BIRZEIT UNIVERSITY

Faculty of Graduate Studies

Master Program in Water and Environmental Sciences

Evaluation of a Natural Phytoremediation System in Wadi Zomer for Pollution Reduction in Industrial Wastewater from Nablus West, Palestine

تقييم نظام إصلاح حيوي طبيعي في وادي زومر لخفض التلوث في مياه الصرف الصناعي من غرب نابلس-فلسطين

A Master Thesis

By

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Supervisor

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August, 2020

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Thesis was prepared under the supervision of Prof. Dr. Rashed Al-Sa'ed and has been approved by all members of the Examination Committee.

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The findings, interpretations, and conclusions expressed in this study do not necessary express the views of Birzeit University, the views of individual members of the MSc committee or the views of their respective employers.

DEDICATION

I Dedicate My Work

To Whom I Belong,

To My Parents,

Abdulqader Attili and Ferdous Attili

To My Brothers and Sister

To My Wife

To My Son Abdulqader

To My Uncle Romel Attili

To My Best Friends,

For Their Help, Support and Encouragement

All the Way Long

Acknowledgments

I would like to thank those who helped and supported me during my study in the M.Sc. Program in Water and Environmental Sciences. This thesis would not have been possible without your support.

My deepest gratitude are due to my supervisor, Dr. Rashed Al-Sa`ed, whose vast expertise, invaluable advice and continual patience added substantially to my graduate knowledge. With appreciation, I thank Dr. Nidal Mahmoud, and Dr. Khaled Swaileh, members of the examination committee, for the remarks they made on thesis report.

Special thanks go to Tareq Aqhash and Bilal Amous for their technical support in sampling and lab analysis in the Testing Laboratories Center of Birzeit University.

The research conducted in this thesis was made possible through the financial support of the Palestinian-Dutch Academic Cooperation (PADUCO2) Program on Water within the project "Promotion of Applied Integrated Practices and Technologies for Sustainable Industrial Wastewater Management in Palestine (INWA)".

Finally, I would also like to thank my family for their support and encouragement.

Abstract

In Nablus Governorate, agrifood industries including dairies, olive mills, and slaughterhouses discharge diverse wastewater streams without pretreatment due to the lack of onsite pre-treatment systems. Nablus West Sewage Treatment Plant (NWSTP) is facing major operational challenges with associated economic and environmental impacts. NWSTP is not designed to co-treat high organic pollution loads of industrial origin without pretreatment. Treated waste water from NWSTP, the main water flow in Wadi Zomer, is mixed downstream with raw industrial discharges from Nablus West. Besides impairing Wadi Zomer water quality, the illicit industrial discharges into public sewer networks lead to non-compliance of NWSTP with the Palestinian Specification (PS 227, 2010) pertaining to industrial wastewater discharge into water bodies. This study investigates the role of natural wetlands along Wadi Zomer in reducing the organic and inorganic pollution loads from diverse industrial discharges including the residual pollution loads originating from the NWSTP. Along a length of 5 km downstream of NWSTP, four sampling stations were selected to assess the purification capacity of Wadi Zomer including the role of natural wetlands plant (*Phragmites australis*) in pollution loads reduction. Since, the watercourse of Wadi Zomer and its major tributaries pass through various hydrogeological, topographic landscape with diverse industrial sites, four main sampling stations (S1 to S4), distributed over a flow distance of 5 km long from NWSTP (S1), and were chosen for water quality monitoring. A total number of one hundred samples (44 water, 44 sediment and 12 vegetation samples) including one vegetation control, were analyzed for physical and chemical parameters over a period of eight months (August-December, 2019, and Jan-March, 2020). The results show that sampling stations S2 (0+0.5 km) and S3 (0+3.0 km) were identified as key stations reflecting an increase in pollution loads due to illicit industrial discharge and sewer overflow discharge form NWST during emergency conditions in the results obtained. The BOD values varied significantly along sampling sites and ranged from 6.64 to 437.10 mg/l. The study revealed that the water in S1 and S2 had BOD levels below PVL standard (PSI, 227/2010) and that S3 and S4 had BOD levels (437.1±300.8), (333.9±233.7) mg/l respectively, above the maximum permissible limits. Similar fluctuation tendencies in the concentration of COD and nutrients (NH_4 and PO_4). Compared to control site values, the water samples from all sites (S1-S4) showed a decreasing tendency in the concentrations of heavy metals (Fe>Cu>Zn>Cr >Ni)

and were below the national standard limits. The pollution tendency of heavy metals in the sediment followed the same decrease pattern in water samples with the flow course of Wadi Zomer. The concentration of Fe (6687 mg/kg) and Cu (1384.7 mg/kg) were found at highest in sediment samples (S1-S4), this might be due to point, and non-point sources of pollution, with a similar tendency, found for Zn, Cr and Ni for all sites. This may be due to direct discharge of industrial wastewater from metal, tanneries, and textile industries, established in the western side of Nablus city, into Wadi Zomer without pretreatment. Wadi Zomer catchment area is coupled to the mountain aquifer, where polluted environmental flows could infiltrate into the aquifer. Significant phytoremediation capacity was found for iron, copper and zinc within the roots of *P. australis*, and largely retained in the sediment. Despite the short-term period of data collection, the findings in this study should still provide technical help and a valuable reference for policymakers and joint service councils to implement effective pollution control and monitoring associated with science-based land-use planning. Further study is required to examine the seasonal variations in mass balance for water and metal contents in the different compartments of the natural wetland system along the Wadi Zomer course. The results obtained suggest the development of rehabilitation programs using nature-based technologies along Wadi Zomer watercourse and help selection of primary monitoring stations aiming at sustainable water management for the whole watershed area. The urgent needs to improve the environmental flows of the Wadi watercourse considering the multi-beneficial uses for agricultural irrigation and recreational use warrant further investigations.

الملخص

في محافظة نابلس، تقوم الصناعات الغذائية بما في ذلك الألبان ومعاصر الزيتون والمسالخ بتصريف مجاري مياه الصرف الصحي المتنوعة دون معالجة مسبقة بسبب عدم وجود أنظمة معالجة مسبقة في الموقع. تواجه محطة معالجة مياه الصرف الصحي في غرب نابلس (NWSTP) تحديات تشغيلية كبيرة مع الآثار الاقتصادية والبيئية المرتبطة بها. لم يتم تصميم محطة (NWSTP) للمعالجة المشتركة لأحمال التلوث العضوي العالية ذات الأصل الصناعي دون معالجة مسبقة. يتم خلط المياه المعالجة من محطة NWSTP، التدفق الرئيسي للمياه في وادي زومر، في اتجاه مجرى النهر مع تصريفات صناعية خام من غرب نابلس. إلى جانب الإضرار بجودة مياه وادي زومر، تؤدي التصريفات الصناعية غير المشروعة في شبكات الصرف الصحي العامة إلى عدم امتثال محطة المعالجة (NWSTP) للمواصفة الفلسطينية (PS 227, 2010)، المتعلقة بطرح مياه الصرف الصناعي في المسطحات المائية. تبحث هذه الدراسة في دور الأراضي الرطبة الطبيعية على طول وادي زومر في تقليل أحمال التلوث العضوي وغير العضوي من التصريفات الصناعية المتنوعة بما في ذلك أحمال التلوث المتبقية الناتجة عن محطة المعالجة (NWSTP) على مسافة مجرى طوله 5 كم أسفل مخرج محطة نابلس الغربية (NWSTP). تم اختيار أربع محطات لأخذ العينات لتقييم قدرة تنقية وادي زومر بما في ذلك دور نبات الأراضي الرطبة الطبيعية (*Phragmites australis*) في تقليل أحمال التلوث. منذ ذلك الحين، يمر مجرى وادي زومر وروافده الرئيسية عبر مختلف المناظر الطبيعية الهيدروجيولوجية مع مواقع صناعية متنوعة، وأربع محطات رئيسية لأخذ العينات (S1-S4)، موزعة على مسافة تدفق بطول 5 كم من مخرج محطة NWSTP كموقع رقم S1، لمراقبة جودة المياه. تم تحليل مائة عينة (ماء: 44، رواسب: 44، ونباتات:12) بما في ذلك موقع حيادي (نبات) واحد ، من أجل تحليل المقاييس الفيزيائية والكيميائية على مدى ثمانية أشهر (آب – كانون أول، 2019، كانون ثاني - آذار 2020). أظهرت النتائج أنه تم ملاحظة محطات مراقبة أخذ العينات (S2 (0 + 0.5km و(S3 (0 + 3.0 km تكشف زيادة في أحمال التلوث بسبب التصريف الصناعي غير المشروع وتصريف المجاري الفائضة من NWSTP أثناء ظروف الطوارئ. اختلفت قيم الطلب البيولوجي على الأكسجين بشكل كبير على طول مواقع أخذ العينات وتراوحت من 6.6 إلى 437.1 ملغم / لتر. كشفت الدراسة أن الماء في الموقع 1 والموقع 2 يحتوي على مستويات BOD أقل من معيار (2010 PS ،227 PVL) وأن الموقع 3 والموقع 4 يحتويان على مستويات (300.8 - 437.1) BOD ، -333.9) 233.7)ملغم / لتر على التوالي تفوق الحد الأقصى المسموح به. اتجاهات تقلب مماثلة في تركيز COD والمغذيات (NH_4) و (PO_4) مقارنة بقيم الموقع الضبط، أظهرت عينات المياه من جميع المواقع (S1- S4) اتجاه تنازلي(Fe> Cu> Zn> Cr> Ni) في تركيزات المعادن الثقيلة وكانت أقل من الحدود القياسية الوطنية. اتبعت اتجاه تلوث المعادن الثقيلة في الرواسب نفس نمط الانخفاض في عينات المياه مع مسار التدفق في وادي زومر. تم العثور على

تركيز لعنصر الحديد 6687 ملجم / كجم و للنحاس 1384.7 ملجم / كجم بأعلى مستوى في عينات الرواسب (المواقع S1-S4) ، قد يكون هذا بسبب نقطة، مصادر غير محددة للتلوث. مع نفس الميل تم العثور عليه لـ Zn و Cr و Ni لجميع المواقع. قد يكون هذا بسبب التصريف المباشر لمياه الصرف الصناعي من الصناعات المعدنية والمدابغ والنسيج، التي تم إنشاؤها في الجانب الغربي من مدينة نابلس، إلى وادي زومر دون معالجة مسبقة. تقترن منطقة مستجمعات وادي زومر بطبقة المياه الجوفية الجبلية، حيث يمكن أن تتسرب التدفقات البيئية الملوثة إلى الخزان الجوفي. تم العثور على قدرة كبيرة على المعالجة النباتية للحديد والنحاس والزنك داخل جذور *P. australis* ، ويتم الاحتفاظ بها إلى حد كبير في الرواسب. على الرغم من الفترة القصيرة الأمد لجمع البيانات، إلا أن النتائج الواردة في هذه الدراسة يجب أن توفر مساعدة فنية ومرجعًا قيمًا لصانعي السياسات ومجالس الخدمات المشتركة لتنفيذ مراقبة ومراقبة فعالة للتلوث المرتبط بتخطيط استخدام الأراضي المستند إلى العلم. مطلوب مزيد من الدراسة لفحص التغيرات الموسمية في توازن الكتلة لمحتويات المياه والمعادن في الأجزاء المختلفة لنظام الأراضي الرطبة الطبيعية على طول مسار وادي زومر. توصي نتائج البحث إلى تطوير برامج إعادة التأهيل باستخدام التقنيات القائمة على الطبيعة على طول مجرى وادي زومر وتساعد في اختيار محطات المراقبة الأولية التي تهدف إلى الإدارة المستدامة للمياه لمنطقة مستجمعات المياه بأكملها. تتطلب الاحتياجات العاجلة لتحسين التدفقات البيئية لمجرى مياه الوادي مع الأخذ في الاعتبار الاستخدامات المتعددة الفوائد للري الزراعي والاستخدام الترفيهي مزيدًا من التحقيقات.

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List of Abbreviations

BOD	Biochemical Oxygen Demand
BZU	Birzeit University
CWs	Constructed wetland system
°C	Degree Celsius
COD	Chemical Oxygen Demand
INWA	Industrial Wastewater
NWSTP	Nablus West Sewage Treatment Plant
NWs	Natural Wetlands
N	Nitrogen
OM	Organic mater
pH	Measure of acidity or basicity of aqueous solutions
PADUCO2	Palestinian-Dutch Academic Cooperation Program, 2^{nd} phase
PVL	Palestinian values limit
S1	Sampling site outlet of NWSTP (0+0.0 km)
S2	Sampling site (0+0.5 km); Beit Leed Bridge
S3	Sampling site (0+3.0 km); Anabta entrance
S4	Sampling site (0+5.0 km); Anabta middle
SSF	Subsurface flow
SF	Surface flow
TP	Total phosphorus
TSS	Total suspended solids
WWTP	Wastewater Treatment Plant

Chapter One – Introduction

1.1 Background

Since 1994, the Palestinian Authority invested huge capital and technical support to improve the water quality and recue public health hazards through upgrading and erection of new wastewater treatment facilities (Palestinian Water Authority, 2014). Increased human activities and using streams and rivers at large-scale resulted in water quality and ecosystem degradation (Vörösmarty et al., 2010). Currently, environmental laws in many countries call for the establishment of wastewater treatment plants (WWTPs) to improve sanitation service and to enhance ecological processes in the receiving water bodies. However, effluent quality standards and technology selection vary widely among countries (Angelakis and Snyder, 2015; Libralato, et al., 2012). The treated water discharged by WWTPs could be used in agricultural irrigation, commercial and industrial recycling, groundwater recharge, and direct potable reuse. In addition, treated water can be directly discharged into nearby water bodies including small Wadis, streams, rivers, lakes and oceans (Brooks et al., 2006; McEneff et al., 2014).

Natural Wetlands (NWs) and constructed wetlands (CWs) describe nature-based treatment processes aiming at the removal of organic and nutrients from municipal wastewater. The use of constructed wetlands (CWs) is an accepted eco-technology, especially beneficial to rural areas or industries that cannot afford expensive conventional treatment systems (Wu et al., 2010). However, CWs technologies are considered to be still in their primary stage, since the inside biotic and abiotic forms happening in wetlands have not been satisfactorily measured (Wallace, 2005). CWs are considered to be suitable for secondary and tertiary treatment of municipal wastewater but only for tertiary treatment of industrial wastewater (ITRC, 2003; Sustainable Conservation, 2005).

Both CWs and NWs, established at various scales, are constructed for domestic, industrial, municipal wastewater and leachate. Ever increased and stringent water quality rules and effluent standards urged policymakers to search for ecofriendly natural treatment systems including wetlands (Zhang et al., 2014; Suhad et al., 2018).

Reviewing self-monitoring reports of Nablus West sewage treatment plant (NWSTP) revealed shock loads events during September, 2019. Lab analysis of influent showed high organic pollution loads (COD= 955 mg/l), of industrial origin. Such results indicated that the industries in Nablus West, established along the course of Wadi Zomer, are not in compliance with technical rules issued by the Council of Ministers in 2013 (WWTP Nablus West, 2019).

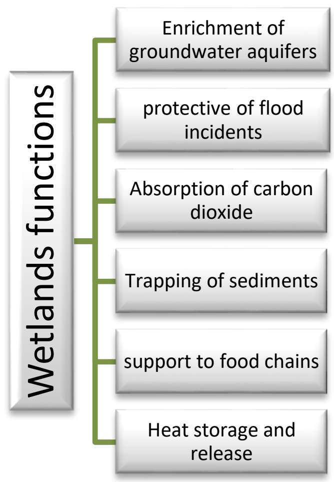

Figure 1: Wetland functions.

Al-Sa`ed (2010) has developed a policy framework for receiving water bodies including groundwater, streams and water reservoirs, subject for incidents of industrial pollution loads (organic and inorganic substances). He reported selected case studies, where transboundary watercourses are heavily polluted with illicit industrial discharges. This practice caused political and economic disputes between the Palestinian Authority and Israeli water related agencies. According to Al-Sa`ed (2010), organic and inorganic pollutants of divers origins are heavily polluting almost all water bodies in Palestine.

Compared to organic pollution, Bragato et al., (2009) reported that bioremediation of polluted water bodies with inorganic substances (e.g. heavy metals) received important attention. Knowing that heavy metals are non-biodegradable, high treatment costs and complicated treatment schemes are required. Both natural wetlands (NWs) and constructed wetlands (CWs) are considered as natural treatment systems that fit for developed and less developed countries. Wetlands have low capital and operational expenditures . The treatment processes behind the reduction of organic and inorganic pollutants within natural wetlands entail physical and biochemical mechanisms (Yalcuk and Ugurlu, 2009).

Published literature (Kouki et al., 2009; Hamouri et al., 2007), report the importance of vegetation planted in wetland systems. This is true, since plants require C:N:P as nutrient for growth and energy source. The C:N:P are ingredients of all types of wastewater, a biotic and biotic environmental conditions could enhance the removal efficacy of wetlands. However, care should be taken into consideration pertinent to inhibitory substance that might form constituents in agrifood industries including phenols, heavy metals and high organic and nitrogenous pollution loads. Therefore, deep insight studies are required to explore the capacity of wetlands and understand their role in pollution reduction of organic-rich industrial wastewater.

1.2 Problem Statement and Justification

In Palestine, the water and environmental problems have increased in spatial distribution over the last two decades with improper practices and inadequate management of industrial and municipal wastewater streams. Lack of sustainable management and poor financial resources are responsible for the gross pollution of the receiving water bodies, increased water borne diseases, loss of water value and political dispute with regional water agencies. Previous studies (Samhan et al., 2010) reported that five Palestinian Wadis, small streams with seasonal flows, are heavily polluted but have been unsuccessful in provide policy advice or deep insights into alternative nature-based technologies to improve water quality and reduce public health and ecosystem hazards. With an increased understanding of the importance of surface water quality monitoring to public health, groundwater and aquatic life, there is a great need to assess the water quality and understand the role of phytoremediation in major Wadis restoration in Palestine.

This master thesis research is an activity within the ongoing INWA project, a joint initiative supported by the second Palestinian-Dutch Academic Cooperation (PADUCO2) Program on Water (Al-Sa`ed, 2019). The aim of the INWA project is to promote applied integrated practices and technologies for sustainable industrial wastewater management in Palestine (Fig. 2). The study of phytoremediation using natural wetlands, an ecotechnology for pollution reduction from the industrial wastewater discharges along the flow course of Wadi Zomer forms the main goal of this thesis works.

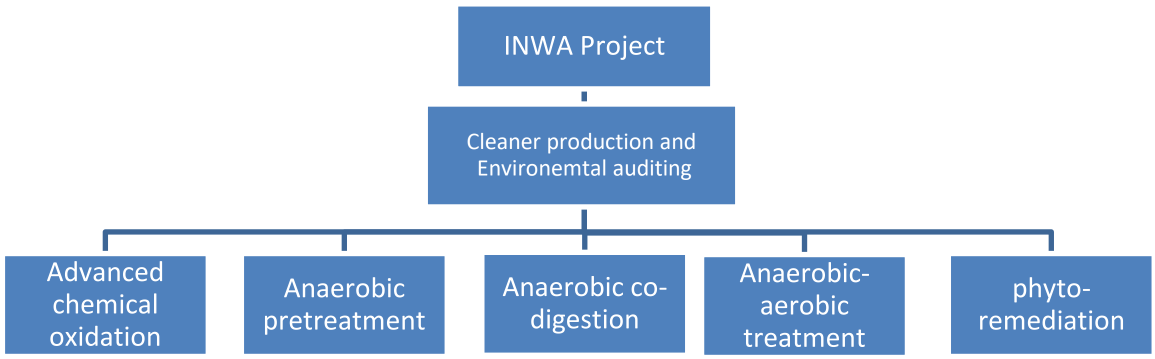

Figure 2: Applied practices and technologies for industrial wastewater management within INWA project.

1.3 Aim and Objectives

The main goal of this research is to study the self-purification capacity using natural wetlands along the Wadi Zomer for the reduction of industrial pollution loads in wastewater from the western side of Nablus city, Palestine.

The specific objectives of the thesis are as follows:

1. Identify monitoring stations to assess the water quality variations of Wadi Zomer.
2. Monitor and estimate the phytoremediation efficacy in reducing the industrial pollution.
3. Assess the vegetation role in natural wetland in improving water quality in Wadi Zomer.

1.4 Research Questions

1. Where and how to monitor seasonal variations in the water quality of Wadi Zomer?
2. How efficient natural wetlands in the reduction of organic and inorganic pollution loads?
3. What role do vegetation of natural wetlands have in removal of selective heavy metals?

1.5 Scope and Limitations

The practice of discharging raw industrial wastewater from small-scale family owned factories in Nablus West, lead to increased concentrations of toxic chemicals and nutrients in Wadi Zomer, a small streams passing through Palestinian communities in Nablus West watershed area. The original concept of this research study entailed the design, establishment and monitoring of constructed wetlands (CWs) along the Wadi Zomer. Nablus Municipality enforced the municipal by-law on the industrial enterprises, located in Nablus West, not to discharge industrial wastewater without pretreatment into Wadi Zomer. Therefore, the established constructed wetlands along the Wadi Zomer was abandoned since no environmental flows were observed. To complete the activity within the INWA project, the current study represents an alternative study section, natural wetlands (NWs), for the sampling stations along the Wadi Zomer course, while keeping the research objectives and research questions unchanged. The main difference is replacing the CWs (man-made) by the NWs (nature-based solution), as a study site section.

Natural wetlands (*P. australis*) as a control, which are not impacted with wastewater, were observed along the course of Wadi Zomer. Therefore, three vegetation samples for the control, were taken from natural wetlands irrigated with freshwater nearby Bala` groundwater well. Growing under similar weather conditions and lab analysis made in triplicates were key elements to assess the value of phytoremediation through possible bioaccumulation of heavy metals by the wetlands` vegetation (*P. australis*).

Chapter Two - Literature Review

2.1 Background

Constructed wetlands (CWs) apply natural treatment processes as phytotechnology and low cost treatment for diverse types of wastewater streams. This nature-based treatment system depends on temperature from the sun, wetland plants and micro-organisms, which are the active agents in the treatment processes. CWs are used for water quality improvement, pollutant removal, and remediation of polluted rivers and water bodies. some times CWs are considered as an alternative technology for wastewater management due to reduced capital expenditures and low annual running costs (Du et al., 2009).

Constructed and natural wetlands (CWs, NWs) offer numerous important ecological services to human society. CWs are gaining acceptance in the recent years as a viable option for the treatment of industrial effluents and removal of toxic. The constructed wetlands technology is still used naturally in wastewater treatment, but recent research indicates that wetlands constructed under controlled conditions are much better than those that exist naturally. The wastewater flows through the wetland, it is treated by physical, chemical and biological processes (Vymazal, 2011).

CWs technology can be used to treat municipal water and can also be used to treat industrial and agricultural water, stormwater runoff, and livestock farm effluent. In urban areas, water flowing from industry, agriculture, or some commercial activities carries a lot of pollutants, in addition to carrying many nutrients that cause huge problems in water quality. Where in some countries of the world Cws a technology has been considered an economic solution to treat flowing water (Kurzbaum et al., 2012).

Wetlands, a phytoremediation processes, use plants and microorganisms to degrade contaminants for biomass production utilizing light as an energy source.

On an Indian dairy, Dipu et al., (2011) performed a pilot study using different plant species to investigate the potential for contaminants load reduction. With improved effluent turbidity, they found that the hydraulic retention time (15 days) was a key design parameter for the removal of On the other hand, those results were supported by the findings published by Wu et al., (2010).

Wood et al., (2007) evaluated CWs for agricultural drainage treatment and reported low removal rates of 48% for BOD and 40% for nutrients, while high efficacy in TC reduction (96%). The removal mechanisms behind pollution reduction by natural wetlands is complex. River beds (soil) forms a suitable media structure and texture, where microbial flora exhibit a biofilm with filtration capacity. The soil-plant-microorganisms relations provide CWs and NWs with aerobic and anaerobic conditions responsible for high removal efficiency for TKN and phosphor (Akratos & Tsihrintzis, 2007).

Constructed wetlands (CWs) can be categorized (Fig. 3) based on, hydrology, flow path and type of macrophytes. According to the wetland hydrology CWs are classified into three types: surface flow (SF) CWs, subsurface flow (SSF) CWs, hybrid systems and combined systems. CWs depend on Substrates and this indispensable parts, the substrates play a good role to remove pollution (Wang, et al., 2020).

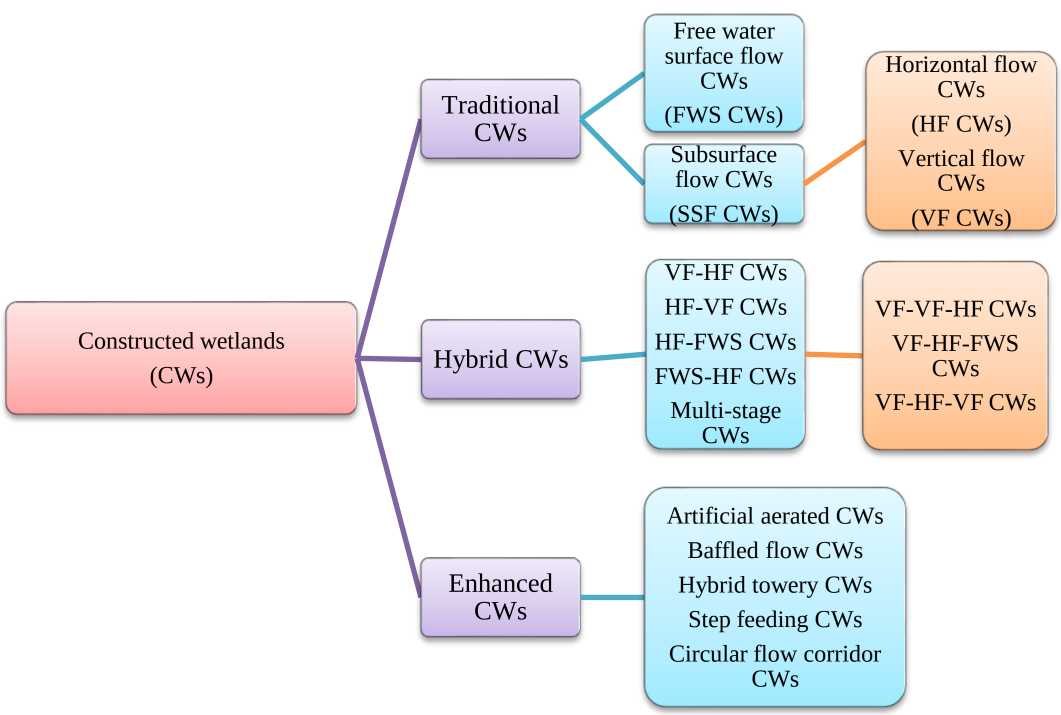

Figure 3: Classification of CWs used in wastewater treatments

2.2 Constructed wetlands components

2.2.1 Plant

Plant used in constructed wetlands, frequently used a macrophytes include emergent plants, submerged plants, floating leaved plants and free-floating plants. Wetland plant has been reported to be one of the main factors influencing water quality in wetlands.

In Palestine, the most common reeds used in constructed wetlands are *Phragmites* spp., locally found vegetation in natural wetlands. *Phragmites australis* (*P. australis*) is one of the most productive, locally spread with variable wetland species in Palestine (Fig, 4). Due to its climatic tolerance and rapid growth, it is the predominant species used in constructed wetlands (UN-HABITAT, 2008). The reed and cattail growth can be considered as an indicator of their wastewater treatment by nutrients uptake for growing. Plants act as intermedium for purification reactions by enhancing a variety of removal processes and directly utilizing nutrients (Liu et al., 2013; Ko et al., 2011) In addition, they can accumulate toxic elements, such as heavy metals (Lu et al., 2014). The phytoremediation potential parts of *P. australis* was more effective and successful than all other macrophytes were able to accumulate a good proportion of heavy metals in their roots and shoots, but conspicuously in the roots (Shahid et al., 2020).

Figure 4: Common Reed Plants (*Phragmites australis).*

The weeds *P. australis* was used by Bonanno et al., (2013) and found a high capacity for the bioaccumulation of heavy metals removal and suggested macrophytes to be used as biomonitors for the stream sediment contamination by heavy metals.

Other studies (Chung et al., 2008) reported that plants could bioassimilate a small percentage of nitrogen in CWs. This was explained by While Xu et al., (2010) that large ammonia content inhibited the plant physiology with reduced nutrients uptake. Other studies ((Dunbabin and Bowmer, 1992; Duman et al., 2007)) used constructed wetlands (*P. australis*) for the treatment of industrial wastewaters containing metals and found higher concentrations in the root systems, while the above-ground parts of the plants contained lower concentrations.

2.2.2 Substrate material

Substrate is a very important parameter which affect the performance of the constructed wetlands system. Within the past, soil was nearly solely utilized as filter media. Nowadays, most systems contain rock layers of distinctive sorts and roots as filter media (Fig. 5). As media Stefanakis et al., (2014) reported on the use of sand (0.2-0.6 mm), fine gravel (6-16 mm), medium gravel (24-32 mm), and coarse gravel (60-130 mm), and found those media were of poor media options.

Other studies (Babatunde et al., 2010; Saeed and Sun, 2012) published few data on media composition to optimize the removal of nutrient and organics. Among the proposed media were alum slime, peat, rice husk and compost.

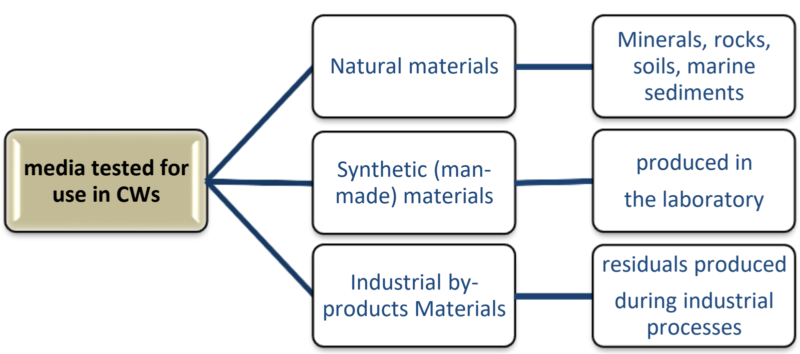

Figure 5: The media tested for use in CWs.

2.2.3 **Wastewater flow**

Water flowing to wetlands, whether municipal, agricultural, domestic or industrial water and rain water is loaded with many of the most important of materials like (nitrogen (N), phosphorus (P), organic matter (O.M), ... etc.). In addition, the water flowing into wetlands, whatever their source have may carry trace metals like (Cd, Cu, Pb, Zn) and other pollutant (Wang et al., 2017).

Most constructed wetlands are designed for the treatment of sewage either alone (74%) or together with storm water runoff (21%). other types of wastewater include landfill leachate, storm water runoff and secondary treated wastewaters from factories (Vymazal, 1996). Large absorption of heavy metals did not occur due to the constant running off of water which does not allow the sediments to remain the heavy elements (Maine et al., 2017).

WWTP in Nablus West receives an estimated 650,000 cubic meters of wastewater every month which is mixed with many type of water. For example, the concentration of the COD to the water entering the WWTP is 1000 mg/liter. After treatment, this percentage 1000 mg/l decreases to 40 mg/liter and this remainder is drained to the Wadi near the WWTP (Wadi Zomer).

2.2.4 **Environmental conditions**

For a successful CWs to work, it must be in the tropical and subtropical regions, and this does not prevent CWs to be successful in the cold climate (Zhang et al., 2014).

Stanković (2017) investigated climatic influence on the constructed wetland and found temperature as the most important factor, as it influenced chemical reactions and biological activity). Climate can be divided categorized into a hot climate (mean annual temperature over 20°C), a cold climate (mean annual temperature below 10°C) and a moderate climate (mean temperature in between 10 and 20°C). Other studies (Quan et al., 2007) showed the change in seasons directly affects wetland plants in the buildup of heavy metals in roots. The uptake of specific heavy metals is most valuable in the wintertime season due to decrease in microbial metabolic rates (Duman et al., 2007).

2.3 Pollutant removal processes in constructed wetlands

Stottmeister et al., (2003) reported that CWs can remove different pollutants including pathogenic microorganisms, heavy metals, organic substances (BOD, COD), nutrients (N and P) and suspended matter. Temperature plays key impacts on the processes of pollutant removal, such as sedimentation, filtration, precipitation, volatilization, adsorption, plant uptake, and various microbial processes (Stottmeister et al., 2003).

2.3.1 Heavy metals removal

Ujang et al., (2005) underlined that heavy metals in CW systems cannot be destroyed but their chemical and physical are modified. The removal processes is very complex and these processes include a combination of biotic and abiotic reactions (Kosopolov et al., 2004; Ujang et al., 2005). The concentration of heavy metals in sediments decreases due to partial precipitation along CWs (Bragato et al., 2009). Bello et al., (2018) showed the *P. australis* performed better at a pH value of 10 for the remediation of nickel.

2.3.2 Organic substance

In their study, Yalcuk and Ugurlu (2009) observed that the water temperature influence on the COD removal was not significant. Kouki et al., (2009 indicated that the decrease of BOD_5 is dependent on the oxygen availability. Aslam et al., (2007) noted that the use of wastewater with low organic content was important in order to prevent the clogging of the substrates pores, while high COD levels ($COD \geq 400$ mg/L) caused physiological changes in *P. australis* (Xu et al., 2010).

2.3.3 Nutrients (N and P)

The CWs achieved an average removal of 72 ± 16% for phosphorus and 38 ± 19% for nitrogen was mentioned in the study of (Kouki et al., 2009).

Uptake of phosphorus occurs by some mechanism into microbial and plant biomass (Tanner et al., 1999). Organic phosphorus is converted by the bacterial activity into mineral phosphorus, phosphorus is mainly removed by roots (Drizo, 2000). Clarke and Baldwin (2002) reported that nitrogen in excess of 200 mg/L of NH_4-N would inhibit the growth of plant used in CWs cattails.

Table 1: Overview of pollutant removal processes in constructed wetlands. Stanković (2017)

#	Pollutant	Purification process (Removal)
1	Organic matter (BOD or COD)	Undissolved organic matter (OM) removal by sedimentation and filtration and converted into dissolved BOD. Biofilm fixes DOM that is removed by biofilm on plants, roots, substrate particles
2	Suspended matter	Filtration and decompose by special microbes in soil
3	Nitrogen	Nitrification and denitrification in biofilm.
4	Phosphorus	Nitrogen retained in soil (adsorption). Precipitation with calcium, aluminum and iron. Plant uptake (limited influence only).
5	Pathogens	Filtration. Adsorption. Natural die-off.
6	Heavy metals	Precipitation and adsorption. Plant uptake
7	Organic pollutants	Adsorption to biofilm and clay particles.

2.4 Current Status of Industrial Wastewater Management in Nablus city

According to the reports of published the Palestinian Environmental Quality Authority (EQA, 2015), the main sources of pollution for water bodies are:

- Industrial resources.
- Agricultural resources.
- Sewage sources and storm water runoffs.

Industrial waste contains 60% of all contaminants in seas, lakes, and rivers. Most of the pollutants are mainly sourced from factories such as tanning, lead, mercury, copper, nickel, paint, cement, glass, detergents, dairy factories, slaughterhouses, and sugar refineries. As well as pollution of hydrocarbons resulting from oil pollution (EQA, 2015). Table 2 lists the current industries established in Nablus city, and the current disposal practices (Dalhem et al., 2017).

Table 2 : Summary of heavy industries in Nablus city (Dalhem et al., 2017)

Industries of Nablus city	**Current Practice for Effluent Disposal**
Stone cutting firms	Wadi Zomer
Tahini factories	Wadis and public sewers without prior treatment
Jeans factories	Wadis and sewer network without treatment
Olive Mills	Wadis and sewer network without treatment
Slaughterhouse/Nablus East	Public sewer network prior treatment
Dairy/Nablus East	Public sewer network prior treatment
Tannery	Wadis and sewer network without treatment
Aluminum/Nablus West	Public sewer network prior treatment
Veterinary	Public sewer network prior treatment
Restaurants	Public sewer network prior treatment
Chicken shops	Wadis sewer network prior treatment
Lead factory	Wadis sewer network prior treatment

Based on Dalhem et al., (2017) report, the Monitoring and Control Unit at Nablus Municipality opted for a strategy in which industries are required to build and operate onsite equalization basins. In doing so, balanced industrial wastewater should be co-treated in the anaerobic digesters at Nablus West STP.

Apart from the findings published by Mant et al., (2006), where they claimed that vegetation of *P. australis* was not adequate for bioremediation of chromium under tropical environment. This research aimed at exploring the possibility of local natural reeds (*Phragmites* sp.) in reducing pollution loads, which are still discharged into Wadi Zomer from Nablus West STP and agri-food industrial firms established along the Wadi course.

Chapter Three – Materials and Methods

For a successful achievement of study objectives, two key methodological approaches were opted for. The first, studying and critical analysis of published literature, scientific studies, official reports and some theses and guidelines in designing CWs. In doing so, this will help data collection and information compilation on the possibility of local plant (*Phragmites* spp.) growing on the banks of Zomer stream in reducing the pollution loads. The later originates from the treated water leaving NWSTP, and illicit industrial discharges. The second, sampling and lab analysis of physical and chemical parameters including water, sediment and vegetation, with data analysis using Excel software.

3.1 Study area

The Zomer stream is running from the mountains of the West Bank to the coastal plains. The study area and the selected sample stations are depicted in (Fig. 6). Since the 1950's, Wadi Zomer has served for municipal wastewater transport. Wadi Zomer extends over 27 km from the western side of Nablus city to Tulkarem city in the northwestern of the West Bank, forming a tributary for small streams crossing the green line inside Historical Palestine with its end in the Mediterranean Sea.

Figure 6: Map of the study area showing the location of sampling sites

3.2 Study design

The study involved taking a four samples from different places along a distance of 5 km for eight months [August – December, 2019, January – March, 2020). Located within the fence of Nablus West sewage treatment plant (NWSTP), sampling site one (**S1)** was at the outlet before discharge (0+0 km) into Wadi Zomer, site two **(S2)** was selected at 500 meters (0+0.5 km) from site one. Site three (**S3)** was located about 3 kilometer from site one (0+3 km), while site number four (**S4)** is located about 5 kilometers (0+5 km) downstream from site one (S1). Potential environmental flows into the different sampling stations were considered while selecting the different sites along the flow course of Wadi Zomer.

3.3 Sampling

Samples were collected for a period of eight months (August to December, 2019, and January to March, 2020) through the flowing water in the Wadi. Four sampling stations were identified considering the diverse environmental flows in Wadi Zomer (Fig. 7).

Sampling station S1 (0+0.0 km) represents the first site for water sampling, the outlet of Nablus West sewage treatment plant (NWSTP). This the main tributary as baseline environmental flow, which meets incidental sewer overflows form NWSTP headworks, illicit industrial discharges and septage disposal into Wadi Zomer. Station 2, located about 500 meters (0+0.5 km) far from S1, is the bridge near the main entrance to Beit Leed town. Here it is worth noting that the treated water from NWSTP is further mixed with domestic sewage from Beit Leed town. Station 3 (0+3.0 km), represents a water flow section without additional industrial activities or domestic sewage discharge into the Wadi but there could be drainage from the settlement near the third site. The final station S4 (0+5.0 km) receives mixed pollution loads from households and agri-food industries in the middle town of Anabta and some nearby village.

The sampling points were designed in relation to the volume of pollutants entering to the treated water come from the outlet of the WWTP as shown in (Fig. 7). All samples for laboratory analysis were placed into thoroughly cleaned (plastic bottles and tightly closed). These samples were placed in a box and protected from sunlight and then taken to the laboratory for analysis on the same day.

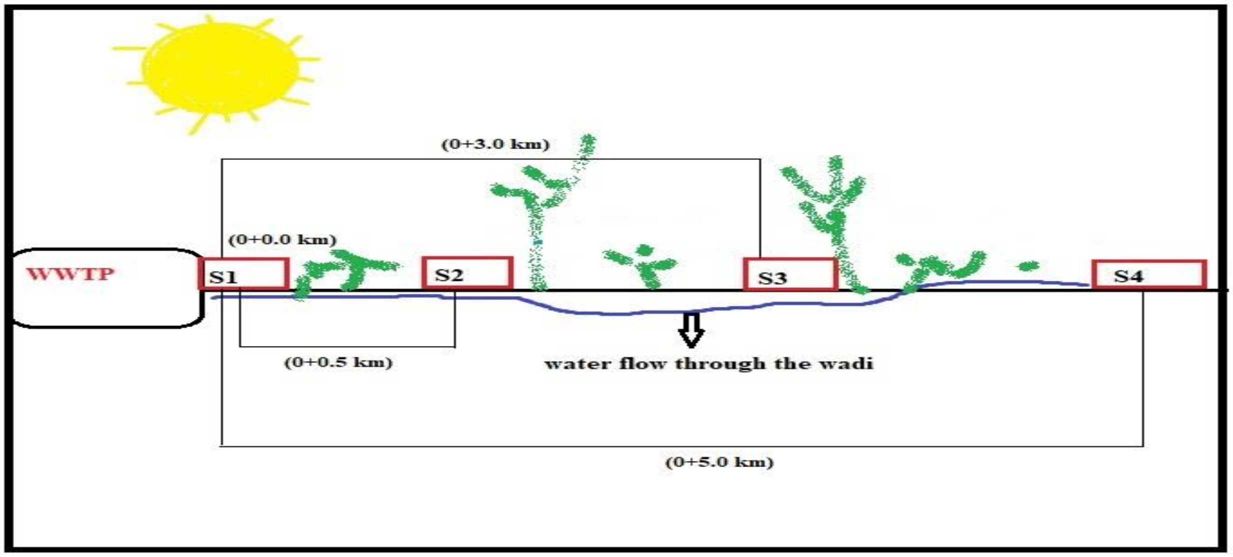

Figure 7: A schematic diagram shwoing the selected sampling sites along the Wadi Zomer.

3.4 Methods and Equipment for Lab Analysis

Table 3 below lists the physical and chemical parameters together with methods used lab analysis applied in the Testing Laboratories of Birzeit University.

Table 3: Methods used and water quality parameters measured for Zomer stream.

Parameters measured	**Instruments used for analysis**	**Methods of analysis**	**Location of analysis**	**Reference**
pH	pH-meter 3320, Jenway	SM#4500-H+(B)	Onsite, Hanna pH meter	Direct measurement as manufacturer procedure APHA 2005
T	T-meter	Calibrated Thermometer	Onsite, Hanna pH meter	
DO	DO-meter 98196		Onsite, Hanna pH meter	
Conductivity	Conductivity meter, 4320, Jenway	2520-B	Onsite, Hanna EC meter	
TSS	Filtration and drying	2540-D	IEWS lab	APHA 1995
TDS	Filtration/evaporation	2540-C,	IEWS lab	APHA 1995
TP	ICP-AES		BZU lab	APHA 2005
NO_3-N	UV 300/ UV-Visible spectrophotometer/	4500- NO_3-	IEWS lab	APHA 1995
NH_4-N	Nesselarization	4500A- NH3	IEWS lab	APHA 1995
Organic material COD, BOD_5	Hach COD reactor DO meter – Oxi 197	5210-B 5220-D	IEWS lab	APHA 1995
heavy metal (Zn, Fe, Mn, Cu, Ni, Pb, Cr)	ICP-AES Atomic Emission Spectrophotometer		BZU lab	APHA 2005

3.5 Sampling and Lab Analysis Sampling of Water, Sediment, and Vegetation

3.5.1 Physical and chemical parameters

The pH, total suspended solids (TSS), Dissolved Oxygen (DO), and Electrical Conductivity (EC) were measured using field instruments, WTW (Germany) Inolab pH/Oxi meter.

3.5.2 Chemical parameters

BOD5, COD, TP, NO_3-N and Ammonium were measured according to Standard methods (APHA, 1995).

3.5.3 Stream sediment samples

Sediments samples, taken from stream bed, were collected and analyzed for selective heavy metals according to (APHA, 2005).

3.5.4 Leaves and roots of wetland vegetation

Parts of the wetland vegetation (leaves, stem and roots) were collected three times from one site (S4) along the Wadi Zomer, while vegetation samples for the control (reference) were taken from natural wetlands grown on freshwater nearby the groundwater well in Bala` town. All vegetation samples were analyzed in triplicates for selective heavy metals according to the American Standard Methods (APHA, 2005).

3.6 Data analysis

The MS Excel and Graphpad prism software was used to analyze the obtained results data. The mean and standard errors were used to assess the data accuracy. The mean of parameters (±SE) and one-way analysis of variance (ANOVA) followed by a post hoc multiple comparison (Tukey's test) were calculated to compare the mean values of observation based on the sites under investigation. The differences in mean values obtained were considered significant if calculated P-values were less than 0.05. The correlation analysis was done to test the association between different parameters along testing sites along the Wadi Zomer.

Chapter Four – Results and Discussion

This section presents the results of physical and chemical parameters as determined in samples collected from Wadi Zomer flow and measured heavy metals in vegetation, water and sediment samples along the Wadi at first site inside Nablus West sewage treatment plant (NWSTP) in the its outlet before discharge into Wadi Zomer, second site was 500 meters from site number one, third site was a 3 kilometer from site number one and site four was 5 kilometer from site number one. *(n=11)* were taken for each Earlier monitoring station over the course of the study months (August-December, 2019, and Jan-March, 2020).

4.1 Wadi Zomer flow characterization

4.1.1 pH

In our study we found that the pH value was considered normal and it was within the normal range in site one was 7.61±0.05, site two 7.4±0.04, site 3 7.23±0.04, site 4 7.24±0.04

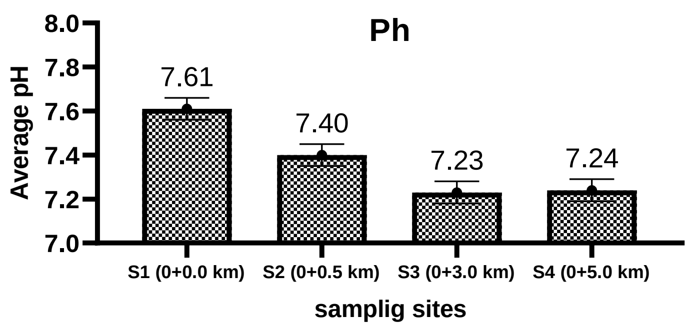

Figure 8: pH along the Wadi Zomer.

PVL 227/standard (PSI, 2010)= 6-9

The pH values showed insignificant variations along the sampling sites and ranged between 7.23±0.04 and 7.61±0.05 (Fig 9). The obtained pH values were all within the Palestinian Values Limit (PVL 227 range, 6-9) (PSI, 2010) at all study sites**.** Another study conducted by Elmanama et al., (2006) in Gaza under title Seasonal and spatial variation in the monitoring parameters of Gaza Beach during 2002–2003, reported that most pH measurements were found to be in the acceptable range of values between 6.5 and 8.5.

4.1.2 Water temperature

Additionally, concerning the temperature parameter, our study showed that also the temperature in all sites were normal between 20.2-22 C°, except in the first site it was below than the average normal range. Probably is that the first site inside NWSTP in the final assembly area (outlet) before discharge into the Zomer stream, which is often covered from the sunlight.

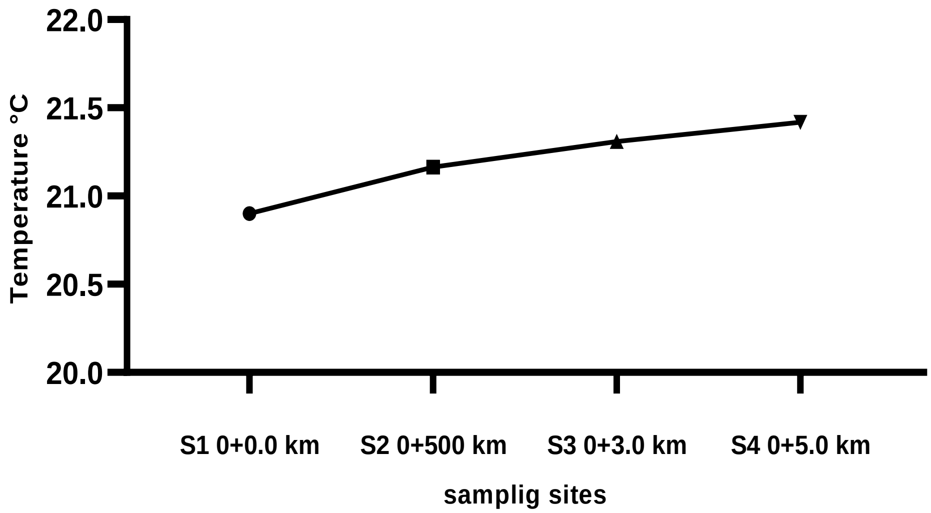

Figure 9: Water temperature along the Wadi Zomer.

4.1.3 Dissolved oxygen (DO)

To further extend our study, we investigated some other parameters as the dissolved oxygen, in our study we could show that the dissolved oxygen was significantly affected and it showed a significant increase in the amount of dissolved oxygen DO.

Interestingly, in our study as shown in Table 1, the dissolved oxygen appeared to be higher than 2 in site 3 and site 4. According to the established criteria the range must be below than 2. This may be due to geographical distribution of monitoring stations and the time of sample take which may change from month to month (Chen et al., 2009). When studying the water quality of flowing rivers Matamoros and Rodríguez (2017) recorded an dissolved oxygen rise in the direction of the downstream flow.

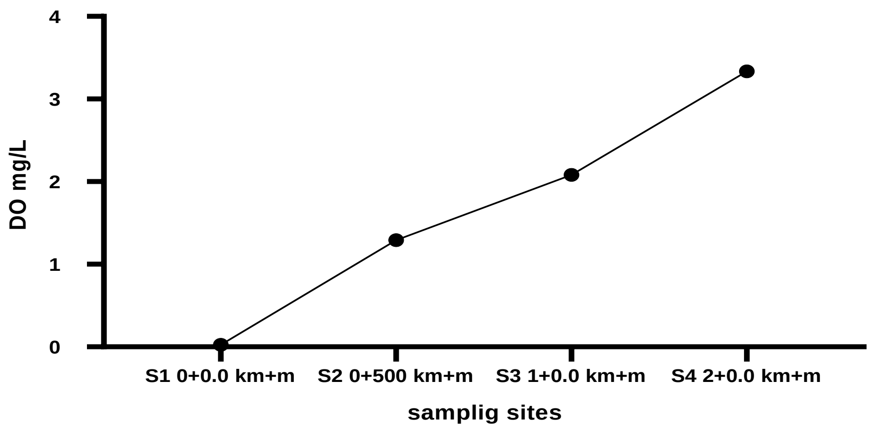

Figure 10: DO in water along the Wadi Zomer

(PVL 227 standard (PSI, 2010)= <2)

4.1.4 Total suspended solid (TSS)

Total suspended solid was 5.6±0.9 mg/l at site 1, 109.1± 14.5 mg/l at site 2, 102.5±9.7 mg/l at site 3, 81.1±5.5 mg/l at site 4.

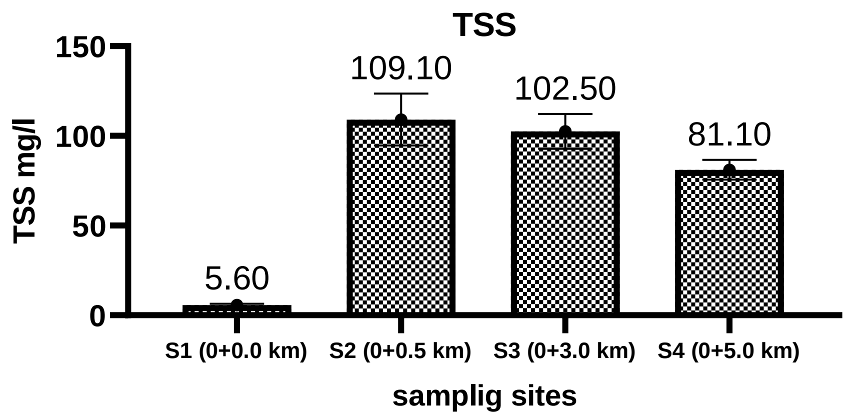

Figure 11: Total suspended solid in water along the Wadi Zomer.

TSS varied significantly and ranged from 5.6±0.9 mg/l to 109.1± 14.5 mg/l (Fig. 12). TSS level were generally above the PVL standards (PSI, 227/2010) permissible limits (60 mg/l) except site 1.

A promising result were shown between TSS and temperature, TSS and dissolved oxygen, since as shown in Table 2. There is a significant correlation between both parameters and TSS, in which a moderate significant decrease and a kind of negative correlation was between TSS and temperature (R= -0.522), and a positive correlation which was moderate significant increase between TSS and dissolved oxygen (R=0.447). This high significant increase results from the illegal leak of additional pollution loads from the tributaries located between the river sections that enter the river stream downstream (Zubaidah., 2019).

4.1.5 Ammonium-N (NH_4-N) and Nitrate-N (NO_3-N)

Ammonium was 8.2±1.02 mg/l at site 1, 28.1±1.95 mg/l at site 2, 21.3±1.97 mg/l at site 3, 16.5±1.07 mg/l at site 4 (Table 4). Ammonium was elevated in all site above the limits of PVL 227 (PSI, 2010) which was 5 mg/l.

Nitrate was 0.24±0.06 mg/l at site 1, 0.13±0.01 mg/l at site 2, 0.19±0.01 mg/l at site 3, 0.49±0.02 mg/l at site 4 (Table 4.1). Nitrate was reduced in all site below the limits of PVL 227 (PSI, 2010) which was 50 mg/l. Ammonium and nitrate concentrations significantly changed along the length of the Zomer stream (Fig. 13).

Similar results were reported by Chen et al., (2009), who studied a study case on a river receiving effluent rich-organic matter, where a nitrification process (ammonia oxidation to nitrite and ultimately to nitrate) was noticed with improved nitrogen removal.

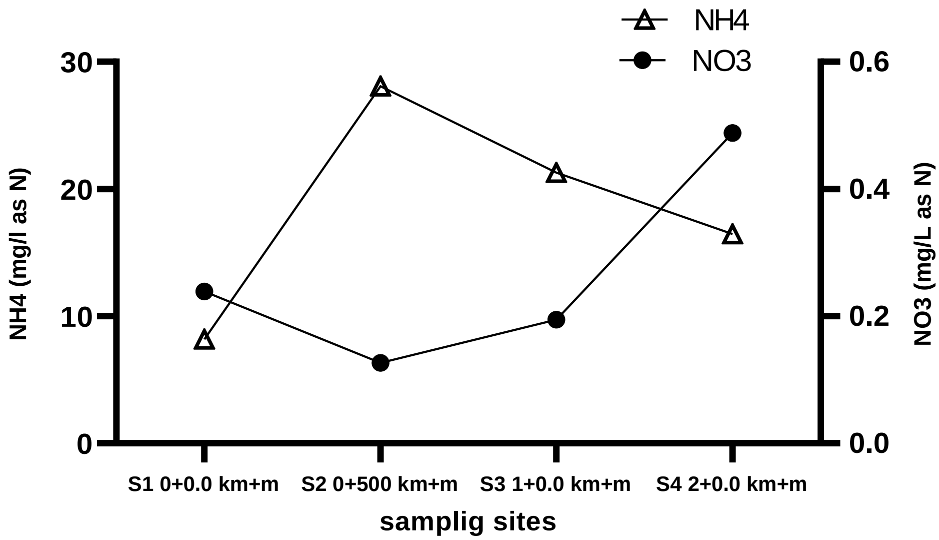

Figure 12: Ammonium and Nitrate in water along the Wadi Zomer.

A previous study confirms that nitrates are less as they move downstream, and this is due to the influence of biological, chemical and physical processes. In some cases, nitrates increase due to evaporation or lack of dilution during the flow downstream (Hur et al. (2007). Ammonium values decrease as downstream movement (Chen et al., 2009)

4.1.6 Total Phosphorus (TP)

Total phosphorus is a measure of organic and inorganic forms of phosphorus. Phosphorus can be present as particulate matter or dissolved. It is important as a plant nutrient.

Total phosphorus was 4.9±0.2 mg/l at site 1, 6.2±0.3 mg/l at site 2, 5.6±0.3 mg/l at site 3, 6.3±0.2 mg/l at site 4 (Table 4). In all site TP mg/l were considered normal and ranged from 4.9-6.2 mg/l. TP levels were generally below the PVL 227 (PSI, 2010) permissible limits (15 mg/l) at all sampling sites.

Phosphorus enter the water from human activities and animal waste, wastes from industrial processes and fertilizer runoff from agricultural lands. (Mosley, 2004). In our study the TP in all sites was considered normal because usually phosphate is obtained from different organic source in which high amount of P leads to large amount of oxygen which result into death of aquatic organisms. This explains that low levels of total phosphorus observed along the Zomer stream is due to plants and algae which ware observed along the stream and was dependent on the presence P concentration.

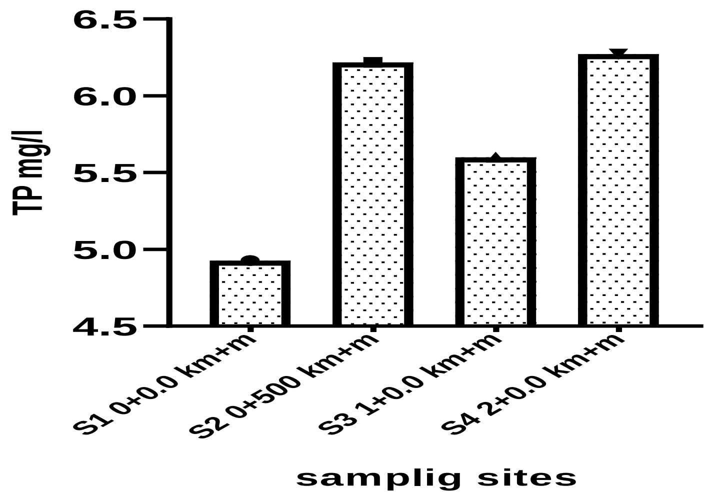

Figure 13: Total Phosphorus in water along the Wadi Zomer.

PVL 227 (PSI, 2010) = 15 mg/l

4.1.7 Electrical conductivity

The electrical conductivity (EC) is the measure of how much salts are dissolved in water. According to Mosley et al., (2004), a water sample with high ionic strength reflects higher EC values. (Fig. 15) shows little variations in the EC values as follows: 1407.3±26.8 µS/cm at site 1, 1595.3±27.4 µS/cm at site 2, 1508.6±21.7 µS/cm at site 3 and 1508.7±33.2 µS/cm at site 4.

Our result are in agreement with Koushik and Saksena (1999), where high value for EC was measured in the water sample taken from site 2 (1595.3±27.4 µS/cm). The high dissolved solids originates from diverse chemical substances used as preservatives or additives in the food processing industry. In other sites, where high EC values are measured may be due to discharge of nitrogen rich wastewater. Koushik and Saksena (1999) reported that nitrification process may responsible for high EC values.

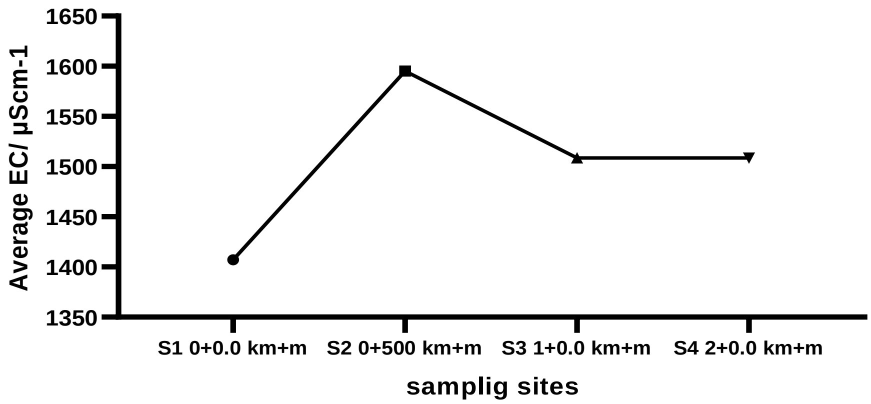

Figure 14: Electrical conductivity of water along the Wadi Zomer.

4.1.8 Biochemical Oxygen Demand (BOD_5)

The biological oxygen demand (BOD_5) is a biochemical process that measures the amount of dissolved oxygen consumed by bacteria, which have the capacity to oxidize organic pollutants under aerobic condition at a given temperature and time (e.g. five days).

Figure (16) shows the Bio-Oxygen Demand (BOD) along strem sites. BOD was 6.6±0.7 mg/l at site 1, 57.6±11.4 mg/l at site 2, 437.1±300.8 mg/l at site 3, 333.9±233.7 mg/l at site 4 (Table 4).

BOD varied significantly along sampling sites and ranged from 6.6 to 333.9 mg/l. The study revealed that the water in site 1 and site 2 had BOD levels below PVL 227 (PSI, 2010) and that site 3 and site 4 had BOD levels (437.1±300.80), (333.9±233.70) mg/l respectively, above the maximum permissible limits given by the PVL 227.

High values of BOD exceeding PVL 227 (PSI, 2010) standards were also observed in effluents from site 3 and site 4. The highest value of BOD was recorded at site 3 indicating the discharge of organic rich industrial discharges, which could be from industry olive mills or the slaughterhouse.

The low levels of BOD at sites 1, and 2 could be due to effective treatment at NWSTP and natural purification systems along the Zomer stream. Also, compared with site 3 and site 4, discharge of raw or partially treated sewage from industries along Wadi Zomer could be behind higher BOD values.

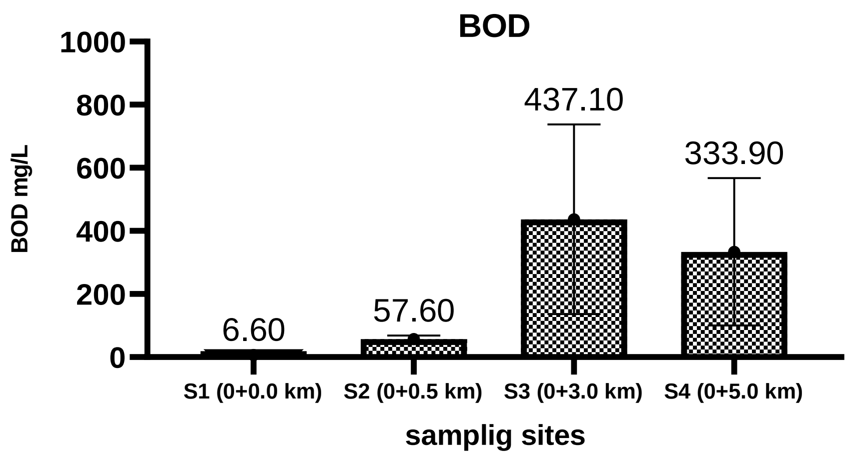

Figure 15: BOD_5 in water along the Wadi Zomer.

PVL 227 Standards (PSI, 2010) = 60 mg/l

4.1.9 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is a measure for estimating how much oxygen consume by water during the decomposition of organic matter would be depleted from a body of receiving water. COD measurements are performed in wastewater samples flowing into valleys or natural waters contaminated with domestic, industrial, and agricultural waste.

COD was 24.8±3.6 mg/l at site 1, 122.2±24.2 mg/l at site 2, 899.7±605.9 mg/l at site 3, 708.1±511.1 mg/l at site 4 (Table 4) COD varied significantly along sampling and ranged from 24.8±3.58 to 899.7±605.93 mg/l (Fig 17).

High concentrations of COD above PVL 227 (PSI, 2010) standards were recorded at all sites except site 1 and site 2 indicating a heavy load of organic and inorganic pollution that require more oxygen to oxidize under increased thermal conditions (Koushik and Saksena, 1999).

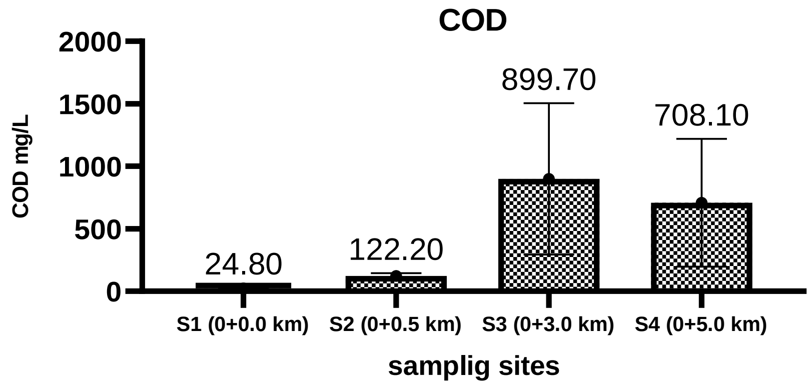

Figure 16: COD along the Wadi Zomer.

PVL 227 Standards (PSI, 2010) = 150 mg/l

4.2 Heavy Metals in water

4.2.1 Zink (Zn)

Zinc can enter the environment from both natural processes (e.g. weathering and erosion) and anthropogenic (e.g. zinc production, waste incineration, urban runoff) processes. Zinc is an essential trace element required by most organisms for their growth and development. It is found in most natural waters at low concentrations.

Zinc was 0.9±0.8 mg/l at site 0.2±0.04 mg/l at site 2, 0.3±0.03 mg/l at site 3, 0.12±0.02mg/l at site 4 (Fig. 18).

Zink was generally considered normal in which the maximum permissible limits for PVL 227 (PSI, 2010) standard of 2 mg/l at all sampling sites.

4.2.2 Iron (Fe)

Iron is an essential trace element for both plants and animals, required by most organisms for essential growth and development, and iron deficiency could cause adverse biological effects.

Iron is the fourth most abundant element in the Earth's crust and may be present in natural waters in varying quantities depending up on the geology of the area and other chemical components of the waterway. Although other forms may be present in organic and inorganic wastewater streams. In surface waters, iron is generally present in the ferric state.

Iron was 0.2±0.1 mg/l at site 1.8±0.2 mg/l at site 2, 4±0.6 mg/l at site 3, 1.6±0.2 mg/l at site 4 (Fig. 18).

Iron was generally below the maximum permissible limits for PVL 227 (PSI, 2010) standard of 5 mg/l at all sampling sites.

4.2.3 Copper (Cu)

Copper is essential for animal and plant nutrition. Very major limits in copper concentrations cause liver and copper damage that is highly toxic to most forms of aquatic life with low concentrations.

Copper was 0.14±0.002 mg/l at site 0.12±0.002 mg/l at site 2, 0.1±0.004 mg/l at site 3, 0.07±0.005 mg/l at site 4 (Fig. 18).

Copper was generally below the maximum permissible limits for PVL 227 (PSI, 2010) standard of 1.5 mg/l at all sampling sites. The observed low levels of copper along the stream are attributable to the natural purification processes within the stream and this is consistent with the results of Muwanga and Barifaijo (2006) and it is in agreement with our results.

4.2.4 Lead (Pb)

Lead is a toxic element and has the potential to accumulate in body structures. The toxic effects of lead decreases with increasing water hardness and dissolved oxygen. Lead was 0.15±0.005mg/l at site 0.06±0.01 mg/l at site 2, 0.06±0.01 mg/l at site 3, 0.04±0.005 mg/l at site 4 (Fig. 18). Lead was generally below the maximum permissible limits for PVL 227 (PSI, 2010) standard of 0.2 mg/l at all sampling sites.

4.2.5 Nickle (Ni)

Nickel is one of the widely available chemical elements on Earth's surface. Nickel is released into the environment by power plants, metal factories, waste incinerators and WWTP. nickel is commonly used in agricultural fertilizers, and leaks into the groundwater from farm runoff, and the human body contains about 10 mg of nickel.

Nickle was 0.2±0.009 mg/l at site 1, 0.3±0.01 mg/l at site 2, 0.3±0.02 mg/l at site 3, 0.1±0.01 mg/l at site 4 (Fig. 18).

Nickle was below the maximum permissible limits for PVL 227 (PSI, 2010) standard of 0.2 mg/l at site 1 and site 2. High levels of Nickle exceeding PVL limits were recorded at site 2 and site 3. The highest value of Ni was recorded at site 3 (0.3±0.02 mg/l).

4.2.6 Chromium (Cr)

Chromium is widely distributed in the earth's crust. Soils and rocks can contain small amounts of chromium. Where chromium and its salts are used in the leather tanning industry, paints, fungicides, and ceramic and glass industries.

Chromium was 0.14±0.005 mg/l at site 1, 0.22±0.01 mg/l at site 2, 0.08±0.02 mg/l at site 3, 0.04±0.01 mg/l at site 4 (Fig. 18).

Chromium was below the maximum permissible limits for standard of 0.1 mg/l at site 3 and site 4. High levels of Chromium exceeding PVL limits were recorded at site 2.

A similar study by Begum and Harikrishna (2008) entitled ‘Study on the Quality of Water in Some Streams of Cauvery River’, recorded very low levels of Chromium.

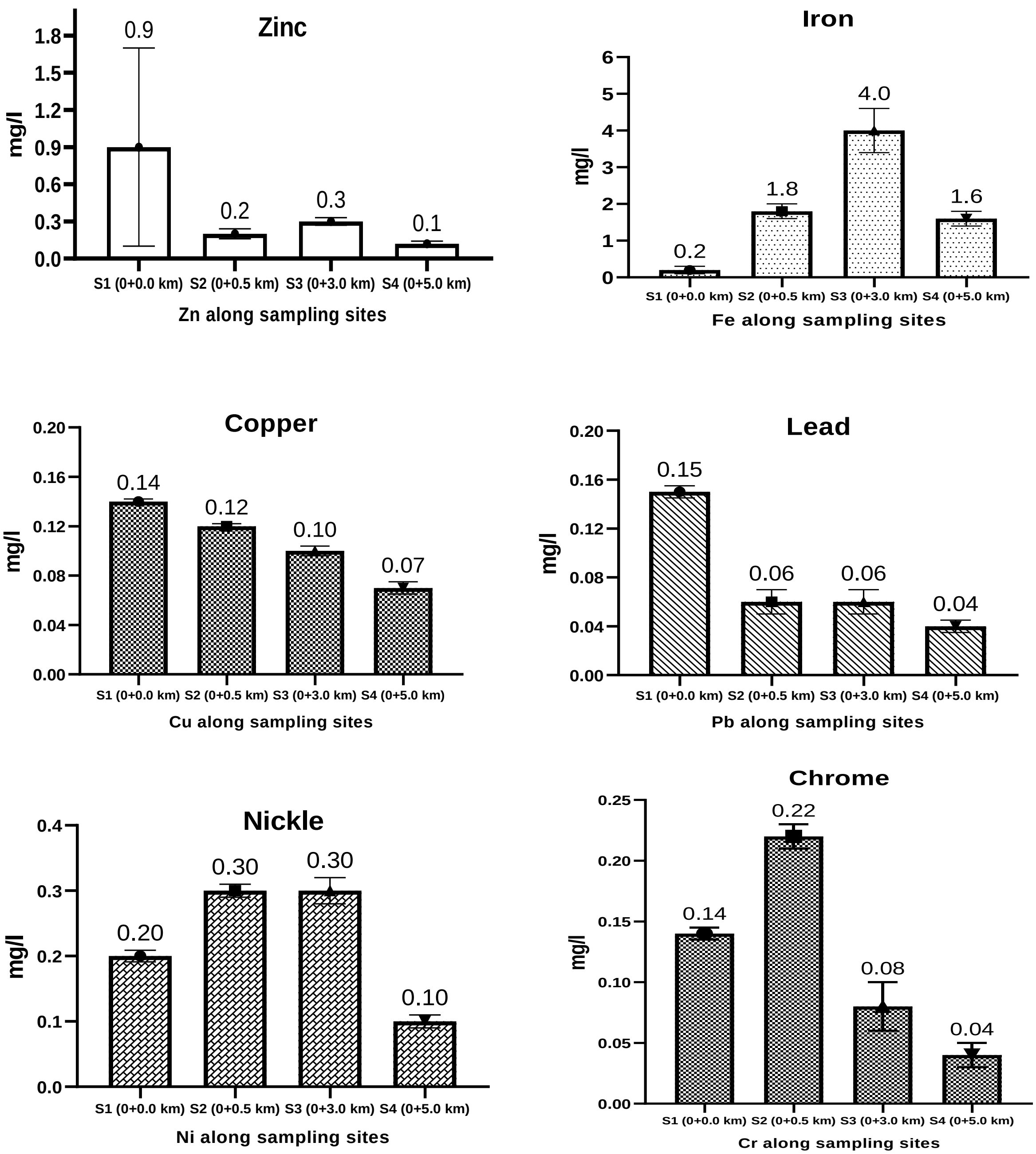

Figure 17: Heavy metals in water along the Wadi Zomer.

Table 4: Mean ± SD for parameter measured in water samples at all sites*)

Parameter/Site	Site 1 (0+0.0 km)	Site 2 (0+0.5 km)	Site 3 (0+3.0 km)	Site 4 (0+5.0 km)	PVL227 (PSI, 2010)
pH	7.61±0.05	7.4±0.05	7.23±.0.05	7.24±0.05	6-9
T	20.9± 0.7	21.2± 0.7	21.3± 0.7	21.4±0.7	-
DO	0.02±.0.01	1.3±.0.12	2.1±0.19	3.3±0.23	<2
TSS	5.6±0.9	109.1± 14.5	102.5±9.7	81.1±5.5	60
NH_4_N	8.2±1.02	28.1±1.95	21.3±1.97	16.5±1.07	5
NO_3_N	0.24±0.06	0.13±0.01	0.19±0.01	0.49±0.02	50
Total-P	4.9±0.2	6.2±0.3	5.6±0.3	6.3±0.2	15-20
EC (µS/cm)	1407.3±26.8	1595.3±27.4	1508.6±21.7	1508.7±33.2	-
COD	24.8±3.6	122.2±24.2	899.7±605.9	708.1±511.1	150
BOD	6.6±0.7	57.6±11.4	437.1±300.8	333.9±233.7	60
Zn	0.9±0.8	0.2±0.04	0.3±.0.03	0.12±0.02	2
Fe	0.2±0.1	1.8±0.2	4±0.6	1.6±0.2	5
Cu	0.14±0.002	0.12±0.002	0.1±0.004	0.07±0.005	0.2
Pb	0.15±0.005	0.06±0.01	0.06±0.01	0.04±0.005	0.2
Ni	0.2±0.009	0.3±0.01	0.3±0.02	0.1±0.01	0.2
Cr	0.14±0.005	0.22±0.01	0.08±0.02	0.04±0.01	0.1

PLV: Palestinian values limit (PSI, 2010)   *) All units are in mg/l, otherwise stated.

4.3 Heavy metals in stream sediment

The results in Table 5 show that the highest value was found in the sediment for iron (Fe) was 6687 mg/kg and the lowest value (10.5 mg/kg) for nickel (Ni). The concentration of zinc, copper, and chrome were at levels of 293.1 mg/kg, 1384.7 mg/kg, and 52.7 mg/kg, respectively. The lead (Pb) content was below the detection limit (BDL) when compared to the blank control (3.6 mg/kg).

Table 5: Concentrations of heavy metals in sediment

Metals	Zn ppm	Fe ppm	Cu ppm	Pb ppm	Ni ppm	Cr ppm
Sediment	293.13	6687	1384.77	BDL	10.53	52.77
Control	21.16	16.81	8.99	3.60	16.92	25.05

In comparison with the control site, the concentrations of heavy metals in table (5) are all heavy metals of the control sample were less than the study sample.

Sediment: Fe>Cu Zn>Cr >Ni

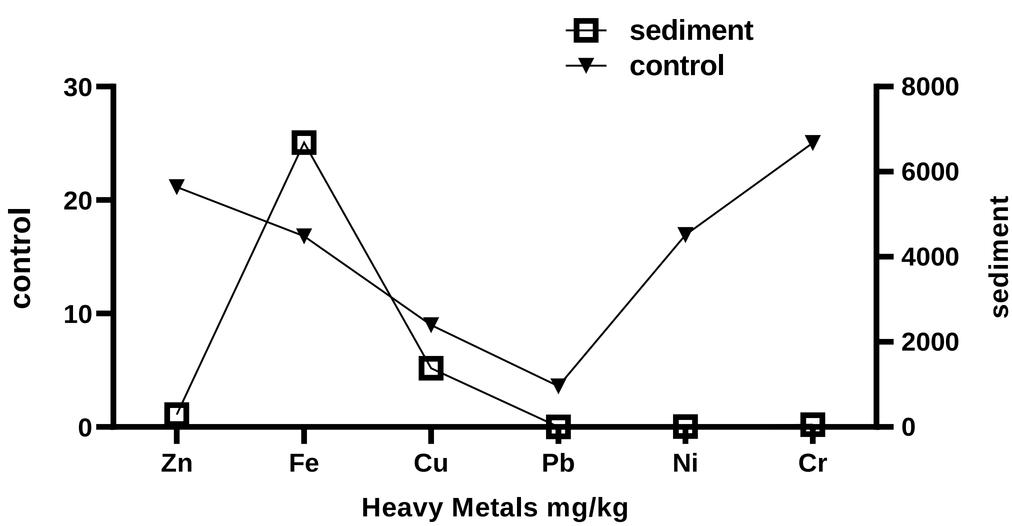

Figure 18: The concentration of heavy metals in sediment.

Anthropogenic activities have a negative impact on the environment, because they can release a diversity of pollutants including heavy metals through point sources. Man-made activities reflected in industrial and agrifood industrial activities could release heavy metals in wastewater (Qian et al., 2015). Lu et al., (2014) reported on heavy metals pollution in rivers from non-point sources.

The heavy metals can be considered the results of industrial and from the outputs of agricultural manufacturing. The heavy metals Cu, Ni, and Zn are important elements in the manufacture of agricultural products and are also sourced from domestic pollution and animal husbandry sites (Bi et al., 2011). A recent study by Khan et al., (2020) found that Cr in the sediment sample was 70 mg/kg compared to our result that was 52.7 mg/kg and Zinc is found 780 mg/kg compared to our result that was 293.1 mg/kg.

Gao et al. (2016), results showed the highest value of Zn 388 mg/kg, Cu 108 mg/kg, Cr 99.7 mg/kg, Ni 82.9 and Pb 54.7 mg/kg. The researcher also confirmed that progress in the distance along the river showed high levels of heavy elements. The first higher in concentration during this study which was Iron (6687 mg/kg) was almost same of that recorded in sediments of SUEZ GULF (7497 mg/kg) (Nemr et al., 2006).

Most of the research did not find a significant increase of copper compared with the result that we have. Copper (Cu), which is regarded as a serious pollutant of aquatic ecosystems, was the second higher in concentration during this study. Nickel is a common pollutant resulting from various industrial activities like production of Ni-Cd batteries, waste incineration, and domestic wastewater. Ni concentrations (10.5 mg/kg), which indicated a presence of Ni contamination in Wadi Zomer. Table 6 shows a comparison.

Table 6: Heavy metals concentration (mg/kg) compared with published literature data.

Site	Cu	Pb	Zn	Cr	Ni	Fe	Sources
Odiel River	607	2369	2874	54.7	29.7	31862	(Bermejo et al., 2003)
Haihe River	28.52	25.20	84	57.55	32.71	29500	(Feng et al., 2011)
Yangtze River	30.7	27.3	94	78.9	31.8	33.394	(Zhang et al., 2009)
Suez Gulf	33.2	70.44	159.4	32.04	71.44	2239.9	(Nemr et al., 2006)
Our study	1384.7	ND[*)]	293.1	52.7	10.5	6687	This study

[*)] ND: not detected

4.4 Heavy Metal in vegetation

The results shown in (Fig. 20) that the highest value was found in the plant leaf are iron (Fe) 326.3 mg/kg and that the lowest value is for nickel (Ni) 6.7 mg/kg, and the concentrations for zinc, copper, and chrome were at levels of 80.3 mg/kg, 12.5 mg/kg, 51 mg/kg, respectively, except that the lead (Pb) metals was below detection limits.

Table 7: Concentrations of Heavy Metal in both control and plant leaves (*P. australis)*

Heavy Metals	Plant leaf (mg/kg)	Control (mg/kg)
Zn	80.3	50.6
Fe	326.3	210.3
Cu	12.5	10.1
Pb	BDL	BDL
Ni	6.7	22.6
Cr	51	23.1

P. *Australis* (leaf): Fe>Zn>Cr>Cu>Ni>Pb

In comparison to heavy metals contents in leaves from vegetation grown along Wadi Zomer, concentrations of heavy metals in control sample were less those leaves from *P. australis* in Wadi Zomer sample (Table 5).

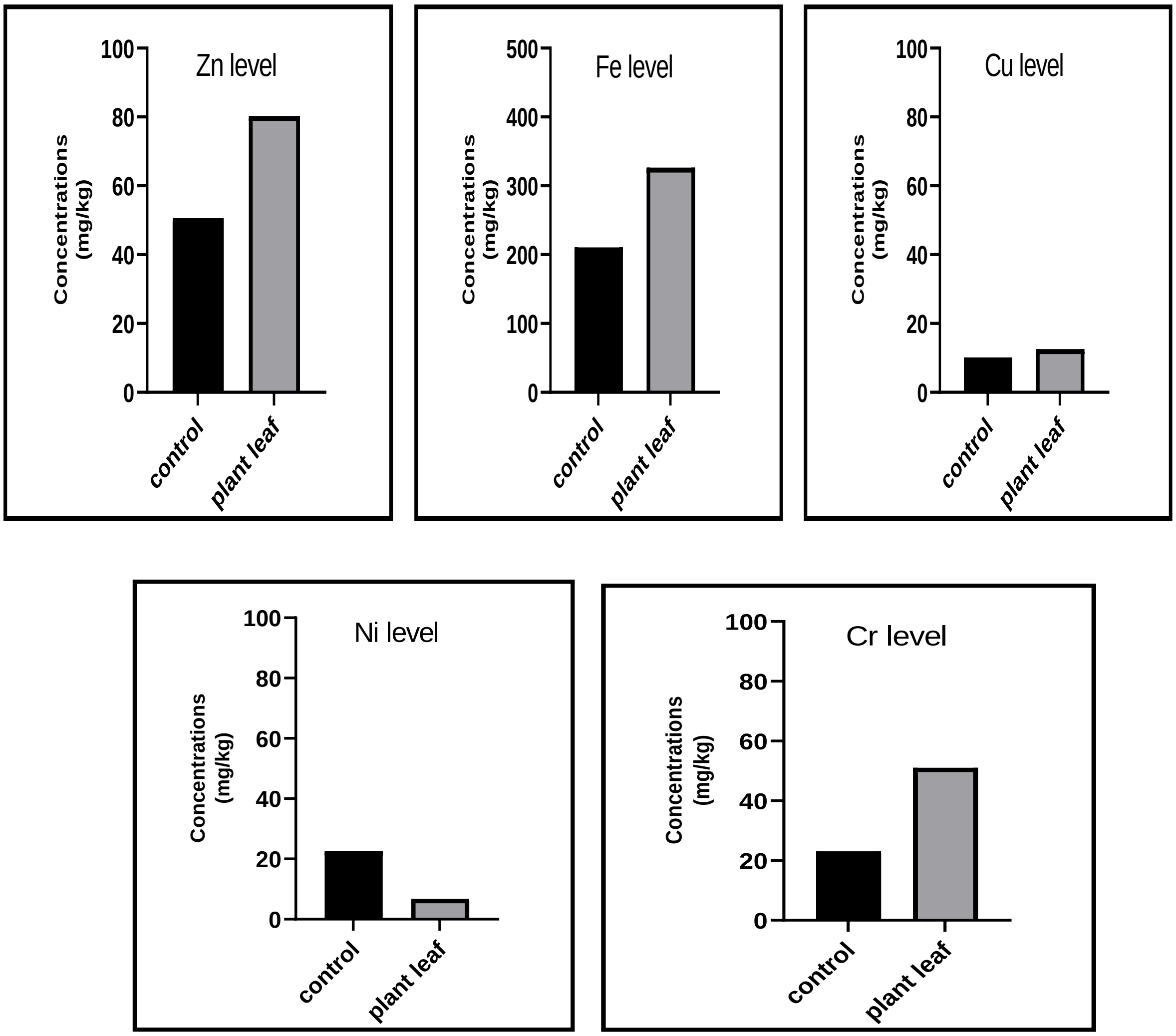

Figure 19: Concentration of Heavy Metals level in Both Control and Plant Leaf (*P. australis)*

The results shown in (Fig. 21) shows that the highest value was found in the plant stem are iron (Fe) 435.1 mg/kg and the lowest value for chrome (Cr)1.6 mg/kg, and the ratio of Zinc, Copper, Nickle, and Lead were at levels of 73.3 mg/kg, 11.9 mg/kg, 6.4 mg/kg, 4.9 mg/kg respectively, the metal of lead was not present in the leaf, but present in the stems with a ratio of 4.9.

Table 8: Concentrations of heavy metals in both control and plant stem (*P. australis*)

Heavy Metals	Plant stem (mg/kg)	Control (mg/kg)
Zn	73.3	62.4
Fe	435.1	96.4
Cu	11.9	8.4
Pb	4.9	BDL
Ni	6.4	4.5
Cr	1.6	2.7

P.australis (stem): Fe>Zn>Cu>Ni>Pb>Cr

In comparison with the plant control concentrations of heavy metals in table (8), all heavy metals of the control sample were less than the study sample, except the chrome.

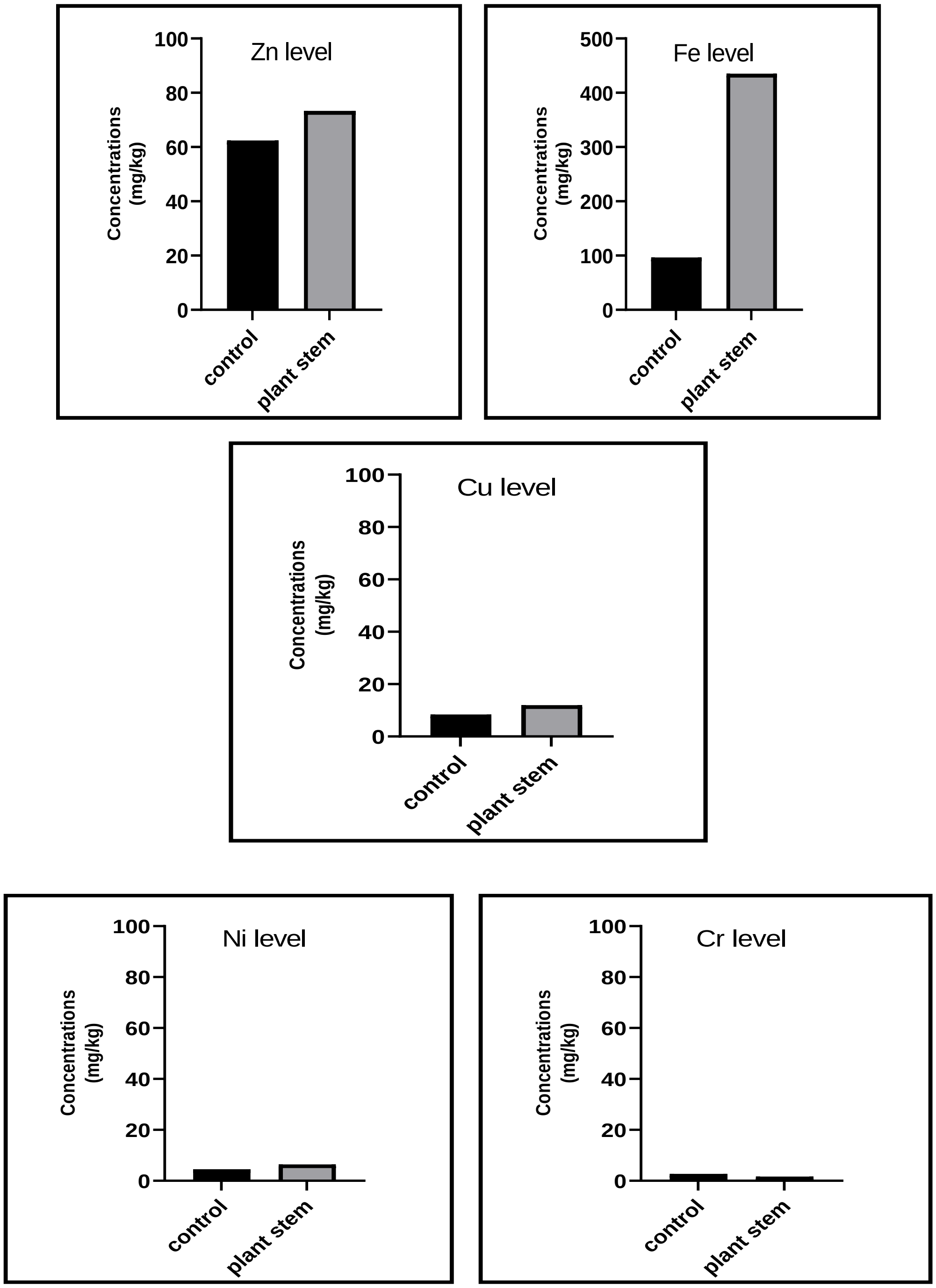

Figure 20: Concentration of Heavy Metals level in Both Control and Plant stem (*P. australis*)

The results shown below in (Fig. 22) that the highest value was found in the plant root are iron (Fe) 21654 mg/kg and the lowest value for lead (Pb) 6.6 mg/kg. The concentration of zinc, copper, chrome and nickel in the roots were recorded as 127 mg/kg, 30.3 mg/kg, 22.4 mg/kg respectively.

Table 9: Concentrations of Heavy Metal in both control and plant root (*P. australis)*

Heavy Metals	Plant root (mg/kg)	Control (mg/kg)
Zn	127	101
Fe	21654	3210
Cu	30.3	20.6
Pb	6.6	7
Ni	22.4	14.1
Cr	24.4	19

In comparison with the plant control concentrations of heavy metals in table (9), all heavy metals of the control sample were less than the study sample, except the lead.

P. Australis (root): Fe> Zn> Cu> Cr> Ni>Pb

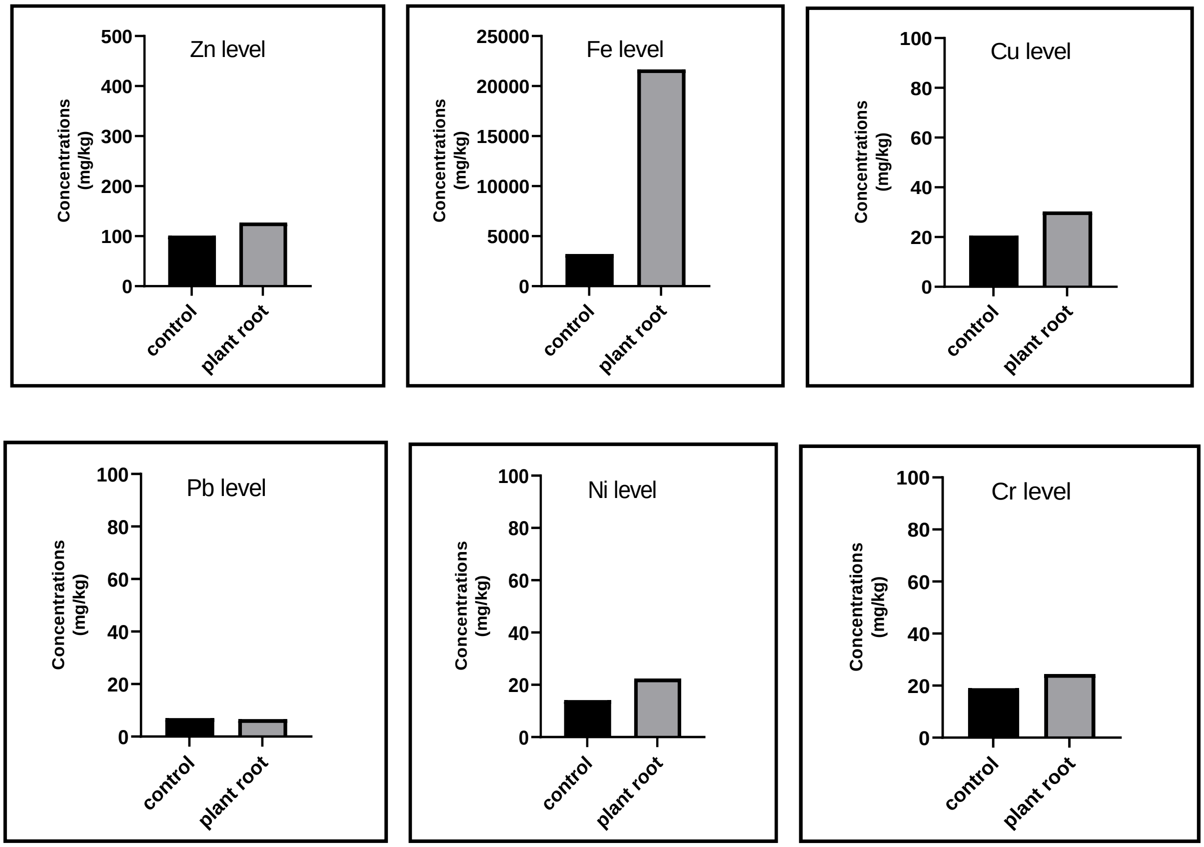

Figure 21: Concentration of Heavy Metals level in Both Control and Plant root (*P. australis)*

Metal uptake by plants can be affected by numerous variables including soil pH, cation capacity, clay substance, organic matter substance and the presence of other ions (Kabata-Pendias, 2001).

P. australis are for the most part impacted more by metals in sediment than by those ones in water, subsequently, bioaccumulation is more noteworthy when sediments are contaminated. We found the highest concentration in root except chrome. The highest concentrations were found in Fe, Zn in root. Moreover, the concentration of trace metals was high in the roots than in the aerial parts (Shahid et al., 2020). For assessment of contaminants (lead, nickel) in the plant our results reveals that it is accumulated more heavy metals in roots (Bello et al., 2018).

Previous study measurements indicate a gradual accumulation of trace metals in the roots of *P. australis* during the seasonal cycle (Baldantoni et al., 2009). In addition to previous studies reported that wetland plants have more capability of accumulate heavy metals in roots (Bragato et al., 2006).

All the plant organ displayed strong abilities to accumulate heavy metals in their roots and stems whereas large accumulation was found in the roots. Here ready to contend that more bioaccumulation inside roots might have moreover constrained the metal transfer to the aboveground plant tissues as established earlier (Karami et al., 2011).

A few works report higher accumulation of metals within the belowground parts of plants than within the aerial parts leaf and stem. The researcher conducted a study on the accumulation of heavy metals in plant parts and the results showed a high accumulation of (zinc and copper) in the roots (Stoltz & Greger, 2002).

In our research, the roots showed a high accumulation of heavy metals, which is due to sediment. According to Sawidis et al. (1995), roots of *P. australis* can accumulate awesome amount of overwhelming metals because of the cortex parenchyma with intercellular air spaces.

Fe in all plants organ was translocated from roots to stems, but the accumulation of roots remained higher. By contrast, results with high translocation of Fe in the shoot have also been previously reported but in different plant types (Ji et al., 2018).

Zn plays an important role in the environment and can revitalize the most prominent role in plant nutrition and enzymatic activities. The concentration value that detected in stems and leaves were in agreement with various authors (Windham, Weis, & Weis, 2003). Zn concentrations in all plant organs were significantly below the phytotoxic range of 500–1500 mg/kg (Chaney, 1989).

Search results showed zinc concentration was around 70.2 mg/kg compared to our research results 80.3 mg/kg that use *Phragmites australis* for land fill leach at treatment (Peverly et al,. 1995).

Research results for another researcher showed that the concentration of zinc in the leaf reached 79.03 mg/kg compared to the search result that we reached 80.3 mg/kg (Windham et al, 2003).

Cu plays an vital role in plant sustenance at low concentrations but becomes harmful at higher levels (Fairbrotheretal., 2007). However, Cu concentrations in all plant were below the phytotoxic range of 25–40 mg/kg (Chaney, 1989).

A recent study showed the removal of plant leaf from the copper element 12 mg/kg when constructed wetlands receiving river water contaminated by confined swine operations compared to the research result that we reached 12.5 mg/kg (Yeh et al,. 2009).

Swedish examination uncovered that copper and zinc were taken by plants with the most noteworthy aggregation found within the roots (Tam & Wong, 1996).

Pb is immobile in soil and tends to accumulate in roots (Carranza-Álvarezetal., 2008). Pb concentrations found in this study were higher than values reported by various author, especially as regards stem (Phillips et al., 2015).

Pb leaf concentrations were below the detection limit of the analytical instrument used. Danube Delta, Romania in 1993 and 1994 investigated patterns of spatial variability in trace metal concentrations in tissues of Phragmites australis they found Pb in leaf were 0.2 mg/kg (Keller et al,. 1998).

Compared to the results of our study that was below detection limit, the highest value was for the presence of lead in plant leaves 31-50 mg/kg with a purification and removal rate of 64-81% (Samecka-Cymerman,. 2004).

Ni is toxic effects on plants. The values of bioaccumulation in the plant organs agree with author (Laing et al., 2009). Nickle concentrations in leaf of (Phragmites australis) in the Scheldt estuary was 0.5-5.8 mg/kg and the differences between our studies might be related to pollution levels and physic-chemical sediment, water or sediments characteristics at the sampling sites (Laing et al., 2009).

For treating domestic wastewater in Belgium, Metal concentrations in the stems for Nickle was 0.52 compared with our result was 6.4 mg/kg, and the chrome for our result was 1.6 mg/kg compared the 1.3 mg/kg for the researcher (Lesage et al,. 2007).

The plant organs in this study showed toxic levels of chrome, Cr is a toxic for plants. According to Allen (1989), Cr concentrations greater than 0.5 mg/kg are toxic to plants. In this study, all of plant organ parts showed Cr values above the phytotoxic threshold. Cr concentrations in roots were comparable with data found in other studies showed the concentrations of aerial parts and rhizomes are in agreement with (Vymazal and Březinová, 2014).

A study of patterns of accumulation in the parts of the plant of heavy elements was the result of the accumulation of Zn in the stems 26.6 mg/kg as the lowest value and the highest value was 75.3 mg/kg. The result was close to the research result that we reached 73.3 mg/kg, and when compared the result of copper with our result 11.9 mg/kg we can show the lowest value 1.6 mg/kg and the highest 19.2 mg/kg (Windham et al,. 2003).

Chapter Five –Conclusion and Recommendation

5.1 Conclusions

This study was undertaken to investigate the efficacy of phytoremediation using natural wetlands in Nablus West watershed to improve the water quality along Wadi Zomer flow course. It entails the collection of water, sediment and vegetation samples over time at various sampling sites and analyses of the samples for diverse physical, chemical and biological water quality parameters.

According to the findings of this study, the industrial wastewater that is discharged to the wastewater treatment plant or illegally leaked into Wadi Zomer contains many organic and inorganic pollutants and a rise in the percentage of heavy metals.

- The natural wetlands (NW) proved an efficient role in phytoextraction of organic carbon and selective heavy metals, thus improved the water quality of Wadi Zomer.
- The highest percentage of heavy metals was iron in all parts of the study.
- The efficacy of self-purification capacity of natural wetlands was not severely impacted by the present pollution loads.
- The occasional uncontrolled illicit industrial discharges along the Wadi course and the occasional sewer overflows under emergency events at NWSTP have impaired the water quality at Station S2 (0+0.5 km) and Station S4 (0+2.0 km).

5.2 Recommendations

The results obtained in this study are short-term, further research studies should address the long-term impacts on the accumulation potential of heavy metals in the soil and the vegetation along the water course of Wadi Zomer.

- Develop and endorse effective water quality management in agrifood industries within the catchment of Wadi Zomer, and avoid the discharge of combined sewer overflows.
- Enforce effective national water quality monitoring on industrial and sewage works outlets along Wadi Zomer. Water quality monitoring should include emergent chemicals and bio-indicators pertaining to water-borne disease including viruses.

- Develop local and regional rehabilitation programs for heavily polluted small Wadis/streams, Wadi Zomer as a pilot case study. Modelling of the interface between of the surface/groundwater and the water quality will help achieve an effective water quality monitoring.
- Use of the principal component analysis is necessary to evaluate the effectiveness of surface water quality monitoring in major Palestinian small Wadis/streams, and considering the establishment of stationary monitoring stations.

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ANNEXS

Annex (A): Industrial treated wastewater

المياه العادمة الصناعية المعالجة

Industrial treated wastewater

م م ف 227

1- المجال

تختص هذه المواصفة بتحديد الاشتراطات والمتطلبات والقيود المفروضة على تصريف المياه العادمة الصناعية المعالجة، الخارجة من المنشآت الصناعية أو محطات المعالجة التابعة لها ، إلى السيول أو الأودية أو الأنهار أو ربطها على شبكة المجاري العامة أو المسطحات المائية، أو إعادة استعمالها لأغراض الري أو أية أغراض أخرى حسب ما هو وارد في هذه المواصفة.

2 - المراجع التكميلية

الوثائق المرجعية التالية لا يمكن الاستغناء عنها لتطبيق هذه الوثيقة ، في حالة الإحالة المؤرخة تطبق الطبعة المذكورة أدناه (متضمنة أي تعديلات) ، علماً بأن مكتبة مؤسسة المواصفات والمقاييس تحتوي على فهارس للمواصفات السارية المفعول في الوقت الحاضر .

- كتاب " الطرق القياسية لفحص المياه والمياه العادمة " الصادر عن الجمعية الأمريكية للصحة العامة والجمعية الأمريكية للمياه ، وتعديلاته .
- مواصفة وكالة حماية البيئة الأمريكية .

3- المصطلحات والتعاريف

لأغراض هذه المواصفة تستخدم المصطلحات والتعاريف الواردة أدناه :

3-1 المنشأة الصناعية (المشروع الصناعي)

أي منشأه يكون غرضها الأساسي تحويل الخامات إلى منتجات نمطيه كاملة الصنع أو نصف مصنعة أو تحويل المنتجات شبه المصنعة إلى منتجات نمطيه كاملة الصنع بما فيها أعمال المزج و الفصل و التشكيل و التجميع والتعبئة و التغليف ، شريطة أن تتم أو معظم هذه العمليات بقوة آليه، بما فيها الصناعات المعرفية والبيئية.

3-2 الصناعات المعرفية: هي الصناعات التي تقوم على أساس الأفكار و المعلومات و البرمجيات و الابتكار و التجارب و الدراسات و الأبحاث العلمية القابلة للاستثمار .

3-3 المياه العادمة

المياه الملوثة بفعل تأثير مواد صلبة أو سائلة أو غازية أو طاقة بكافة أنواعها أو كائنات دقيقة نتجت أو تخلفت عن المنازل أو المباني أو المنشآت المختلفة.

3-4 المياه العادمة الصناعية

المياه الناتجة من استعمال المياه في كل أو بعض مراحل التصنيع أو التنظيف أو التبريد أو غيرها، و/أو تحتاج لمعالجة وتكون مطابقة لمتطلبات هذه المواصفة.

3-5 المياه العادمة الصناعية المعالجة

هي المياه العادمة الصناعية التي تم معالجتها وتكون مطابقة لهذه المواصفة وفقاً للطرق المتبعة.

3-6 المواد الخطرة

المواد أو مركبات المواد ذات الخواص الخطرة التي تشكل ضرراً على البيئة، مثل المواد السامة، والمواد المشعة، والمواد المعدية بيولوجيا أو المواد القابلة للانفجار أو الاشتعال.

3-7 النفايات الخطرة

مخلفات الأنشطة والعمليات المختلفة أو رمادها المحتفظة بخواص المواد الخطرة والتي ليس لها استخدامات تالية مثل النفايات النوية، والنفايات الطبية، والنفايات الناتجة عن تصنيع أي من المستحضرات الصيدلية و الأدوية أو المذيبات العضوية أو الأصباغ والدهانات أو غيرها من المواد الخطرة.

3-8 النفايات الصلبة

هي النفايات الناشئة من مختلف النشاطات المنزلية والتجارية و الزراعية والصناعية والعمرانية والرواسب الناتجة عن محطات معالجة المياه العادمة ولا تكون من النفايات الخطرة.

3-9 حرم المنشأة

المساحة الكلية المقام عليها المنشأة الصناعية والمباني التابعة لها.

3-10 وصلة المجاري الخاصة

المجري الذي يربط المجاري الخاصة (تجارية أو صناعية) بشبكة المجاري العامة.

3-11 المجري العام

المجري الذي يملكه ويشرف عليه مقدم الخدمات ويشمل حفر التفتيش و الوصلات وكافة التجهيزات التابعة له.

3-12 شبكة المجاري العامة

مجموعة من أجهزة الجمع و خطوط الأنابيب و الوصلات و المضخات مخصصة لصرف المياه العادمة، ويتم نقلها من موقع إنتاجها إلى محطة مقدم الخدمات لمعالجة المياه العادمة.

4- الاشتراطات و المتطلبات العامة

4-1 يجب أن تطابق المياه العادمة الصناعية المعالجة الخارجة من المنشآت الصناعية الخواص الموضحة في الجداول من 2 إلى 7 الواردة في هذه المواصفة ، وحسب الاستخدام النهائي المخطط له لمنع الإخلال بعناصر البيئة المختلفة .

4-2 يجب أن لا يعاد استخدام المياه العادمة الصناعية المعالجة لأغراض الري في المناطق ذات الحساسية العالية لتلوث مصادر المياه، أما في المناطق البعيدة عن مصدر المياه يتم الري حسب الجداول (6،7،8).

4-3 يجب أن يتم قياس وتحليل الخواص وفحصها كما هو وارد في كتاب "الطرق القياسية لفحص المياه والمياه العادمة " الصادرة عن الجمعية الأمريكية للصحة العامة والجمعية الأمريكية للمياه وتعديلاته أو أية طرق تحليل معتمدة أخرى إذا لم تتوفر في المرجع المشار إليه.

4-4 يمنع خلط المياه العادمة الصناعية المعالجة الخارجة من المنشآت الصناعية بمياه عذبة بقصد تخفيفها ومطابقتها للاشتراطات الواردة في هذه المواصفة.

5- الاشتراطات القياسية

تقسم المياه العادمة الصناعية المعالجة إلى أربعة أقسام حسب الاستخدام النهائي لها :

- المياه التي يتم طرحها إلى السيول والأودية والمسطحات المائية .
- المياه التي يتم إعادة استعمالها لأغراض الري .

- المياه التي يتم إعادة تدويرها في المنشأة الصناعية .
- المياه التي يتم ربطها مع شبكة الصرف الصحي.

6- النوع الأول – المياه التي يتم طرحها إلى السيول والأودية والمسطحات المائية

6-1 يسمح بطرح المياه العادمة الصناعية المعالجة إلى السيول والأودية أو المسطحات المائية شريطة تطابق نوعيتها مع متطلبات هذه المواصفة والخواص والمعايير الواردة في الجداول من 1 إلى 4 أو حسب ما تحدده الجهات المختصة مناسباً.

الجدول 1- خواص نوعية المياه العادمة الصناعية المعالجة التي يتم طرحها للسيول و الأودية والمسطحات المائية :

الخواص	الرمز	الحد الأعلى المسموح به	الوحدات
الاكسجين المستهلك حيوياً	BOD5	60	ملغم/لتر
الاكسجين المستهلك كيميائيا	COD	150	ملغم/لتر
الاكسجين المذاب	DO	لا يقل عن 2.0	ملغم/لتر
المواد العالقة الكلية	TSS	60	ملغم/لتر
الرقم الهيدروجيني	pH	6-9	وحدة
النترات	NO3	50	ملغم/لتر
النيتروجين الكلي*	T-N	60	ملغم/لتر
التغير في درجة حرارة المياه المستقبلة	T	6	م°
اللون	C	15	وحدة كوبالت
العكارة	NTU	5-10	وحدة عكارة نيفيلومترية
* فيما يخص تقييم محتوى المياه العادمة الصناعية المعالجة من النيتروجين الكلي، يستخدم المعدل الحسابي وبحيث لا يقل عدد العينات المشمولة في حسابه عن خمس.			

الجدول 2- الخواص الميكروبيولوجية للمياه العادمة الصناعية المعالجة التي يتم طرحها للسيول والأودية والمسطحات المائية

الخواص	الرمز	الحد المسموح به	وحدة القياس
الإيشيريشيا كولاي*	Escherichia coli	1000	العدد الأكثر احتمالا أو وحدة مكونة للمستعمرة/100مل
بيوض الديدان المعوية	Intestinal Eggs	≤1	بيضة لكل لتر
*1- يستخدم المعدل الهندسي لاحتساب نتائج عصيات القولون المقاومة للحرارة أو			

الإيشيريشيا كولاي عند تقييم نوعية المياه.
2- تعتبر نتائج فحص عصيات القولون المقاومة للحرارة بديلاً عن نتائج فحص الايشييريشيا كولاي عند عدم توفر الإمكانات الفنية اللازمة للفحص .

الجدول 3- الخواص الكيميائية والفيزيائية للمياه العادمة الصناعية المعالجة التي يتم طرحها للسيول والأودية والمسطحات المائية .

الخواص	الرمز	الحد الأعلى المسموح به ملغم/لتر
الزيوت والشحوم	FOG	5
الفينول	Phenol	0.002 >
المنظفات	MBAS	25
المواد الصلبة الذائبة الكلية	TDS	1500
الفوسفات - فسفور	PO_4-P	20-15
الكلورايد	CL	350
الكبريتات	SO_4	300
الأمونيوم	NH_4	5
البيكربونات	HCO_3	400
نسبة امتصاص الصوديوم	SAR	5.83
الكربون العضوي الكلي	TOC	55

الجدول 4- الحد الأعلى المسموح به من تركيز المعادن الثقيلة في المياه العادمة الصناعية المعالجة التي يتم طرحها للسيول والأودية والمسطحات المائية :

العنصر	الرمز	الحد الأعلى المسموح به ملغم/لتر
السيانيد	CN	0.05
الباريوم	Ba	1.0
الألمنيوم	AL	2
الزرنيخ	As	0.05
البيريليوم	Be	0.1
النحاس	Cu	0.2
الفلورايد	F	2
الحديد	Fe	5
الليثيوم	Li	2.5
المنغنيز	Mn	0.2
النيكل	Ni	0.2
الرصاص	Pb	0.2
السيلينيوم	Se	0.02
الكادميوم	Cd	0.01
الخارصين	Zn	2
الكروم الكلي	Cr	0.1
الزئبق	Hg	0.001
فاناديوم	V	0.1
الكوبالت	Co	0.05
البورون	B	0.7
الفضة	Ag	0.1

Annex (B): Correlation Coefficient R

	PH	T	DO mg/l	TSS	NH4_N	NO3_N	TP mg/l	EC	COD mg/l	BOD mg/l	Zn mg/l	Fe mg/l	Cu mg/l	Pb mg/l	Ni mg/l	Cr mg/l
PH																
T	-.252															
DO mg/l	-.637**	.249														
TSS	-.522**	.047	.447**													
NH4_N	-.472**	.099	.296	.695**												
NO3_N	-.207	.115	.558**	-.130	-.330*											
TP mg/l	-.236	-.077	.412**	.427**	.382*	.149										
EC	-.199	.228	.255	.437**	.527**	-.105	.121									
COD mg/l	-.076	-.028	.304*	.184	.309*	.101	.210	-.096								
BOD mg/l	-.083	-.025	.304	.189	.314*	.102	.213	-.090	.999**							
Zn mg/l	.265	-.239	-.174	-.185	-.182	-.092	-.052	-.148	-.056	-.057	.532**					
Fe mg/l	-.356*	-.082	.211	.313*	.159	-.190	-.098	.178	.998	.002	-.048					
Mg mg/l	-.332*	.164	.756**	.082	-.038	.729**	.273	.079	.184	.176	.144	-.078				
Cu mg/l	.562**	-.081	-.887**	.599	-.239	-.561**	-.383*	-.216	-.288	-.283	.248	-.309				
Pb mg/l	.613**	-.074	-.668**	-.408**	-.480**	-.173	-.471**		-.218	-.223	.019	-.270	.679**			
Ni mg/l	-.062	-.017	-.238	-.639**	.507**	-.771**	.002	.130	.043	.051	-.030	.531**	.231	-.107		
Cr mg/l	.329*	-.065	-.569**	.365*	.386**	-.722**	-.065	.220	-.170	-.171	.532**	-.189	.610**	.293	.491**	

R= Correlation Coefficient.

≥ 0.5 indicates existence of a strong correlation between parameters.

< 0.5 indicates existence of a weak correlation between parameters.

ANNEX (C): Photos from the Lab and study area

1. Photo of the study area from which the plants were collected

2. Photo while measure the flow characterization

3. Photo while prepare plant and sediment sample

4. Photo while using Atomic Emission Spectrophotometer