges from less than -424 m (below mean sea level) at the surface of the Dead Sea up to the 1812 m of Jebel Rum resulting in different climates exist in the country (Figure 1).

Most of the precipitation falls in the form of rain or drizzle. Snow may fall on highlands and hail is frequent during thunderstorms. About 75% of precipitation falls during winter season, which extends from December to March. In general, the annual precipitation in the Jordan valley is less than that over mountainous regions located west or east of the Valley. The annual precipitation in the northern parts of the valley is the highest at the north, decreasing gradually southward. The annual precipitation ranges from 394 mm in the northern parts at Baqura to 74 mm in the southern parts at Ghore Safi (JOMET, 2008).

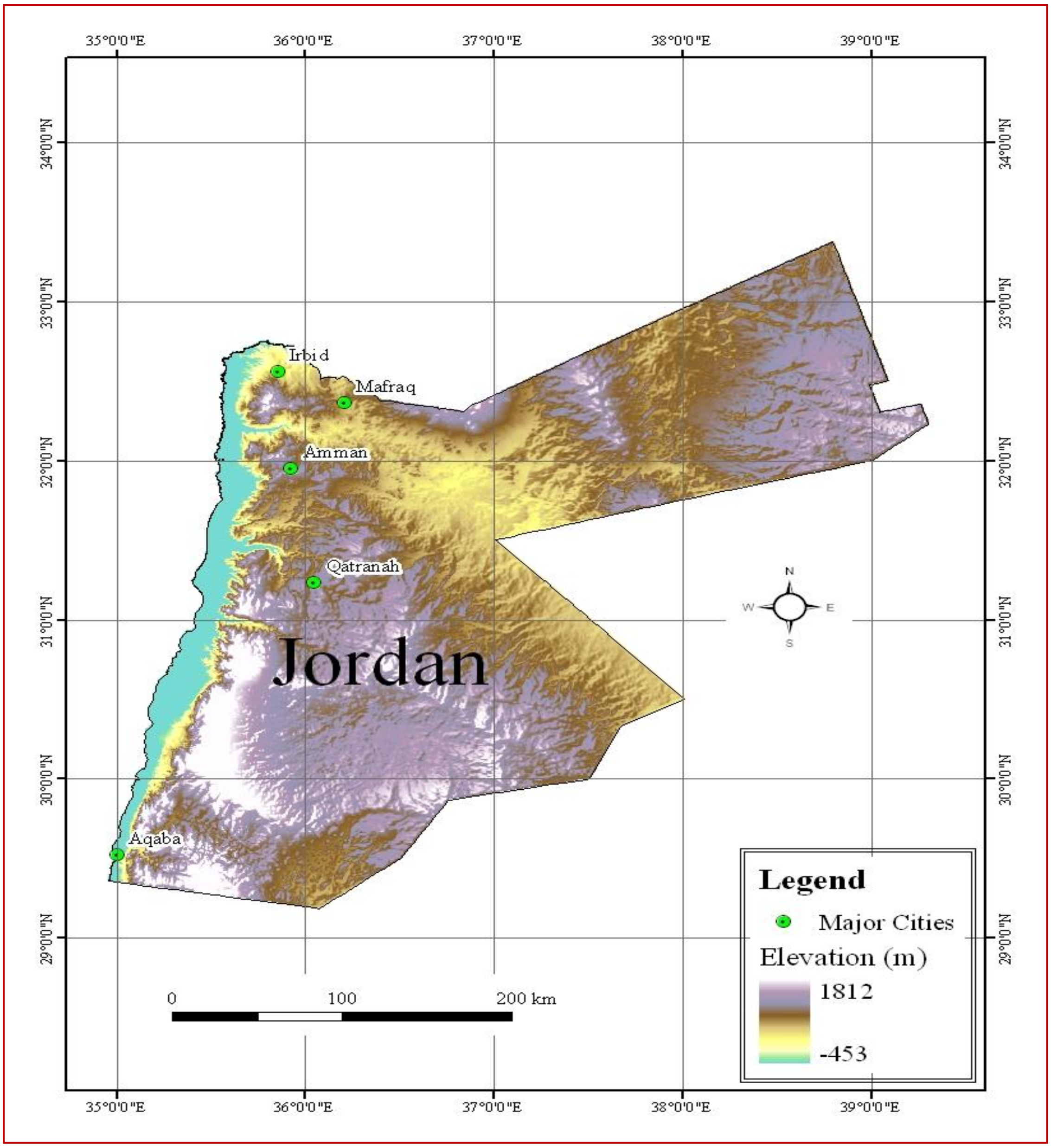

Figure 1: General topography map of Jordan showing its major cities.

As shown in figure 2, the amount of annual precipitation in Mountainous Region is the highest. It exceeds 550 mm in Ajloun and Balqa Mountains, decreasing gradually southward to about 339 mm in Rabba/Karak, 294 mm in Shoubak, and 238 mm in Tafeeleh. In the Steppes Region, the amount of rainfall is about 100-200 mm. The northwestern part of Jordan has the greatest annual rainfall amount with 572 mm in Ras Muneef (1150 m above sea level). The total rainfall decreases eastward, and southward to minimum values as in the extreme southern parts, 32 mm in Aqaba, and in the southeastern parts 33 mm in Jafr. In spite of the higher elevations in the southern region, it has rainfall amounts less than the lower northern heights. Shoubak with 1365 m above sea level has a total annual rainfall of 288 mm while the northern mountains are totally lower than 1150 m, and have annual rainfall of more than 400 mm. In the eastern desert (arid) area and in the south, the rainfall occurrences are of small scale and rather random (MoEnv, 2009).

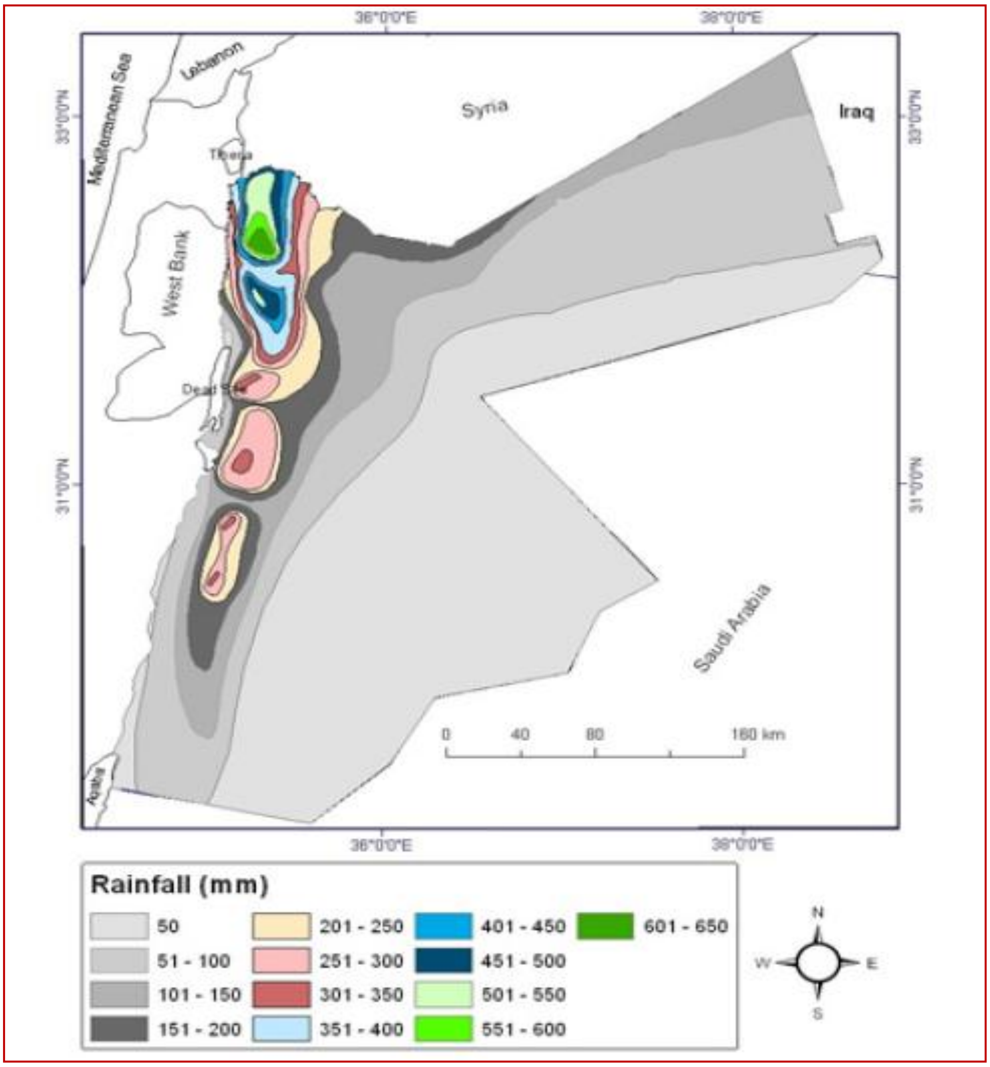

Figure 2: Main annual rainfall in Jordan (source: MoEnv, 2006).

The country has a long summer, which might extend from mid of May to end of September, which reaches a peak during August with daytime temperatures frequently exceeding 36°C and averaging more than 32°C. Atmospheric pressures during summer months are relatively uniform. For a month or more before the summer dry season, hot, dry air from the desert, drawn by low pressure, produces strong winds from the south or southeast that sometimes reach gale force. This wind is known as the *khamasin* and usually accompanied by great dust clouds, a falling barometer, a drop in relative humidity to about 10 percent and a 10°C to 15°C rise in temperature. These windstorms ordinarily last a day or more and result in advection that causes much discomfort and frequent failure of many rain fed field crops at the flowering stage. Another wind of some significance comes from the north or northwest, known as *shammal*, generally at intervals between June and September. Remarkably steady during daytime hours but becoming a breeze at night, the *shammal* may blow for as long as nine days out of ten and then repeat the process. It originates as a dry continental mass of polar air that is warmed as it passes over the Eurasian landmass. The dryness allows intense heating of the earth's surface by the sun, resulting in high daytime temperatures that moderate after sunset (MoEnv, 2006).

IMPACT OF CLIMATE CHANGE

Climate change or global warming is known as an increase in the earth's temperatures that is believed to be caused by human activity. The main expected consequences of climate change are believed to be global temperature change; a rise in sea level; an increase in droughts and floods as well as other natural catastrophes; decreased air and water quality; loss of biodiversity; stratospheric ozone depletion; and migration and mitigation issues between countries.

The Middle East is the world's most water-stressed region. Climate change is expected to make water resources even more scarce in countries such as Jordan, which are already among the most water-scarce countries in the world, and will thereby contribute to even greater water stress in the region making reuse of treated wastewater one of the most important future water resources especially for irrigational purposes under new climatic conditions.

The annual decrease in precipitation has led to less freshwater availability for surface or ground water. In addition, a reduced amount of agricultural land will be available due to desertification and urban sprawling.

Most of Jordan’s territory is classified as desert. Summers are generally hot and dry, while winters can be cold in some areas. The annual rainfall varies from little more than 30 mm in desert areas up to 572 mm in the hilly northwest of Jordan. Almost all precipitation falls between October and May.(MWI, 2010). In the Jordan Valley, winters are mild and summers very hot, with very little rainfall throughout the year (Suleiman et al. 2008).

Jordan’s Second National Communication includes a chapter on observed and projected climate change in the country. Concerning the past, data for the period 1961-2005 (or shorter in some cases) of 19 meteorological stations all over Jordan were evaluated with the following results:

- The minimum temperature increased by 0.4-2.8°C, the maximum temperature by 0.3-1.8°C.
- Thirteen stations show a decreasing total annual precipitation by 5-20%. Six stations experienced an increase by 5-10%.
- The number of rainy days decreased by 3-10% in most of the stations
- In most stations, relative humidity decreased while evaporation increased
- The World Bank Climate Change Data Portal shows results which are similar to those of the Second National Communication. Climate change for the period 2030-2049 was projected by several GCMs. The tool shows the number of GCMs agreeing in the direction of change, as shown in the table below.

Table 1: The number of GCMs agreeing in the direction of change

Projection (2030 - 2049 vs. 1980-1999)	
Mean Annual Precipitation	-11% to -18%
Runoff	-20% to -21%
Mean Annual Temperature	+2°C
Daily Precipitation Intensity	+4% to +6%
Consecutive Dry Days	-5 to +4 days

According to the data portal, temperature is projected to increase in all locations. Precipitation is projected to decrease in all locations by most models, but there is a certain uncertainty in Amman, Aqaba and Ma'an, where about three quarters of the models agree. Precipitation intensity is projected to increase by at least three quarters of the models in all locations. The results concerning consecutive dry days are completely uncertain with half of the models projecting more and the other half less consecutive dry days. There seems to be an error concerning runoff, since the data portal shows impossible data concerning uncertainty. (UNFCCC, 2009)

In 2009 another government report noted that "Jordan's remarkable development achievements are under threat due to the crippling water scarcity, which is expected to be aggravated by climate change (Wardam, 2010) Rainfall is expected to decline significantly and evaporation and transpiration of plants will increase due to increased temperatures. The National Water Strategy has been criticized for missing out the impact that climate change is projected to have on the availability of water resources (Jordan Times 1998).

The agricultural sector is particularly threatened by climate change and its impacts, since it is the largest water user in Jordan. Climate change does not change the challenges in Jordan, which are mainly related to water scarcity. Instead, it is another factor contributing to aggravate the existing shortage, adding to the rapid population growth.

The Earth's climate system is intimately connected to the movement of water and key biogenic greenhouse gases. Microbes could have various positive and negative feedback responses to climate change especially in temperature, but the magnitudes of these are inadequately understood. This lack of knowledge is probably the reason why microbial activity is missing from most climate change models (Singh *et al.,* 2010).

Bacteria represent largest population size where there are 10^8 to 10^9 bacterial cells per g of dry soil (Wingate *et al.,* 2009). Such population size has influence directly on greenhouse gas production of temperature, changing precipitation and extreme climatic events. It indirect influence changes in plant productivity and diversity which alter soil physicochemical conditions, the supply of carbon to soil as microbe communities are involved in decomposition processes and carbon release from soil (Bardgett *et al*., 2008).

Nevertheless, the influence of climate change on the soil carbon sink remains a major area of uncertainty, especially as there is scope for warming to increase the liberation of carbon dioxide from soil to atmosphere due to enhanced microbial breakdown of soil organic matter.

WASTEWATER TREATMENT AND REUSE

It was stated in wastewater strategy of Jordan 2008-2022 that it should continue to expand the safe use of treated wastewater by building new wastewater treatment plants and exploring productive uses in agriculture, industry, and urban landscapes. In addition to explore the potential for using treated wastewater for aquifer recharge as is done in other parts of the world. The overall strategy aimed to achieve Goal 5 that stated treated wastewater effluent is efficiently and cost-effectively used on 2022.

One of Jordan's future challenges is the safe use of treated wastewater for irrigation in the Jordan Valley and its produce will need continuous monitoring and reinforcement. Additionally, drought management and adaptation to climate change will need to be addressed through proper policies and regulations. A major decrease in the amount of water available for agricultural and household purposes in Jordan is anticipated as a direct effect of global warming Increasing temperatures in the Jordan Valley, coupled with varying amounts and timing of rain in the next few decades would put many Jordanian farmers out of business, posing an extra challenge to policy makers.

In areas such as Jordan where amounts of surface water and groundwater recharge are projected to decrease, water quality will also decrease due to lower dilution (Environment Canada, 2004).

Jordan's water consumption in 2007 totaled 941 million cubic meters (MCM), of which 64% is consumed by agriculture, 31% domestic, 4% industrial, and 1% by other activities MWI, 2007. Wastewater is currently treated in 23 wastewater treatment plants throughout the country, with total influent measuring 111.8 MCM yr-1 and effluent of 86.53 MCM yr-1. Most of the effluent water is currently used in Jordan for agriculture purposes and groundwater recharge Al Nasir & Batarseh, 2008. As of 2006, only 14% of the wastewater was being reused, because farmers in the Jordan Valley are reluctant to use the poor quality reclaimed water for irrigation

Reuse of treated wastewater in agriculture is of highly import as wastewater treatment plants generate effluents that must be disposed of. It is well known that sewage sludge represents a potentially valuable source of nutrients and organic matter for arable farming, for the reconditioning of sandy and degraded soils, as well as for a major source of irrigation water under scarce water resources. Although sewage sludge improves soil properties and its use in the rehabilitation of degraded natural and anthropogenic soils seems to be the most convenient, it is controversial because of possible health and environmental risks involved

Now a day, the treated wastewater produced from twenty three existing wastewater treatment plants is an important component of the Kingdom's water resources. About 100 MCM per annum of treated wastewater is primarily used for irrigation, mostly in the Jordan Valley. Wastewater quantity is increasing with the increase in population, increasing water use and development of the sewerage systems. Thus, by the year 2022 about 256 MCM /year of wastewater is expected to be generated (MWI, 2009). . The Jordanian standards restrict the re-use of treated wastewater. Water is reused mainly for irrigation in the Jordan Valley, though a small share is allocated to industry.

Although irrigated agriculture is the largest user of water in Jordan, however, most of the available water resources for irrigation come from treated wastewater. Therefore, the key challenges to irrigated agriculture are the improvement of water use efficiency and the alleviation of adverse environmental impacts resulting from the reuse of treated wastewater. On the other hand, rain fed agriculture will face the challenge of climatic variability and change.

According to Al-Bakri et al. (2010), rain fed agriculture in Jordan had high vulnerability to climatic change of increased air temperature and decreased precipitation. The increased air temperature under the different future scenarios had adverse impacts on barley yield, while reduction of precipitation had negative impacts on both wheat and barley. Therefore, adoption of soil water conservation to increase available water to crop could be seen as an important adaptation measure to climate change. Also, the soil properties and water quality measure should be considered to alleviate the adverse impact of climate change.

Generally the country's soils are calcareous and poor in organic matter, nitrogen and the other essential nutrients. So in order to have high crop production, wastewater reuse can be considered as an important source of nutrients to the soil.

MAIN OBJECTIVES AND OUTCOME

The project has three main objectives:

1. Impact of using wastewater under different climatic conditions on pollutants residue in soil and the impact of different climate on wastewater quality.

2. Define the impacts of global climatic change on soil properties and seepage water quality using inorganic and organic contaminants of the irrigation water quality.

3. Define the microbial activities under different climatic conditions.

The expected outcomes of this work can be summarized as follows:

1. Knowing the wastewater and soil quality under different climatic conditions.

2. Impacts of treated wastewater used for irrigation on quality of groundwater recharge as a result of any climate change.

3. Evaluation of organic and inorganic pollution in soil and wastewater qualities under different climatic conditions.

4. To what degree can wastewater be used without any impact on soil, plant and health and minimizing groundwater pollution through the use of treated wastewater by knowing quality and quantity of pollutants under different climatic conditions?

5. All areas where wastewater reuse is practiced will have a safer and healthier environment and the health conditions of farmers and farm workers will also be improved.

6. Filling the knowledge gap on the lack of efficient control and monitoring on safe practices of wastewater reuse in agriculture under different climatic conditions.

7. Better understanding of microbial activities in wastewater and soil under different climatic conditions.

GENERAL PLAN OF WORK

To achieve impact of climate change on wastewater quality, field work will be done in two phases, for the first phase actual conditions under different climate change will be investigated in this work and in the second phase a study impact of climate change for one season will done.

To investigate the actual conditions of wastewater and soil quality under different climatic conditions, five sites were selected representing five climatic conditions along the eastern flank of the Jordan valley to the west of Karak city starting from Momia village where the treated wastewater of Karak province is discharged through pipes supplying irrigation water to farms located along the Wadi Al-Karak and ending near the Jordan Valley at Rassees which is the last location receives treated wastewater along Karak valley. The sites are located along the conveying pipe produced from Karak wastewater treatment plant where the water quality was from the same source for all sampling sites. After

Systematic sampling from these sites was done during January 2011 consisting of treated wastewater discharged from Karak wastewater treatment plant, which is used since many years to irrigate fields along Karak valley, soil samples irrigated with treated wastewater from Karak wastewater treatment plant and collection of available meteorological data when possible.

Soil samples were collected from two depths (0-15cm, 15-30 cm) where it was analyzed for physical parameters such as salinity. For both soil depths and wastewater samples analysis was done for major ionic composition ($HCO3^-$, Cl^-, $NO3^-$, $SO4^{--}$, Ca^{++}, Mg^{++}, Na^+ and K^+), organic content (Polycyclic Aromatic Hydrocarbons-PAHs, Polychlorinated benzene PCBz, Polychlorinated and Polychlorinated Biphenyl PCBs) in order to evaluate the impact of climates on rate of degradation of these organic pollutants through evaluating their concentrations in wastewater and soil in addition to determine their microbial content.

MATERIALS AND METHODS

Study Area

The investigated area is located along the eastern flank of Wadi Al-Karak extending from the Momia village where the Karak wastewater treatment plant discharge its treated wastewater to Rseis village which is the last point receive treated wastewater in the area (Figure 3). The topography of the investigation site is characterized by steep slopes and the treated wastewater flows naturally through pipes to selected farms in the area under the influence of gravity. The western part of the area consists of the deeply dissected upper part of the escarpment to the Dead Sea on calcareous rocks. The western edge falling steeply with free faces, landslip zones. the Rift Valley whilst to the east landform is steep hills with colluvial side slopes.

Geologically, the outcrops of the area are composed of calcareous rocks covered with thin layers of calcareous soil. The vegetation cover is scattered and concentrated into farms located in the area and irrigated with treated wastewater. The treated wastewater produced from Karak city was estimated to be around 0.440 MCM/year and it does not flow into a wadi, but channeled in pipes, in order to by-pass and protect the Wadi Karak reservoir. The treated wastewater then conveyed into the farms along the Wadi Al-Karak directly without be exposed to local climatic conditions of the area along the flow path.

Five sites were selected along Wadi Karak representing different climatic conditions. The sites were selected from areas irrigated with treated wastewater produced from Karak wastewater treatment plant at least for the past fifteen years. The climatic condition of the investigated sites ranges from mild Mediterranean climatic conditions near KWWTP (Site 1) changing gradually to hot and arid climatic conditions at site 5 as moving from high elevations of around 485 meter above sea level to 100 meter below sea level at site 5. The location map of the sampling sites is shown in Figure 3.

FIGURE 1

Sample Collection

Because the objective of the study was to examine the distribution of organic pollutants (PAHs, PCBz, PCB) in soils irrigated with wastewater, potential sampling sites were constrained to areas with different climatic conditions along.

A total of ten soil samples were collected during January 2011 from five sites subjected to different climatic conditions along the eastern flank of Wadi Al-Karak.

Sample Collection and Compositing

At every location, samples were collected from two depths (0-15 cm and 15-30 cm). The samples were collected using pre-cleaned stainless steel trowels and then carefully transferring the soil from each depth interval into pre-cleaned stainless steel bowls. Each sample was briefly mixed and any rocks, glass, wood or other debris was removed before the entire sample was transferred to a pre-cleaned soil jar.

The samples were labeled, packed on ice, and shipped to the laboratory at Mutah University for further analysis. All of the samples were composited in the laboratory as described in the following paragraphs.

The samples from each site were composited by thoroughly mixing equal weights of soil from the two samples collected from 0 to 15 cm at each site to generate a to 15 composite, and similarly mixing equal weights from the two samples collected from 15 to 30 cm to generate a 15 to 30 cm composite.

For wastewater samples, prewashed dark glass bottles were used for determination of organic pollutants and polyethylene bottles for determination of inorganic constituents. pH and EC were determined on site.

For microbiological determination autoclaved sterilized glass bottles were used for sampling.

ANALYSIS OF MAJOR IONS

The electrical conductivity and pH of wastewater samples were determined on site using EC meter and pH meter from WTW-Germany. For soil samples EC was measured by mixing soil to water samples at a ratio of (1:1).

Major ionic composition of wastewater (Cl, NO3, SO4, PO4, Ca, Mg, Na and K) was determined using ion chromatography method based on former method (Jiries et al 2004), for HCO3 titration method was used.

ANALYSIS OF ORGANIC POLLUTANTS

Analysis of PCBs

50 g of soil material was placed separately into 500 mL Erlenmeyer flask. Extraction was carried out with acetone/water mixture 2:1/v:v overnight using horizontal shaker at shaking velocity of 220 cycle/min. The liquid/liquid partitioning was performed by adding 15 g of NaCl and 100 mL cyclohexane, where the mixture was shaken for one hour. The organic layer was decanted into 250 mL Erlenmeyer flask and dried over 15 g sodium sulfate. 100 mL of the extract was rotary evaporated and dissolved in 5 mL ethylacetate and cyclohexane mixture (1:1).

The sample was micro-filtered using PTFE syringe filter before column chromatography clean up. Furthermore, to eliminate other interference substances, the samples were cleaned up using silica gel column. The silica gel was activated at 130 oC overnight, then it was partly deactivated with 2 % H_2O. The chromatographic column was packed with 10 g of deactivated silica gel and 1 g of oven dried anhydrous Na_2SO_4 on the top of the column. The sample was eluted with 50 ml hexane and this fraction given number 1, the second fraction was eluted with 70 mL of a mixture of acetone and hexane (50%:50%). Each elute was rotary evaporated and concentrated in a gentle nitrogen stream to 1 mL. Fraction number one was transferring to 1 mL GC vial and analyzed for chlorinated compounds (PCBz, HCBz, PCB congeners) using GC-ECD. The second fraction was analyzied for PAH and phenols using GC/MS.

A PerkinElmer Clarus 500 gas chromatograph equipped with a ^{63}Ni electron capture detector was used for analysis of PCB, HCB, PCB 28, PCB 52, PCB 101, PCB 138, and PCB 180. A 30 m DB-5 fused silica capillary column with 0.25 µm film thickness and 0.32 mm inner diameter was used for the quantification of organochlorine compounds (J&W Scientific, USA). Helium was used as carrier gas (1 mL/min) and nitrogen as make up gas (58 mL/min). The oven temperature was programmed from 60 ^{o}C (1 min) to 160 ^{o}C (1 min) at 15 ^{o}C/min, then to 220 ^{o}C (5 min) at 5 ^{o}C/min, finally at 3 ^{o}C/min to 280 ^{o}C (10 min). The injector and detector temperatures were maintained at 250 ^{o}C and 300^{o}C, respectively. The splitless injection volume was 1 µL. Totalchrom software was used for data analysis and quantification.

Analysis of PAH

GC-MS determination was performed using Agilent gas chromatograph coupled to mass spectrometer (MS) with electron ionization mode (EI). The mass spectrometer was operated at selected ion monitoring modes (SIM) detecting the M^+ ions for 13 PAH, and the ionization source was supplied with voltage at 70 eV. A 1 µL of aliquot was injected by the autosampler with splitless at 250^{o}C. A DB-5 MS fused silica capillary column with 30 m length, 0.25 µm film thickness and 0.32 mm inner diameter was used (PerkinElmer, USA). The oven temperature program was 60^{o}C (4 min) ramped at 15^{o}C min^{-1} to 160^{o}C, then at 3^{o}C min^{-1} to 280^{o}C, and held for 10 minutes. The transfer line temperature was

Table 2. Selected ion monitoring (SIM) program for 13 PAH and LoQ*.

Target compound	**m/z**	**D.L. (ng/L)**	**LoQ (ng/g)**	**Target comp**	**m/z**	**D.L. (ng/L)**	**LoQ (ng/g)**
Flu	146.1	1.17	0.196	CHR	228	0.119	0.020
ACY	152	0.144	0.024	BbF	252	1.270	0.212
FLE	166	0.140	0.023	BkF	252	1.400	0.234
PHE	178	0.177	0.030	BaP	252	1.150	0.193
ANT	178	0.353	0.059	IcdP	276	0.449	0.075
PYR	202	0.131	0.022	DahA	278	0.567	0.095
BaA	228	0.173	0.029	BghiP	276	0.410	0.068

*LoQ: Limit of Quantification.

maintained at 200^oC and the source temperature at 180^oC. A grade 5.5 He was used as carrier gas with flow rate of 1.5 mL min^{-1}. Specific mass to charge ratios (m/z) was used for selected ion monitoring program for the 13 PAH. These ratios and the limit of quantification (LoQ) are summarized according to the chromatographic elution in Table 2.

Microbiological Analysis

Bacteriological analysis of water and soil samples collected from the selected sites along Wadi Karak was carried out directly after sampling and transporting them to the laboratory. All samples were collected in an autoclaved transparent bottle where they were filled either with 100 ml of water samples or 10-20 g of soil samples.

1 ml / 1 g of water / soil samples was transferred to a test tube containing 9 ml of sterile normal saline solution. From this stock a 10 times serial dilutions were performed up to (1:10^7). The last three decimal dilutions were used for microbiological analysis.

Heterotrophic Counts (HPC)

Determining heterotrophic counts in water and soil samples was used to show the effect of altitude, irrigation with treated waste water and soil depth on the enrichment of samples with different bacterial strains and their diversity. Often, the test does not specify the specific bacteria that are detected, and only a small portion of the population is actually culturable. Typically, microbes that are recovered through HPC include those that are part of the natural microbiota of soil and water; and in some instances, they may also include those derived from diverse pollutant sources**.**

100 µl from each of the decimal dilutions was spread over 9 mm plates of nutrient agar, eosin-methylene blue agar, Mannitol salt agar and pheny-ethyl alcohol agar. These plates were incubated at room temperature and used for

enumeration of total heterotrophic bacteria, Gram negative bacteria, Gram positive streptococci and staphylococci like bacteria, and Gram positive bacteria respectively.

All plates were observed daily for two weeks to depict the bacterial growth and variations in colony morphology. Different bacterial colonies were selected for purification based on variation in morphology and growth pattern. They were streaked several times over nutrient agar plate and the purified colonies were used for bacterial identification.

Total coliform and fecal coliform test

Determination of total coliform (TC) and fecal coliform (FC) was done using multiple-tube fermentation technique (i.e. Most Probable Number MPN). The method has three test stages: The presumptive test, the confirmed test, and the complete test. The presumptive tests are designed to grow the target bacteria, while the confirmed test is designed to validate the growth of target bacteria in the presumptive test. Confirmed test conditions are usually more stringent than presumptive conditions

A- Presumptive test

1 mL from each of the decimal dilutions was transferred to 3 test tube containing 9 ml of Lauryl sulfate tryptose broth (LST) and gas collector Durham tubes.

All preparation will be incubated at 35-37°C (for total coliform) and 45°C (fecal coliform). They will be examined at 24 an 48 hours for gas production. Three consecutive sets of tubes that show gas production will be chosen to evaluate the MPN.

B- Confirmation test

Each gassing LST tube will be agitated and a loopful of suspension will be transferred to a tube of Brilliant green lactose bile (BGLB) broth containing a gas collector Durham tube. BGLB tubes will be incubated at both temperatures mentioned previously and examined for gas production at 24 and 48 hours. All gassing tubes are considered to be positive for the presence of coliforms.

C- Complete test

A loopful of BGLB gassing suspension will be transfered to either Eosin-methylene blue and observed for colonial growth indication on coliform bacteria presence or to Escherichia coli (EC) agar medium and incubated at 45.5°C and examined for *E. coli* colonies.

The calculation of the MPN test results requires the selection of a valid series of 3 consecutive dilutions. The number of positive tubes in each of the three selected dilution inoculations is used to determine the MPN/100 mL.

Identification of water/soil bacteria

Purified bacterial isolates from soil and water samples were identified using commercial RapID™ identification kit/Remel. Gram positive coryneform-like bacteria, Gram positive staphylococci-like bacteria, non-fermentative Gram negative bacteria, and enteric bacteria were identified using RapID™CB plus system, RapID™ staph plus system, RapID™ NF plus system, and RapID™ one system respectively.

RESULTS AND DISCUSSION

Generally, water and sediments quality any area is usually investigated through determination of its chemical composition. The climatic conditions plays an important role in determination of wastewater and sediments quality as higher temperature results in increasing the concentrations of major ions through evaporation and on the other hand photochemical degradation of organic pollutants and increasing microbial metabolism occurs at warmer climatic conditions rather than cool climates. The results of soil and wastewater in terms of inorganic, organic and microbial concentration under different climatic conditions are discussed below.

Major Ionic Composition

Wastewater

The concentration of major ionic composition of treated wastewater produced from KWWTP is shown in table 3, It is clear that although the treated wastewater in conveyed through pipe to farms along the eastern flank of the Jordan valley, there was a slight difference between sampling locations as lower concentrations were observed upstream at high altitude where mild climatic conditions prevailed and higher concentration were found downstream at lower altitude where warmer climatic condition prevails. This can be attributed to impact of different climates on wastewater was after reaching the wastewater to the farms. The wastewater quality in terms of its suitability for irrigational purposes was found to be safe at both mild and warm climatic conditions

as there was no big variation in terms of SAR which ranged from 25.8 to 27.5 and the increase of EC, Cl^- and Na^+ ions were not high. Therefore, climate change will not have a great impact on its quality in terms of inorganic content.

Soil

Soil under different climatic conditions were investigated in terms of its soil salinity and its organic pollutants content which are the major impact of climate

Table 3: Major ionic composition of treated wastewater of the investigation area.

	Karak WWTP	High Altitude	Middle Altitude	Low Altitude
EC	1585	1950	1799	1885
pH	7.8	8.6	8.1	8.4
HCO_3^-	222.7	323.3	267.4	376.0
Cl^-	158.2	166.5	164.5	165.2
NO_3^-	0.6	2.2	0.7	0.7
$SO4^{--}$	105.9	119. 1	117.8	113.2
PO4	32.5	33.5	30.9	32.7
Ca^{++}	80.6	80.7	82.9	101.7
Mg^{++}	38.9	40.1	46.2	23.8
Na^+	207.6	213.6	207.6	216.6
K^+	3.6	3.7	3.8	4.9
SAR	26.9	27.5	25.9	27.3
BOD5	150	180	90	140
COD	236	300	288	258

on soil quality. As shown in figure 4, for upper soil samples (0-15 cm), there was an increase in salinity by moving from high altitude to lower altitude as it increased from 506 μS/cm at high altitude where mild climatic conditions prevailed to 603 μS/cm at middle altitude and to 772 μS/cm at low elevation. For lower sol profiles (15-30), similar trend was observed as the electrical conductivity increased from 404 μS/cm, 469 μS/cm and 318 μS/cm for high, middle and low altitudes respectively. It was clear that impact of different climates was clear on the surface soil than lower soil profiles. Therefore no great influence of climate change can be predicted due to change in climatic conditions.

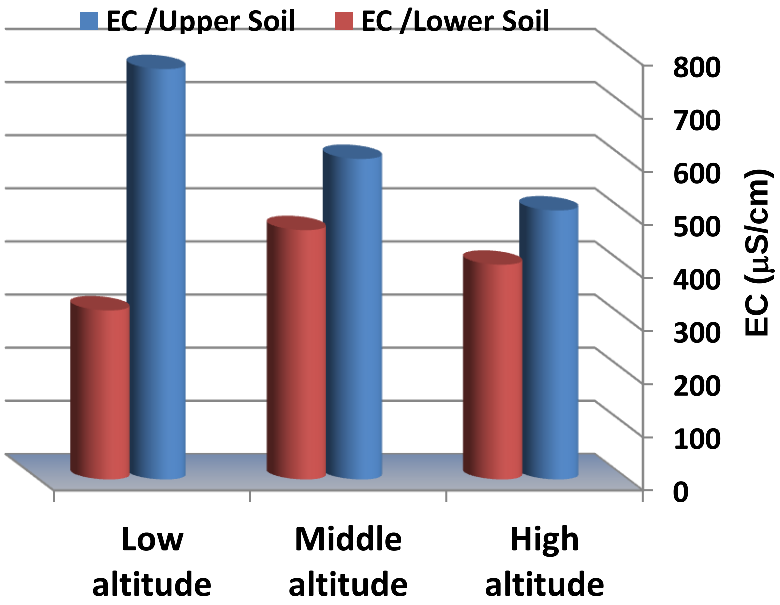

Figure 4: Electrical conductivity of soil collected from different altitudes along the eastern flank of Wadi Al-Karak

PAH-Wastewater

The concentration levels of 13-PAH in wastewater samples at Al-Karak WWTP and along sampling stations are shown in Table 4. The recovery rate of the analytical procedure exceeded 95.2% ±4.2 for all targeted PAH compounds. The results of wastewater samples led to the identification of 13 PAH, that have been categorized as priority pollutants by the US EPA, with the number of aromatic rings from 2 to 6 benzene rings (Al Nasir and Batarseh, 2009). The concentration levels of PAH found in wastewater samples were ranged from 0.36 μg L^{-1} to 0.84 μg L^{-1} with an average value of 0.58±0.21 μg L^{-1}. Limited variations in PAH concentration was observed along the sampling sites might be attributed to the transport of wastewater effluents from station W0 to the discharge point at station W3 via a pipeline which limited the photo-degradation, volatilization and biodegradation of PAH compounds. Therefore, climate conditions along sampling stations represented by different sampling site elevations had limited effect on PAH concentrations, Figure 4.

The trends of PAH long-range transport that related to difference in altitude and climate conditions due to high temperature and irradiation at low altitude places was proposed by Nada et al. (2006). They investigated this phenomenon by means of comparison the PAH concentration in different climatic conditions at two environments: Atlantic (Lancaster, UK) and Mediterranean (Tarragona, Catalonia, Spain), the experiment was performed using a joint impact of UV-B radiation and temperature on photo-degradation of polycyclic aromatic hydrocarbons (PAHs) sorbet to an organic solvent. The concentration of 10 PAHs contained in a tetradecane solution was compared under two different temperatures (10 and 20°C) and two UV-B doses (6.5 and 22.5 kJ m−2 day−1). No photodegradation was observed for the high molecular weight hydrocarbons (HMW) such as (benzo(a)anthracene, chrysene, benzo(a)pyrene, dibenzo(g,h,i)perylene and coronene). It was noted that the half-life of PAHs was highly dependent on the molecular weight; therefore, Low Molecular Weight (LMW) hydrocarbons (2-3 benzene rings) are significantly faster photo-degradated than HMW hydrocarbons(4-6 benzene rings). It indicates that a synergistic effect occurred when both temperature and UV-B dose increased. This synergism might have a great implication on the long-range transport of environmental organic pollutants taking into account that low-latitude areas are the hottest and most irradiated of the planet (Nada et al. 2006).

The individual distribution of various PAH compounds were dominated by low molecular weight compound such Fluorene and Phenathrenes that figure more than 86% of the total concentration of all PAH, figure 5. The possible sources of PAH in the environmental samples such as wastewater have been quantatively determined by several molecular diagnostic ratios that based on studying certain ratios of individual polynuclear aromatic hydrocarbon molecules (Katsoyiannis et al., 2008; Batarseh, 2011). For example, based on the ratio of low molecular weight (2-3 rings) divided over high molecular weight (4-6 rings) LMW/HMW of PAH. A ratio <1 suggests a combustion sources of PAH (pyrolytic), while a ratio >1, suggests a non-burnt fossil fuel sources (petrogenic). The results showed that PAH in wastewater samples are mainly from petrogenic sources based on LMW/HMW >1, Table 4. The maximum concentration of PAH compounds was found at station W1 while the lower at station W2 with no significant variations between the sampling sites along the discharge area.

Table 4. PAH in wastewater samples (ng L^{-1}) for wastewater samples stations

	PAH (μg L^{-1})								
Site / **PAH(μgL^{-1})**	W0	W1	W2	W3	**Site** / **PAH(μgL^{-1})**	W0	W1	W2	W
Ace	ND	ND	ND	ND	**Benzo[b]flu**	12.3	38.1	10.0	64.0
Flu	104.3	186.6	057.8	135.7	**Benzo[k]flu**	ND	ND	7.6	ND
Phen	213.8	427.5	155.2	294.8	**Benzo[a]pyr**	60.4	ND	ND	ND
Anth	ND	26.3	10.3	21.6	**Ind[1.2.3.4.cd]pyr**	ND	ND	33.6	76.3
Pyr	43.4	110.5	47.1	75.2	**Dibenzo[a.h]anth**	ND	ND	ND	ND
Benzo[a]anth	6.0	17.2	15.4	ND	**Benzo[g.h.i]per**	ND	ND	ND	ND
Chry	16.0	35.7	24.7	ND	**LMW/HMW**	2.30	3.18	1.61	2.10
ΣPAH	**45.63**	**841.9**	**361.7**	**667.6**					

PAH-Soil

The PAH concentrations were investigated in soil samples at two depths (A: 0-15 cm and B: 15-30 cm) along the sampling stations (S1-S4), their concentration (μg/kg) are summarized in Table 3. The results of molecular diagnostic of PAH such as LMW /HMW ratio was <1, suggesting a combustion sources of PAH (pyrolytic) in soil samples, Table 5. By comparing the molecular diagnostic of PAH profile of wastewater and irrigated soil the difference from petrogenic and pyrolytic, respectively, can be attributed due to high temperatures dominated along the sampling sites that lead to loss of PAH via photo-degradation and volatilization. Furthermore, the sampling sites S1, S2 and S3 showed higher concentration level of PAH than S4 which located at the lower elevation along the sampling sites which reflects the different climatic conditions that affected the PAH concentration such as high temperature and irradiation rate.

It was evident that frequent use of reclaimed water for irrigation impact the soil quality, higher concentration of PAH were mostly found along sampling sites in the lower soil profile (15-30 cm) than in the upper profile (0-15) except that at site S2, table 4. This can be explained due to volatilization and photodegradation of PAH at the surface soil that lead also to the domination of HMW compounds rather than the LMW compounds, Figure 5. Similar trends of PAH degradation was found at different climatic conditions at two environments: Atlantic (Lancaster, UK) and Mediterranean (Tarragona, Catalonia, Spain), and high degradation rate observed at lower altitude areas explaining the effect of high temperatures and solar irradiation (Nada et al. 2006). Moreover, the effect of climate change at three different temperatures (10, 20, and 30°C) on the persistence of polycyclic aromatic hydrocarbons (PAHs) was investigated in soil on lab scale experiment (Coover and Sims, 2009). They found that increasing the soil temperature significantly improved the rate and extent of apparent loss of low molecular weight PAHs but had little effect on loss of five and six-ring PAHs. Those authors recommended further treatment of hazardous waste which containing PAHs before the land application. Furthermore, the conclusion drove from this study proposed that climate change increases the planet's vulnerability to persistent organic pollutants, by increasing emissions and the bio-availability of POPs, and thus the potential for bio-magnification through the food chain, one of the chief pathways of human exposure to POPs.

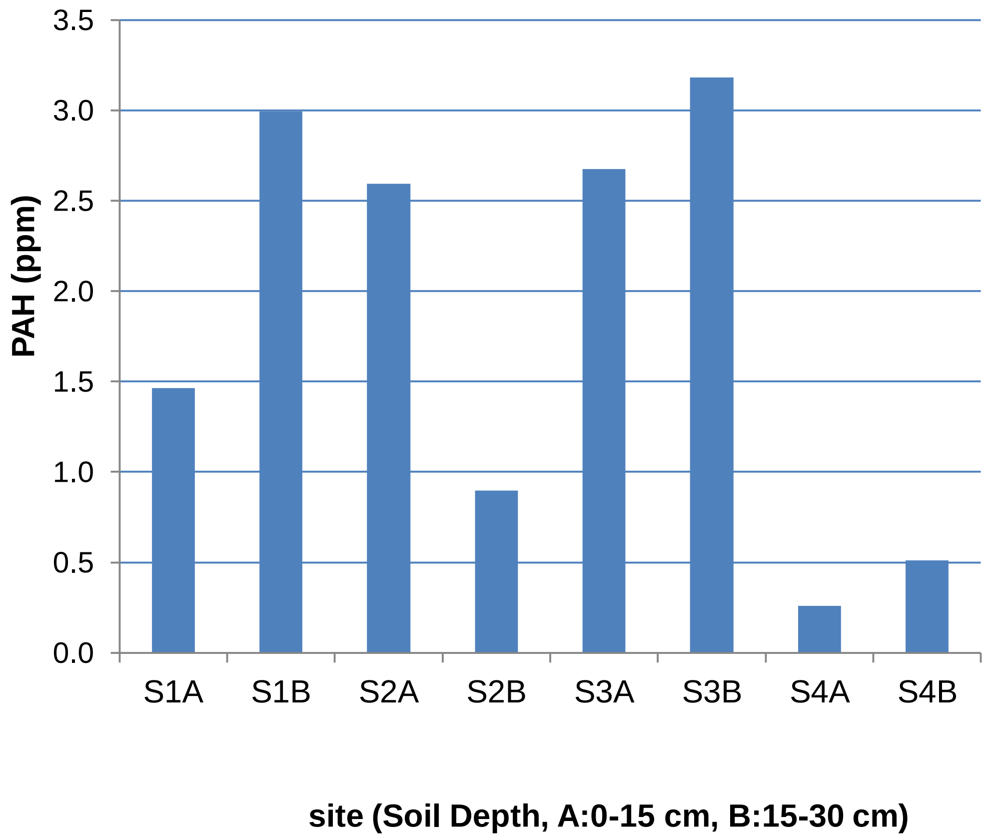

Figure 5. Sum of PAHs in soil profile (A:0-15 cm, B:15-30 cm)

The individual distribution of PAH along sampling station at two soil depths is shown in figure 6. It was found that the whole soil profile was contaminated with different ratios of PAH compounds

Table 5. Concentration (ng/kg) of PAH in soil profile (A: 0-15 cm, B: 15-30 cm) along the sampling stations (S1= WWTP, S2= High altitude, S3= Middle altitude and S4= Low altitude).

PAH soil ng/kg)	S1A	S1B	S2A	S2B	S3A	S3B	S4A	S4B	LOQ (ng/g)
Ace	ND	ND	ND	ND	ND	ND	ND	ND	196
Flu	113.4	403.6	322.3	215.8	139.7	158.3	ND	ND	24.0
Phen	362.7	990.3	933.8	627.5	587.3	512.1	105.8	100.1	230
Anth	ND	ND	ND	ND	ND	ND	139	13.7	30.0
Pyr	98.0	259.2	252.8	052.3	399.2	384.4	045.8	044.5	59.0
Benzo[a]anth	46.8	88.9	ND	ND	393.3	1331.	141.	427.	22.0
Chry	070.0	230.3	203.7	ND	324.6	275.7	041.6	058.3	029.
Benzo[b]flu	553.8	459.8	430.7	ND	ND	519.6	ND	029.2	20.0
Benzo[k]flu	ND	ND	ND	ND	ND	ND	ND	418	212.
Benzo[a]pyr	ND	ND	ND	ND	251.5	223.5	ND	42.9	234.
Ind[1.2.3.4.cd]pyr	218.0	286.2	449.7	ND	578.9	383.7	ND	49.6	193.
Dibenzo[a.h]anth	ND	ND	ND	ND	ND	ND	ND	40.3	75.0
Benzo[g.h.i]per	ND	275.2	ND	ND	ND	592.3	37.5	46.7	95.
ΣPAH	**1.4628**	**2.9934**	**2.5931**	**0.8956**	**2.6745**	**3.1828**	**0.2586**	**0.5097**	68.0
LMW/HMW	0.4825	0.8715	0.9395	16.1389	0.3733	0.2668	0.8616	0.2874	-
ANT/178	0	0	0	0	0	0	$7.8x10^{-5}$	$7.7 x10^{-5}$	-
BaA/228	0.00021	0.00039	0	0	0.0017	0.00058	$6.2x10^{-5}$	0.000187	-
IcdP/(IcdP+BghiP)	1	0.50977	1	-	1	0.39314	0	0.515095	-
PHE/ANT	-	-	-	-	-	-	7.58736	7.27755	-

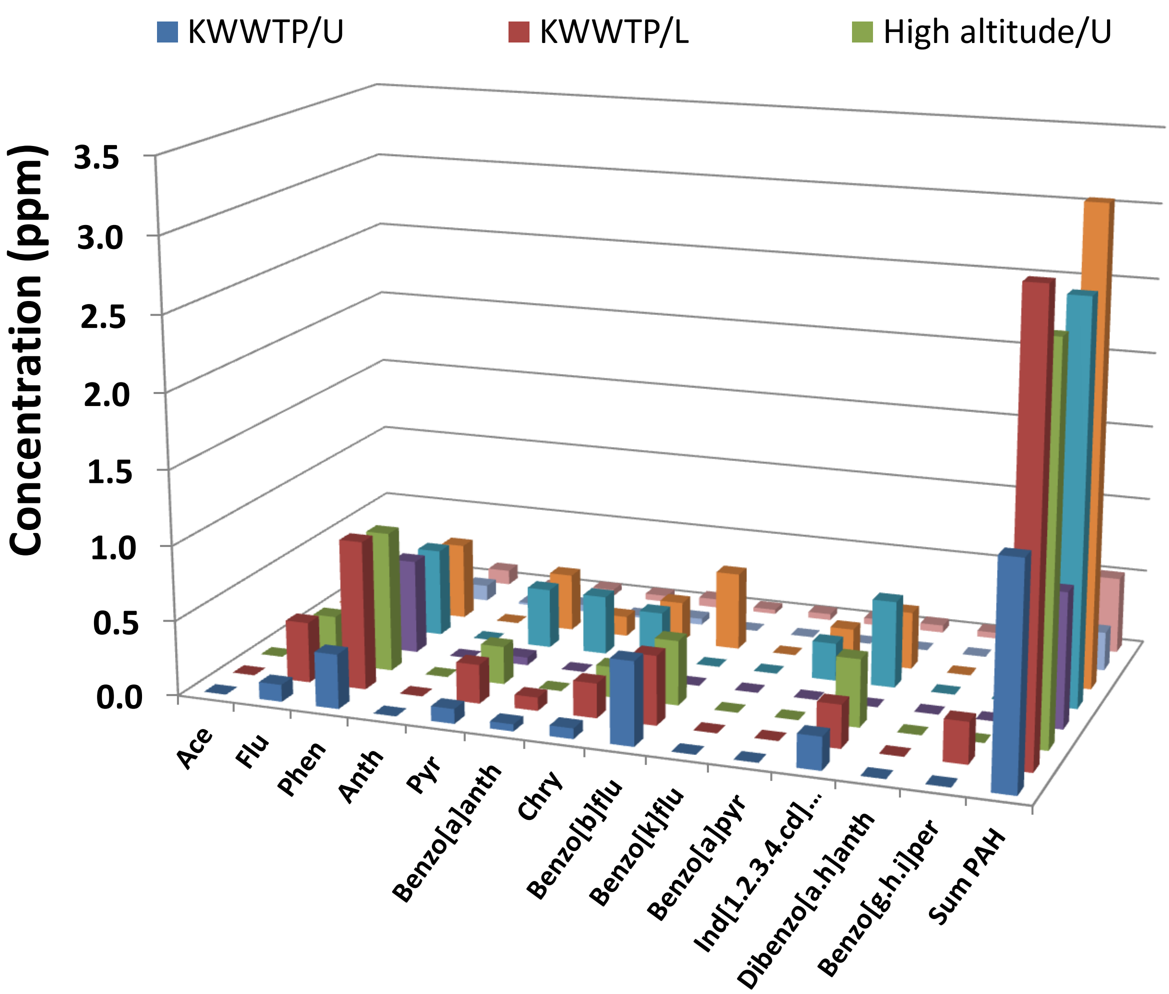

Figure 6. Individual PAH distribution in soil along sampling sites (S1-S4) at two depths (A: 0-15 cm, B:15-30 cm).

Chlorinated Benzenes

Wastewater

Several chlorinated hydrocarbons were investigated in wastewater and soil at the same study area including pentchlorobenzene (PCBz), hexachlorobenzene (HCBz) and six different congeners of polychlorinated biphenyls (PCB 28, PCB 52, PCB 101, PCB 138, PCB 153 and PCB 180). The concentrations of these compounds along the sampling stations are shown in Table 6. The recovery rate of the analytical procedure for these chlorinated compounds ranged from 85 to 105% and the limit of quantization (LOQ) varied from 1 to 15 ng L^{-1}. persistent organic pollutants as they are stable and unaffected by different climate conditions PCBz and HCBz have been detected in all analyzed samples along sampling stations. The concentration of PCBz ranged from 117 to 4442 ng L^{-1} and from 4.86 to 114 ng L^{-1} for HCBz. The potential sources of chlorinated benzenes in the environment might be originated from waste disposal and fungicide application in agricultural field (Batarseh et al. 2003). Significant variations in PCBz and HCBz concentrations were observed along sampling stations, Figure 6.

The different PCBs congeners were detected in 50 percentages of analyzed wastewater samples, their concentration ranged from 25 to 553 ng L^{-1}. The maximum concentration was found for PCB 52 at station W1, while minimum concentration was found for PCB 180 at the same station. All congeners were detected in the original wastewater effluent; however, they were detected infrequently in other sampling stations. The overall evaluation of PCBs profile showed limited effect of different sampling locations and no sampling sites. clear trends can be correlated significantly to the dominated climate conditions

Wastewater	ng/L								
Sample ID	**PCBz**	**HCBz**	**PCB 28**	**PCB 52**	**PCB 101**	**PCB 153**	**PCB 138**	**PCB 180**	**ΣPCBs**
KWWTP	117.33	113.68	58.02	95.91	52.62	35.32	50.99	84.13	376.99
High altitude	4441.89	11.26	249.97	553.32	ND	ND	ND	24.70	827.99
Middle altitude	2388.59	6.50	ND	143.30	ND	ND	ND	30.67	173.97
Low altitude	3217.31	4.86	ND	246.29	ND	ND	ND	ND	246.29

Table 6. Concentration (ng/L) of chlorinated hydrocarbons in wastewater along

photo-degradation, volatilization and biodegradation of chlorinated compounds.

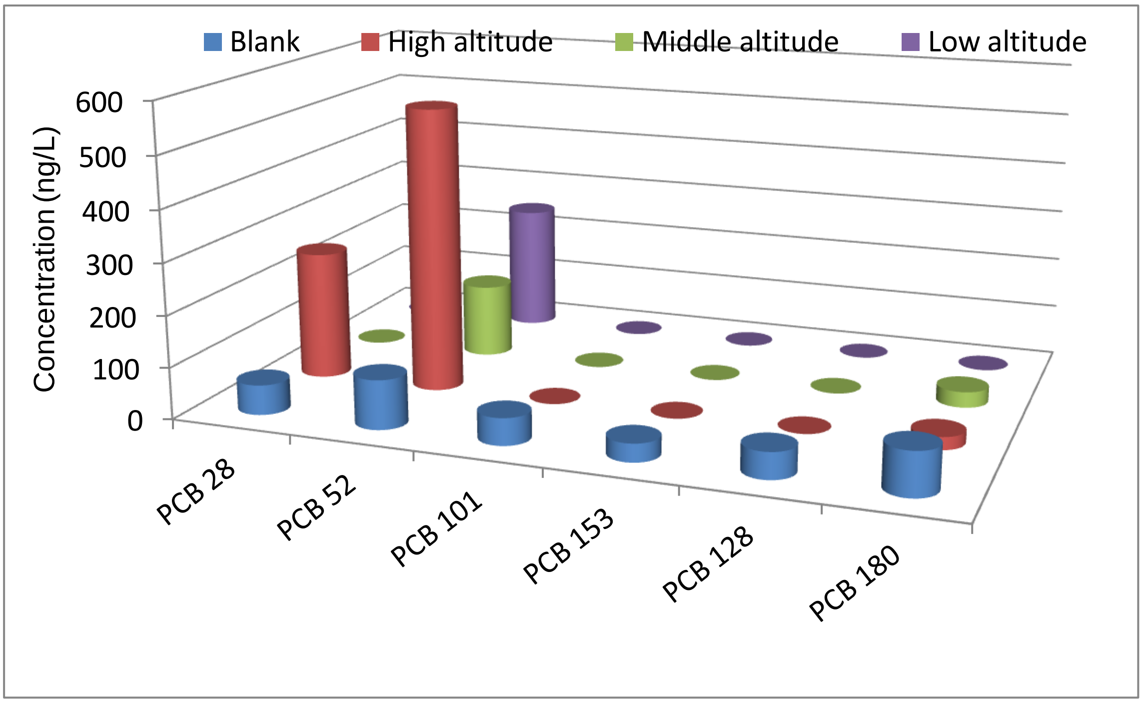

Figure 7. Poly Chlorinated Benzenes PCBs in in ng/L for wastewater samples

Soil

Polychlorinated benzene (PCBz) and chlorinated hydrocarbons (HCBz) were detected in soil samples from all sampling sites. As shown in figure 8, the concentration of PCBz was much higher than HCBz which is due to their concentration in the wastewater as SO showed similar trend. The climatic effect of warmer climatic conditions increased the concentrations of PCBz where samples at higher temperatures showed higher concentrations than the soil near the KWWTP indicating that photo degradation and volatilization was not able to remove it from the soil. On the other hand, for HCBz warmer climatic conditions were able to reduce its concentrations in soil where higher temperatures resulted in lower concentrations. Therefore, warmer climatic conditions due to climate change would result in lowering the concentrations of HCBz and increase the concentrations of PCBz.

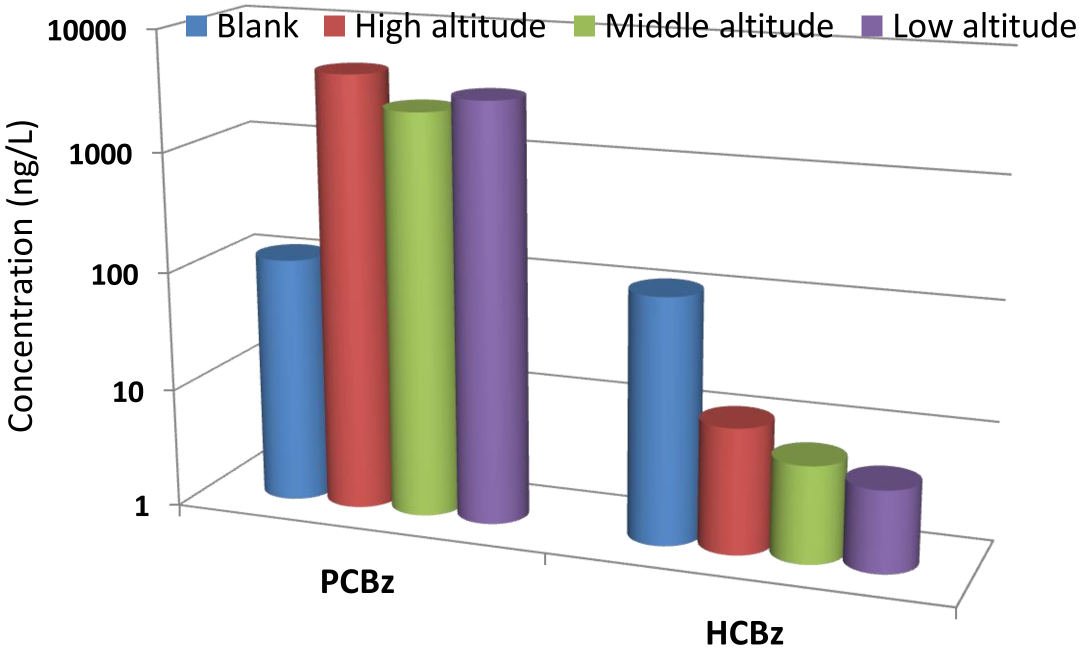

Figure 8: PCBz and HCBz concentrations in soil collected from different altitudes of the investigation site

Table 7 and figure 9 shows the individual distribution of PCBz, HCBz and PCBs in the upper soil profiles (0-15 cm) and in the lower soil profile (15-30 cm). It is clear that these organic pollutants were concentrated in the upper soil profiles than in the lower soil profiles indicating that warmer climatic conditions tend to concentrate these pollutants as photo degradation and volatilization do not have an impact on reducing these pollutants.

Table 7: PCBz concentration in soil samples at two depths from the investigation site

Component	Soil Sample (µg/kg)							
	KWWTP (0-15 cm)	KWWTP (15-30cm)	High Altitude (0-15 cm)	High Altitude (15-30cm)	Middle Altitude (0-15 cm)	Middle Altitude (15-30cm)	Low Altitude (0-15 cm)	Low Altitude (15-30cm)
PCBz	0.050	0.038	0.886	0.040	3.106	0.478	0.074	0.068
HCBz	0.090	0.026	0.310	0.086	0.574	0.164	0.310	0.054
PCB28	0.012	0.018	0.084	0.414	0.062	0.018	0.028	0.054
PCB52	0.238	0.020	0.368	0.496	0.446	0.054	0.392	0.042
PCB101	0.170	0.036	0.406	0.216	1.150	0.244	0.398	ND
PCB153	0.018	ND	2.100	ND	0.134	0.760	0.960	ND
PCB138	0.038	ND	0.058	ND	0.206	0.080	0.034	ND
PCB180	0.838	0.146	1.182	0.130	1.878	0.638	0.700	0.074

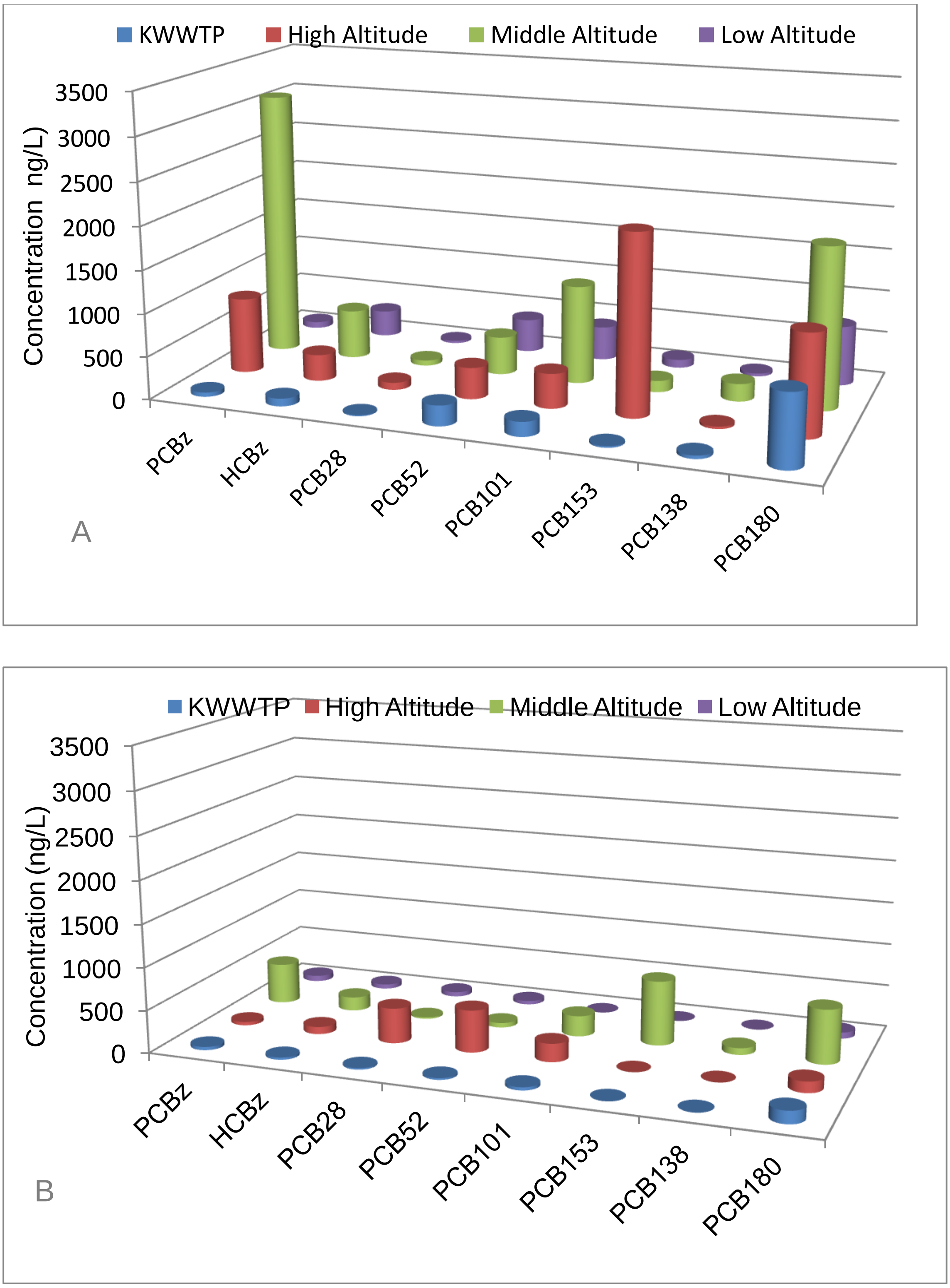

Figure 9: PCBz, HCBz and PCBs concentrations in Top Soil (A) and in lower soil (B)

MICROBIOLOGY

In terrestrial ecosystems, the response of plant communities and symbiotic microorganisms, such as mycorrhizal fungi and nitrogen-fixing bacteria, to climate change is well understood, both in terms of physiology and community structure. However, the response of the heterotrophic microbial communities in soils to climate change, including warming and altered precipitation, is less clear (Singh *et al.,* 2010). This is a crucial factor, as it determines the nature and extent of terrestrial-ecosystem feedback responses.

Thus, both climate change and microbial composition of soil and water are interrelated with each other. Microbial composition and their diversity reflect the influence of climate change and especially warming on the terrestrial biota. Though, there are contradictory results on the influence of climate warming on the diversity and composition of microbes but in this work we found a direct enhancement of warming on the diversity and composition in soil bacteria. We have studies the bacterial composition of soil samples from stations receive treated waste water for irrigation and the diversity of these bacteria population in sampling area along the discharge area.

During this work, the dominant species isolated from the study area were *Acinitobacter* and *Aeromonas* and enteric bacteria (Table.9). They are among the dominant known strains isolated from aquatic sources in different studies (Allen *et al.,* 2004). The entric bacteria represent 30 % (8 out of 27 bacterial genera) of the total isolated bacterial species (Fig. 10)

Although there is an increase in the heterotrophic number in W1 relative to W0, but there is a significant decrease in microbial number between stations W0 and W1 with the other stations, while there was no significant variation in the Gram negative population number among these stations Table.8. The sampling sites W0 and W1 are not far away from each other and are nearly at the same altitude and under the same environmental conditions. So this increase could be attributed to the increase in the sum of availability PAH that could be degraded by microorganisms

Table. 8. Isolated bacterial strains from water samples along the investigated area

Organism	Cell count/ml	Organism	Cell count/ml
Station W0:		**Station W1:**	
Pseudomonas	4×10^4	*Acinitobacter*	
aeruginosa	25×10^4	*caloaceticus*	40×10^5
Aeromonas hydrophila	4×10^4	*Entrobacter intermedium*	8×10^5
Oligella urethralis	3×10^4	*Enterococcus* sp.	3×10^5
Citrobacter freundii	24×10^4	*Bacillus* sp.	4×10^4
Acinitobacter	1×10^4		
caloaceticus		**Station W3:**	
Staphylococcus sp.		*Pseudomonas*	3×10^5
	4×10^5	*oryzihabitans*	2×10^5
Station W2:	2×10^5	*Providencia alcalifaciens*	10×10^4
Acinitobacter	3×10^5	*Acinitobacter*	6×10^5
caloaceticus	10×10^4	*caloaceticus*	10×10^4
Klebsiella Pneumoniae	4×10^5	*Citrobacter freundii*	10×10^4
Yersinia kristensenii	10×10^5	*Leminorella richardii*	7×10^4
Shigella sp.		*Aeromonas hydrophila*	
Aeromonas hydrophila		*Bacillus* sp.	
Micrococcus sp.			

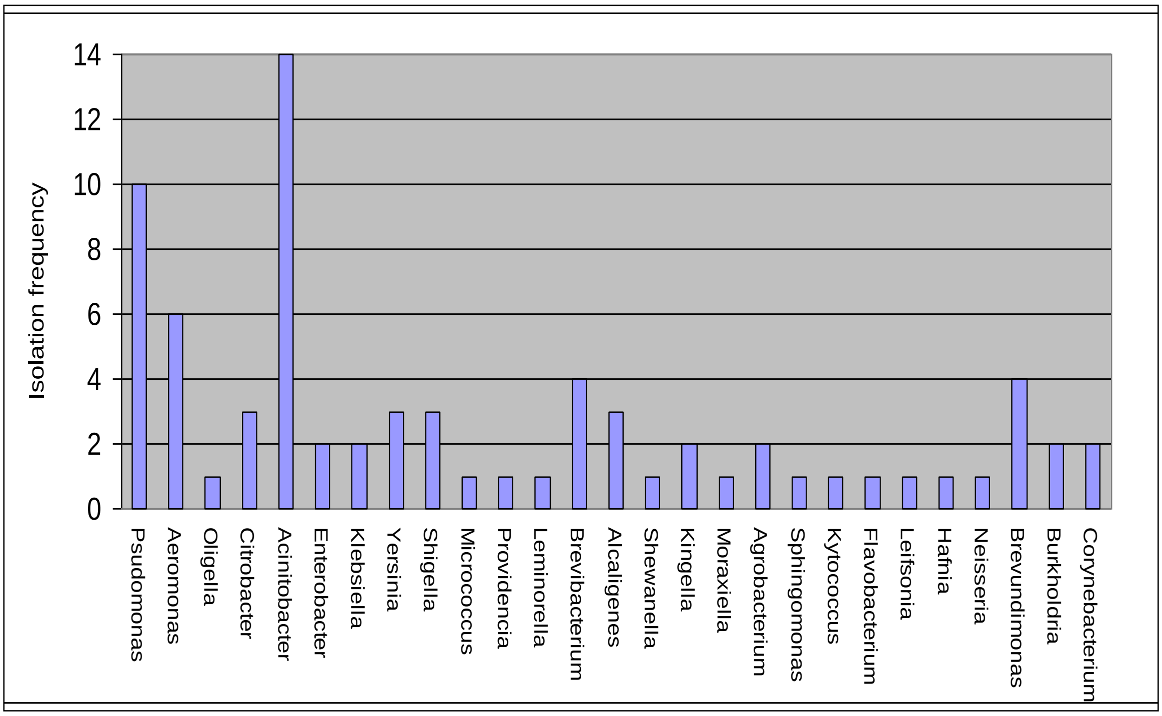

Figure. 10. Frequency of isolated bacterial genera from all stations in the study area.

Table. 9. Bacterial count (CFU/ml) in water samples.

Test	**Station W0**	**Station W1**	**Station W2**	**Station W3**
Heterotrophic count	6.5×10^6	8.1×10^6	6.6×10^6	1.9×10^6
Gram negative	1.4×10^6	2.5×10^6	2.0×10^6	1.5×10^6
Gram positive	6.0×10^4	5.9×10^5	1.0×10^5	1.6×10^5

Similar tendency was noticed in soil microbial composition where there is a decrease in hetertrophs number from S_1 till S_4 and between surface (0-15 cm, A) and deep (15-30 cm, B) soil samples. Nevertheless, Gram negative bacteria represent the large portion of this heterotrophic count (Table. 10).

Also there was a reduction in the population number with depth in most stations except S_3. This reduction could be attributed to the nature of soil and type of environment in deep zones in relation to surface. At the surface, oxygen availability enhance the aerobic respiration and organic compound assimilation which increase microbial number, while at deep zones, soil moisture increases which favor anaerobic metabolism and thus decrease in number of aerobic bacteria. Such results were also documented in the study done by Tate (1979). Although there is a decrease in microbial number with decreasing in altitude along sampling sites, but there is an increase in biodiversity which may be due to increase of relative temperature warming which is in accordance with Carter *et al.* (2000).

Table. 10. Bacterial count (CFU/ml) in soil samples. A: 0-15 cm, B: 15-30 cm

Test	**Station1**		**Station2**	
	A	**B**	**A**	**B**
Heterotrophic count	1.7 X 10^8	1.1 X 10^7	3.0 X 10^7	1.4 X 10^6
Gram negative	1.7 X 10^8	2.5 X 10^6	1.3 X 10^7	6.5 X 10^5
Gram positive	4.8 X 10^5	5.9 X 10^5	1.7 X 10^6	1.0 X 10^5
	Station3		**Station4**	
	A	**B**	**A**	**B**
Heterotrophic count	1.6 X 10^7	1.8 X 10^7	3.3 X 10^6	3.9 X 10^6
Gram negative	8.0 X 10^6	2.3 X 10^6	6.9 X 10^5	9.6 X 10^6
Gram positive	3.2 X 10^6	5.6 X 10^5	1.2 X 10^6	2.5 X 10^6

Increase in heterotrophic and especially Gram negative bacteria is reflected by presences of strains that are known to be apple to degrade PAH compounds such as *Burkholdria, Pseudomonas, Brevibacterium* (Table. 11) which is in accordance with increase in sum PAH. These bacterial strains are known with their ability to degrade aromatic pollutants from environment (Seo *et al.,* 2009). Only a small portion of the population is actually culturable. Typically, microbes that are recovered through HPC include those that are part of the natural microbiota of water; and in some instances, they may also include those derived from diverse pollutant sources.

Table. 11. Isolated bacterial strains from soil samples along the study area

Organism	Cell count/ml	Organism	Cell count/ml
Station 1A:		**Station 3A:**	
Acinitobacter caloaceticus	> 1 x 10^8	*Pseudomonas aeruginosa*	5 x 10^5
Burkholderia capacia	1 x 10^7	*Brevundimonas diminuta*	3 x 10^5
Brevibacterium casei	34 x 10^5	*Neisseria elongata*	2 x 10^5
Micrococcus sp.	24 x 10^5	*Agrobactrium radiobacter*	2 x 10^5
Station 1B:		*Acinitobacter caloaceticus*	53 x 10^5
Acinitobacter caloaceticus	11 x 10^5	*Aeromonas hydrophila*	3 x 10^5
Alcaligenes faecalis	1 x 10^5	*Aeromonas caviae*	2 x 10^5
Alcaligenes xylosoxidans	1 x 10^5	*Shigella sp.*	5 x 10^5
Aeromonas hydrophila	1 x 10^5	*Burkholderia capacia*	1 x 10^6
Klibsiella oxytoca	1 x 10^5	*Alcaligenes faecalis*	2 x 10^5
Station 2A:		*Kyotococcus sedentarium*	1 x 10^5
Pseudomonas aeruginosa	3 x 10^5	*Brevibacterium casei*	1 x 10^6
Shewanella putrifaniens	2 x 10^5	*Streptococcus* sp.	20 x 10^5
Kingella denitrificans	2 x 10^5	*Bacillus* sp.	21 x 10^5
Pseudomonas fluorescens	2 x 10^5	**Station 3B:**	
Pseudomonas mendocina	1 x 10^5	*Acinitobacter caloaceticus*	14 x 10^4
Moraxella nonliquefaciens	14 x 10^5	*Corynebacterium jeikrium*	1 x 10^4
Agrobactrium radiobacter	8 x 10^5	*Corynebacterium minutissimum*	5 x 10^4
Acinitobacter caloaceticus	2 x 10^5	*Brevibacterium casei*	16 x 10^4
Enterobacter cancerogenus	16 x 10^6	*Streptococcus* sp.	8 x 10^4
Brevibacterium casei	24 x 10^6	*Bacillus* sp.	2 x 10^4
Bacillus sp.	17 x 10^4	**Station 4A:**	
Station 2B:		*Flavobacterium sp.*	42 x 10^4
Pseudomonas mendocina	1 x 10^4	*Shigella sp*	2 x 10^4
Sphingomonas paucimobilis	1 x 10^4	*Leifsonia aquatica*	6 x 10^4
Yersinia enterocolitica	10 x 10^4	*Bacillus* sp.	6 x 10^5
Bacillus sp.	4 x 10^4	**Station 4B:**	
		Flavobacterium sp.	59 x 10^4
		Pseudomonas stutzeri	3 x 10^4
		Pseudomonas fluorescens	1 x 10^4
		Brevundimonas vesicularis	2 x 10^4
		Hafnia alvei	14 x 10^4
		Bacillus sp.	2 x 10^4

As reclaimed water is used frequently in irrigation along the sampling area, groups of bacteria that are primarily enteric bacteria and not naturally occurring in aquatic systems are expected within the heterotrophs. Therefore, determination of total coliform and fecal coliform was performed (Tables. 12) as indicator on water quality.

Coliforms are a specific group of bacteria that are normal inhabitants of the gastrointestinal tract of animals and found in the environment. Although most coliforms may not cause disease, their presence often indicates the presence of feces from humans and other warm-blooded animals. The thermo tolerant coliforms are referred to as fecal coliforms; however, some coliforms (*Klebsiella*, *Citrobacter*, *Enterobacter*) are associated with industrial effluents, decaying plant material or soil may also grow at elevated temperatures.

Table. 12. Three tube most probable number of water and soil samples from the study area

Sample site	MPN index/100ml		Estimated bacterial number/100 ml	
	TC	FC	TC	FC
W0	> 24	0.29	> 24000	290
W1	> 24	0.46	> 24000	460
W2	> 24	0.43	> 24000	430
W3	> 24	0.53	> 24000	530
S1A	1.1	0.93	11000	9300
S1B	0.23	<0.03	2300	0-299
S2A	0.93	0.23	9300	2300
S2B	0.036	<0.03	360	0
S3A	1	0.23	10000	2300
S3B	0.091	<0.03	910	0
S4A	0.11	0.036	1100	360
S4B	0.036	<0.03	360	0

The number of bacteria per 100 ml of sample is estimated by using of probability tables by the multiple fermentation tube technique. The method has two test stages: The Presumptive Test, and the Confirmed Test. The presumptive tests are designed to grow the target bacteria. The media used in the confirmed tests are designed to validate the growth of target bacteria in the presumptive test. It's noticed that the index of coliform number was high reflecting the nature of water used in irrigation, but most of these coliforms are not fecal in origin. Although coliforms may be encountered in environmental samples but there number is decreased in soil due to competition with other soil bacterial strains. Therefore, the number of total and fecal coliforms in soil samples does not reflect the real case of these strains. But the decrease in their number with depth indicates the effect of aeration and soil moisture on the growth and survival of this type of microorganisms.

Certain heterotrophic bacteria are considered opportunistic pathogens, include *Pseudomonas, Klebisella,* and *Aeromonas*. *Klebsiella* occurs widely in nature and is often present in surface water used for human consumption or for recreational purposes. The organism can survive in water distribution systems despite chlorination. Many strains give rise to positive fecal coliform tests, even when they are the only organisms present in the water sample (Allen *et al.,* 2004). The public health significance of *Klebsiella* in water is therefore an important concern. The genus *Psuedomonas* is also routinely enumerated in HPC determinations and considered by some to be an opportunistic pathogen.

CONCLUSIONS

Referring to the above discussion the followings can be concluded

- There is slight impact of climate change on wastewater quality in terms of major ionic composition and soil in terms of soil salinity.
- For organic pollutants,
- There is an increase in microbial biodiversity with increase in warming temperature, although there is a decrease in microbial number with decreasing in altitude along sampling sites.
- Climate conditions along sampling stations represented by different sampling site elevations had limited effect on PAH concentrations.

- Higher concentration level of PAH was located at the lower elevation along the sampling sites than at higher elevations indicating that warmer climatic conditions would result in increasing PAHs with high molecular weight.

- Climate change increases the planet's vulnerability to persistent organic pollutants, by increasing emissions and the bio-availability of POPs, and thus the potential for bio-magnification through the food chain, one of the chief pathways of human exposure to POPs.

- Higher concentration of PAH were found along sampling sites in the lower soil profile (15-30 cm) than in the upper profile (0-15) which was attributed to volatilization and photodegradation of PAH at the surface soil that lead also to the domination of HMW compounds rather than the LMW compounds.

- No clear effect of climate change on soil and water quality in terms of PCBs

- Prevalence of fecal colifrom in collection sites indicating the source of irrigating water used with dominance of thermotolerant coliforms (*Klebsiella*, *Citrobacter*, *Enterobacter*) are associated with industrial effluents, decaying plant material or soil may also grow at elevated temperatures.

- High frequency of isolated bacterial strains (i.e thermotolerant species of *Acinitobacter, citrobacter, enterobacter, pseudomonas*) from the soil surface indicating the influence of low water availability due to evaporation and warming on their growth.

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