A RISK-BASED MONITORING AND CONTROL STRATEGY FOR MICROPOLLUTANTS IN A RIVER BASIN

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ABSTRACT

A RISK-BASED MONITORING AND CONTROL STRATEGY FOR MICROPOLLUTANTS IN A RIVER BASIN

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There is a need to develop a methodology for cost-effectively assessing and monitoring the quality of surface waters, and controlling micropollutant discharges from point sources in a river basin. This study aims to develop a monitoring and control strategy by prioritizing micropollutants according to their potential hazard and exposure levels in the Yeşilırmak River Basin (YRB). The temporal and spatial variation in the occurrence of 295 micropollutants was assessed by adopting a statistical screening approach, and 25 micropollutants that were identified as cause of concern (CoC) micropollutants in the YRB were recommended as tracers of water quality monitoring. Based on the temporal variation, spring was suggested as the preferred micropollutant monitoring season. For the first time in the YRB, the applicability of adopting a fixed dilution factor (DF) strategy to control micropollutants in point source effluents was evaluated by calculating the DF for each point source. The results indicated that the fixed DF strategy fails to comply with reaching the target water-quality standards. Ecotoxicological risk assessment methodology developed by combining surface water and point source risk assessment methodologies was used to assess the risk level in each sub-basin. The results of the bivariate correlation analysis carried out indicated that the river water concentrations of 17 CoC micropollutants are correlated to basin characteristics. This information was evaluated together with the results of the DF and ecotoxicological risk assessments to propose a point source management strategy in the YRB. Incorporation of the proposed monitoring and control strategy will ensure that water quality monitoring is cost-effective and water-quality goals are achieved.

Keywords: Micropollutants, River Basin Management, Dilution Factor, Risk Assessment, Monitoring Strategy

ÖZ

BİR NEHİR HAVZASINDAKİ MİKROKİRLETİCİLER İÇİN RİSK BAZLI İZLEME VE KONTROL STRATEJİSİ

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Bir nehir havzasındaki yerüstü sularının kalitesinin uygun maliyetli bir şekilde izlenmesi ve değerlendirilmesi ve noktasal kaynakların mikrokirletici deşarjlarının kontrol edilebilmesi için bir metodoloji geliştirmeye ihtiyaç vardır. Bu çalışma, mikrokirleticileri Yeşilırmak Nehir Havzasındaki (YNH) potansiyel tehlikelilik ve maruziyet seviyelerine göre önceliklendirerek, bir izleme ve kontrol stratejisi geliştirmeyi amaçlamaktadır. 295 mikrokirleticinin tespit edilmesindeki zamansal ve mekansal farklılıklar, istatistiksel eleme yaklaşımı benimsenerek değerlendirilmiş ve YNH'de öne çıkan (ÖÇ) mikrokirletici olarak tanımlanan 25 mikrokirletici, su kalitesi izleme çalışmaları için iz-kirletici olarak önerilmiştir. Zamansal değişime bağlı olarak, tercih edilen mikrokirletici izleme mevsimi olarak ilkbahar önerilmiştir. YNH'de ilk kez, noktasal kaynak deşarjlarındaki mikrokirleticileri kontrol etmek için sabit seyrelme faktörü (SF) stratejisi benimsenmesinin uygulanabilirliği, her bir noktasal kaynak için SF hesaplanarak değerlendirilmiştir. Sonuçlar, sabit DF stratejisinin hedeflenen su kalitesi standartlarına ulaşmada başarısız olduğunu göstermiştir. Her bir alt havzadaki risk düzeyini değerlendirmek için, yerüstü suyu ve noktasal kaynaklı risk değerlendirme metodolojilerinin birleştirilmesiyle geliştirilen ekotoksikolojik risk değerlendirme metodolojisi kullanılmıştır.

Gerçekleştirilen iki değişkenli korelasyon analizinin sonuçları, 17 ÖÇ mikrokileticinin yerüstü suyu konsantrasyonlarının havza karakteristikleriyle ilişkili olduğunu göstermiştir. Bu bilgi, YNH'de noktasal kaynak yönetimi stratejisi önermek için SF ve ekotoksikolojik risk değerlendirmelerinin sonuçlarıyla birlikte yorumlanmıştır. Önerilen izleme ve kontrol stratejisinin uygulanması, su kalitesi izlemesinin uygun maliyetli olmasını ve su kalitesi hedeflerine ulaşılmasını sağlayacaktır.

Anahtar Kelimeler: Mikrokirletici, Nehir Havza Yönetimi, Seyrelme Faktörü, Risk Değerlendirmesi, İzleme Stratejisi

To my beloved family

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TABLE OF CONTENTS

CHAPTERS

APPENDICES

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS

7Q10	The lowest 7-day average flow that occurs once every 10 years
7Q2	The lowest 7-day average flow that occurs once every 2 years
AA-EQS	Annual Average EQS
AF	Assessment Factor
BATAELs	Best Available Technique Associated Emission Levels
BATs	Best Available Techniques
BPAP	Basin Protection Action Plan
CA	Concentration Addition
CAS	Chemical Abstract Service
CCC	Criteria Continuous Concentration
CEC	Contaminants of Emerging Concern
CMC	Criteria Maximum Concentration
COMMPS	Combined Monitoring Based and Modeling Based Priority Setting
CWA	US Clean Water Act
DF	Dilution Factor
DF_1	Local Dilution Factor Scenario
DF_2	Accumulative Dilution Factor Scenario
EC	European Council
EC_X or DC_x	The concentration at which % effect was observed
ELVs	Emission Limit Values
EMP	Emerging Micropollutant
EOC	Emerging Organic Compounds
EP	Emerging Pollutant
EQS	Environmental Quality Standards
EQSD	Environmental Quality Standards Directive
EU	European Union

EUROSTAT	Statistical Office of the European Union
GC-HRMS	Gas Chromatography Coupled with High-Resolution Mass Spectrometry
GC-MS	Gas Chromatography-Mass Spectrometry
GC-MS/MS	Gas Chromatography-Tandem Mass Spectrometry
GDWM	General Directorate of Water Management
GIS	Geographic Information System
IA	Independent Action
IED	Industrial Emissions Directive
LC-HRMS	Liquid Chromatography Coupled with High-Resolution Mass Spectrometry
LC-MS/MS	Liquid Chromatography-Tandem Mass Spectrometry
LC_X or LD_X	The concentration at which % the lethal effect was observed
LoD	Limit of Detection
LoQ	Limit of Quantification
MAE	Mean Absolute Error
MAM(7)	The lowest average flows that occur for a consecutive 7-day period during a year
MF	Mean Flow
MLF	Mean Low Flow
MoAF	Ministry of Agriculture and Forestry
MoEUCC	Ministry of Environment, Urbanization and Climate Change
MP	Micropollutant
NACE	General Industrial Classification of Economic Activities within the European Communities
NOEC	No Observed Effect Concentration
NPDES	National Pollutant Discharge Elimination System
NTS	Non-target Screening
PBT	Persistent, Bioaccumulative, and Toxic

PC	Process Contribution
PCA	Principle Component Analysis
PCPs	Personal Care Products
PEC	Predicted Environmental Concentration
PNEC	Predicted No-Effect Concentration. The lowest value of EC50, LC50, and NOEC
POPs	Persistent Organic Pollutants
PPCPs	Pharmaceuticals and Personal Care Products
PPPs	Plant Production Products
PS	Point Sources
RBMP	River Basin Management Plan
REACH	Registration, Evaluation, Authorization and Restriction of Chemicals
RQ	Risk Quotient
SHW	State Hydraulic Works
SWQR	Surface Water Quality Regulation
THVS	Total Hazard Value Score
TMDL	Total Maximum Daily Load
TU	Toxic Unit Risk Quotient
TUBITAK	Scientific and Technological Research Council of Turkey
USEPA	US Environmental Protection Agency
UT	Untreated Point Sources
WFD	Water Framework Directive
WPCR	Water Pollution Control Regulation
YRB	Yeşilırmak River Basin

CHAPTER 1

INTRODUCTION

1.1 Motivation and Background

This Ph.D. thesis aims to contribute to implementing the European Union (EU) Water Framework Directive (WFD) (2000/60/EC) in Turkey (European Commission, 2000). In the following three sub-sections, first, a short introduction to micropollutants is made, and their control within the framework of the WFD is discussed. Then, challenges in monitoring and control of micropollutants are discussed, and finally, an overview of the transposition of the WFD into national legislation is provided. In the next sub-section, the challenges that raise the motivation of the present study are presented.

1.1.1 Micropollutants and the Water Framework Directive

The management of chemicals has become an important program since there must be a balance between development and human and environmental health. The chemicals used in the industry threaten the health of both humans and the environment because these chemicals can be toxic and/or carcinogenic. According to United Nations Environment Programme, nearly half of the pollutants released in North America are persistent and toxic chemicals (UNEP, 2013). The input of these pollutants from point and diffuse sources has led to contamination of freshwater resources, and management and control of organic micropollutants have become one of the key environmental challenges due to their persistent, bioaccumulative, and non-biodegradable (PBT) nature (Schwarzenbach et al., 2006).

In order to protect human and environmental health in the EU, a comprehensive piece of water legislation was started by the European Council (EC) in 1988, and

“Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy” or in short the “EU Water Framework Directive (WFD)” entered into force in December 2000.

The WFD aims to protect inland waters, transitional waters, coastal waters, and groundwater. The overall aim of the WFD for the Member States is to achieve “good ecological status” and “good surface water chemical status”. The WFD requires the development of River Basin Management Plans (RBMPs), which include basin characteristics, water quality monitoring programs, and measures to take to reach good water status in all water bodies within river basins and to sustain this situation for the Member States for each river basin lying within their territory. The management areas are divided into “River Basins” since rivers do not stop at national borders, and management of these sources requires collaboration among riparian countries in the EU.

The WFD is complemented by specific laws such as the Nitrates Directive (91/676/EEC), the Urban Wastewater Directive (91/271/EEC), the Drinking Water Directive (98/83/EC), and the Groundwater Directive (2006/18/EC). The Environmental Quality Standards Directive (EQSD) (2008/105/EC) (European Commission, 2008), which regulates the chemical quality of surface waters, is stepping forward between those regulations since the ultimate aim of the WFD is to eliminate priority hazardous substances and to reach near background concentrations in the marine environment for naturally occurring substances.

Hazardous substances are defined within the scope of WFD as PBT substances or groups of substances. The EQSD (2008/105/EC) identified the 33 substances of priority concern at the community level. The Directive 2013/39/EU later increased the number of priority substances to 45 priority substances and priority hazardous substances (European Commission, 2013). The Member States are responsible for identifying their river basin specific pollutants (Specific Synthetic Pollutants and Specific Non-Synthetic Pollutants) in addition to priority substances.

River basin specific pollutants are defined as substances or groups of substances that give rise to an equivalent level of concern as the priority substances and are identified as being discharged in significant quantities into a water body. The level of concern of a substance is determined by a prioritization process considering its potential hazard and exposure levels. The generic approach of this prioritization process used for the identification of river basin specific pollutants is detailed in WFD Guidance Document No: 3 – Analysis of Pressures and Impacts (European Commission, 2003a). The methodology (Figure 1) starts with preparing an indicative list of pollutants set out in Annex VIII of the WFD. In the second step, all available information on pollution sources, impacts of pollutants, and production and usage of pollutants are curated to exclude any unnecessary substances. The substances should have at least one proven carcinogenic, mutagenic, or endocrine-disruptive property. The third step selects from those short-listed pollutants that are likely to cause, or to already be causing, harm to the environment, which is highly dependent on the fate and behavior of the substances. Benchmark studies, monitoring data, or environmental quality model results are used in this step to identify river basin specific pollutants. In the fourth step, trend analysis and ecotoxicological uncertainty analysis are carried out to ensure that selected substances are environmentally significant. The final step is the list of river basin specific pollutants relevant to the river basin or particular water bodies within a river basin.

Even though the river basin specific pollutants are categorized as an element of “ecological status” (Figure 2), due to their nature they are also evaluated by EQSD together with priority substances (European Commission, 2018). The other elements of good ecological status are defined as biological elements (phytoplankton, macrophytes and phytobenthos, benthic invertebrate fauna, fish fauna), hydromorphological elements (hydrological regime, river continuity, morphological conditions), and chemical and physico-chemical elements other than river basin specific pollutants (general conditions such as temperature, pH, salinity, alkalinity, etc.).

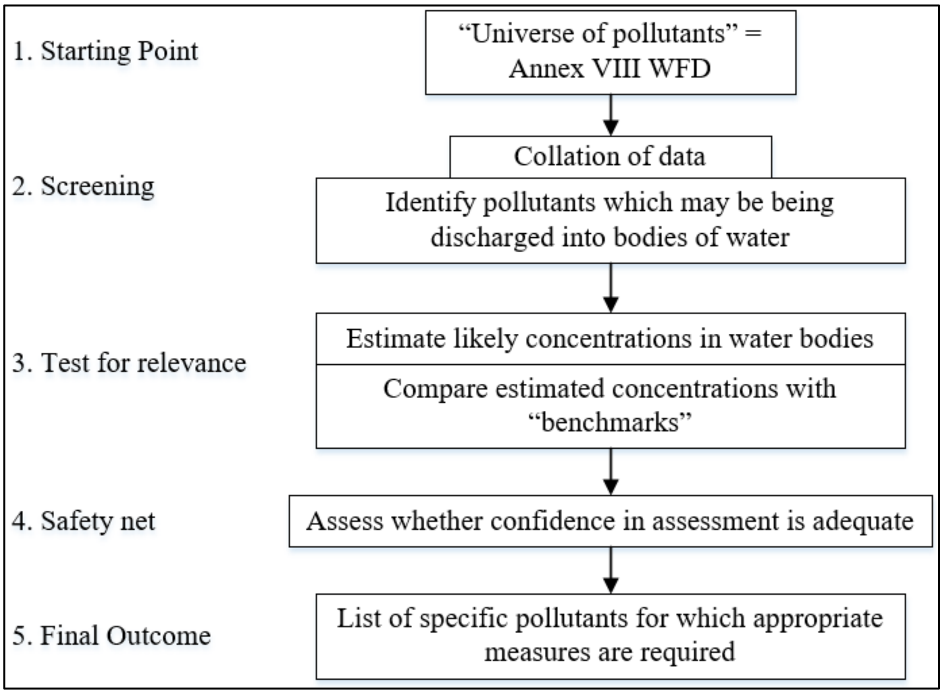

Figure 1. Generic Approach for Deriving List of Selected Pollutants (European Commission, 2003a)

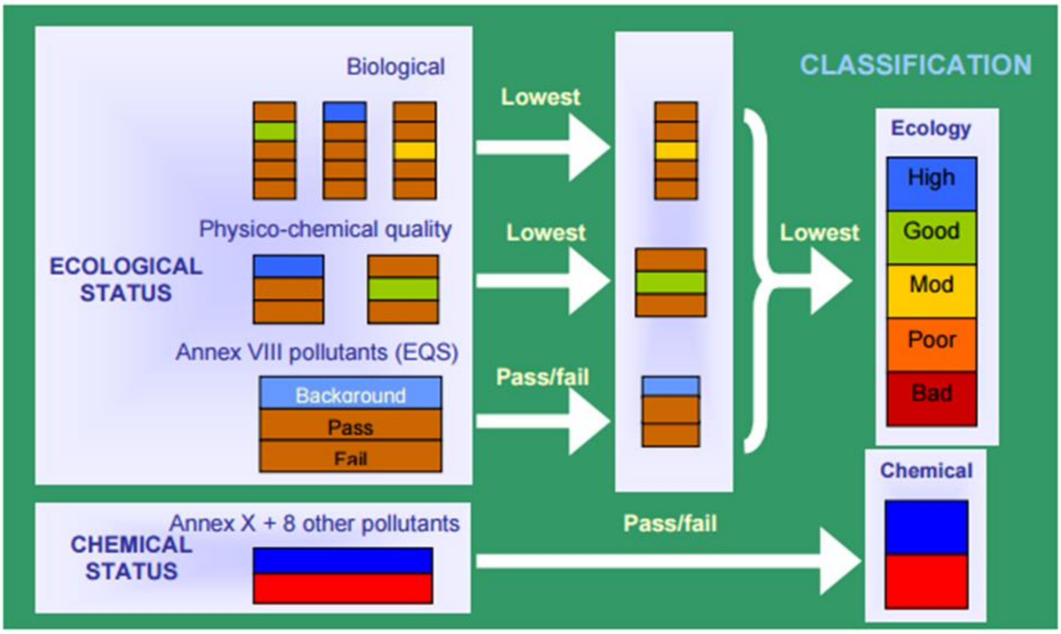

Figure 2. Role of EQSs in Waterbody Classification (European Commission, 2018)

Priority substances, priority hazardous substances, and river basin specific pollutants are a variety of chemicals, including pharmaceuticals, detergents, biocides, industrial chemicals, personal care products, wood preservatives, heavy metals, and disinfection by-products, which occur at very low concentrations in the environment, at nanogram per liter to microgram per liter levels (Chavoshani et al., 2020; Gerbersdorf et al., 2015). In addition to their low concentration in the receiving environment, since these pollutants are not commonly monitored (Geissen et al., 2015) and attract wide attention (Tang et al., 2019), they are referred to as micropollutants, emerging pollutants (EPs), emerging micropollutants (EMPs), emerging organic compounds (EOCs) or contaminants of emerging concern (CECs).

In order to control micropollutant pollution in the freshwater ecosystem, the EQSD sets Environmental Quality Standards (EQS) for substances present in surface waters. EQS is defined as "the concentration of a particular pollutant or group of pollutants in water, sediment or biota, which should not be exceeded to maintain specified quality objectives in terms of both human health and the environment". The EQS is a key tool in assessing pollution and evaluating the classification of waterbodies, as well as regulating discharges to water (European Commission, 2018). The EQS for priority hazardous substances and priority substances are present in the EQS directive, while EQS of river basin specific pollutants must be assessed within river basins. The differences in monitoring and identification of priority substances and river basin specific pollutants are summarized in Table 1.

Table 1. Differences in Monitoring and Identification of Priority/Priority Hazardous Substances and River Basin Specific Pollutants (European Commission, 2008)

Priority/Priority Hazardous Substances	**River Basin Specific Pollutants**
Determined by EU Commission	Determined by the Member States
Need to be revised every 4 years	Need to be revised every 6 years
Monitored 12 times a year	Monitored 4 times a year

1.1.2 Challenges in Monitoring and Control of Micropollutants

Although the concentrations of micropollutants in the natural ecosystems are in trace amounts, they are responsible for major adverse biological effects in the aquatic environment (Stamm et al., 2016). The pollution load ends up in drinking water systems and aquatic biota (Watkinson et al., 2009) and is considered the major exposure route for humans and animals via direct (respiration) or indirect (diet) uptake (Borgå, 2013; Fatta-Kassinos et al., 2011). Their adverse effects are expected to become more acute for species at the top of the food chain in the future as a result of bioaccumulation (Peralta-Maraver et al., 2019).

The biggest challenges in the control of micropollutants in surface waters remain complicated analytical methods and source attribution. Since micropollutants are found in trace amounts in the aquatic environment, separating a substance from its interferences in complex sample matrices and reaching low detection limits are found as challenging subjects (Luo et al., 2014a; Snow et al., 2018). Recent developments in analytical methods such as gas chromatography-mass spectrometry (GC/MS), liquid chromatography-tandem mass spectrometry (LC-MS/MS), and gas chromatography-tandem mass spectrometry (GC-MS/MS) allowed rapid and sensitive analysis of micropollutants; however, there is still limited data on the occurrence and concentration levels of many micropollutants (Bu et al., 2015; Kadokami et al., 2009; Loos et al., 2009; Luo et al., 2014a; Snow et al., 2018; Zoboli et al., 2019). In addition, characterization and differentiation of sources is an important step for identifying risks and mitigating exposures (Fairbairn et al., 2015). Diverse point and diffuse sources and atmospheric deposition of some micropollutants make it challenging to identify the major sources of pollution in the aquatic environment (X. Zhang et al., 2016); however, characterization of micropollutant occurrence at the basin scale with long-term monitoring data can provide valuable information for source identification (Carpenter & Helbling, 2018a). In order to assess pollution sources and develop sound water quality management, the quality of data to be used in environmental risk assessments must be improved with an integrated approach to monitoring and screening studies (Petrie et al., 2015, 2017; Tousova et al., 2017).

Micropollutants can be released from both point and diffuse sources; however, point sources such as industrial and urban wastewater discharges are considered as the main source of micropollutants (Cho et al., 2014; Pal et al., 2010). The natural and anthropogenic micropollutants used or applied in houses, hospitals and industries usually end up in wastewater treatment plants (WWTPs), which are discharged into surface water after treatment and untreated micropollutants combined with micropollutants from agricultural sources end up in surface and groundwater ecosystems. These ecosystems might be a pathway for micropollutants to reach drinking water sources (Figure 3).

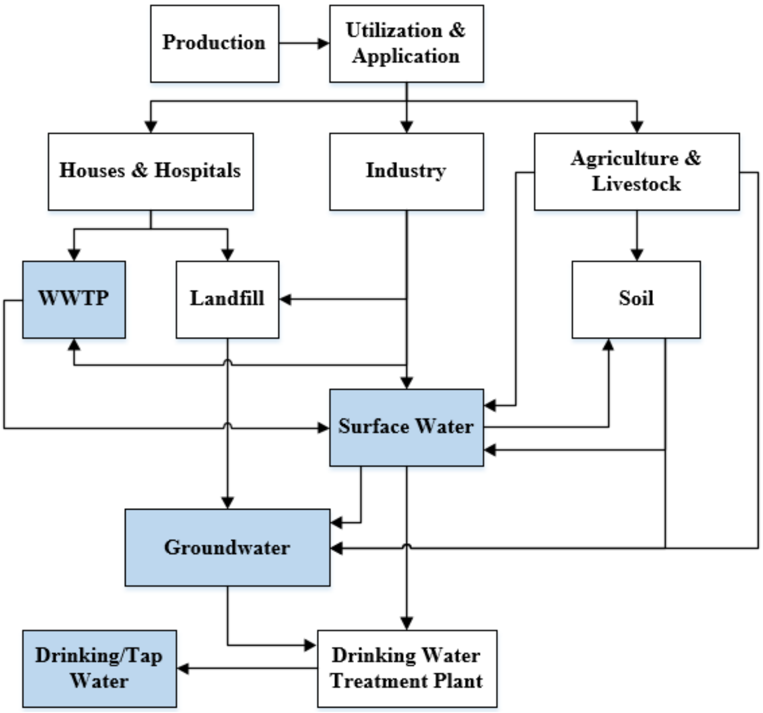

Figure 3. Sources and pathways of micropollutants (Barbosa et al., 2016)

Conventional WWTPs are designed to remove conventional pollution parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and microbiological load (Fatta-Kassinos et al., 2011), and since these WWTPs are not designed to remove pollutants at very low concentrations (Barbosa et al., 2016), majority of micropollutants end up in freshwater systems without any treatment. In addition to micropollutants, biochemical reactions taking place in WWTPs cause metabolites and treatment by-products to be discharged from point sources (Barbosa et al., 2016; Cho et al., 2014; Pal et al., 2010; Rogowska et al., 2020).

The difficulty of managing water quality deteriorations has increased in the past decades, and the approaches that incorporate the water quality of the receiving environment have gained importance in recent years. A combined approach is recommended for pollution prevention and control, where first, sector-specific and technology-based discharge standards are applied in industrial discharges, and then, water quality-based emission limits are set if target environmental standards could not be met (European Commission, 2000). There are three commonly used approaches available to set emission limit values (ELVs). These are the mixing zone approach, the total maximum daily load (TMDL) approach, and the dilution factor (DF) approach (EC, 2010a; USEPA, 2008; Wako, 2012). In the mixing zone approach, the dimensions of the effluent plume are estimated by simple computational methods to set ELVs, while in the TMDL approach, the total mass of a pollutant that can be discharged into a surface water body is calculated and the total load is allocated between point sources. Both of these approaches incorporate the upstream concentration of pollutants into ELV calculations, and the upstream concentrations must be below the target EQS to produce meaningful results. In addition, long-term surface water and point source quality data and comprehensive flow rate and river bed characteristics are required. The DF is a provisional approach, which is used during the transitional period from technology-based discharge standards to water quality-based emission limits. It assumes that effluents from point sources undergo a fixed ratio of dilution after mixing with the surface waters, and sets the ELVs accordingly. The DF approach requires only the effluent concentrations to measure compliance and reduces financial liabilities of sources that face difficulty in meeting water quality-based emission limits.

1.1.3 Transposition of the Water Framework Directive into National Legislation

After the Intergovernmental Conference held in Brussels on 21.12.2009, EU Environmental Acquis (Chapter 27) was opened for Turkey. According to Chapter 27, there are four closing criteria directly related to water management, which can be summarized as:

- Turkey should adopt the horizontal and framework legislation to harmonize environmental legislation of the EU including cross-border elements,
- Framework Law on water protection should be adopted, river basin protection action plans are created and significant developments in the field of regulatory compliance are achieved by adopting implementing legislation,
- Turkey should adopt legislation in alignment with the acquis in the fields of industrial pollution control and risk management, including waste management and nature protection,
- Turkey should continue to improve the capacity of administrative units at all levels.

Within the EU harmonization process, basin-based management of water with a holistic approach was adopted in accordance with Chapter 27, targeting the improvement of the existing water resources in terms of both quantity and quality by taking into consideration the balance of protection and utilization. The General Directorate of Water Management (GDWM) was established within the Ministry of Agriculture and Forestry (MoAF) in 2011. The purpose of GDWM is to resolve conflicts in water management, coordinate the national and international institutions during the harmonization period, prepare water management legislation and coordinate the utility of water resources in basins regarding the quality and quantity. The WFD and its daughter directives were included in the Turkish legal system with regulations within the framework of the hierarchy of norms. Turkey is trying to implement the WFD and the GDWM is developing River Basin Management Plans

(RBMPs) to achieve this goal. To this end, several projects have been carried out and 250 river basin specific pollutants have been identified based on their PBT properties and level of occurrence in the surface waters (MoAF, 2013, 2014a, 2014b). These pollutants, which are mainly organic pollutants and metals, and their EQS for water, sediment and biota were covered in the "Surface Water Quality Regulation (SWQR)" (MoAF, 2012).

The Ministry of Environment, Urbanization and Climate Change (MoEUCC) is responsible for setting ELVs to municipal and industrial WWTPs in accordance with the SWQR. A realistic EQS-based discharge standard/limits implementation strategy has been proposed to the Water Pollution Control Regulation (WPCR) (Official Gazette No: 25687, Date: December 31, 2004) (MoEUCC, 2004) by considering the technical capabilities, and economic conditions of the industrial facilities and municipalities (MoEUCC, 2018). The strategy incorporates a dilution scenario, which introduces a fixed DF of ten in all point sources as a provisional approach. The fixed DF approach aims to provide a smooth transition period to cover the cost of treatment investments required at point source discharges and to reduce the surface water concentration of micropollutants to a value below the EQS.

1.2 Objectives and Structure of the Thesis

The above discussions raise the main motivations of the present thesis. The MoAF is trying to implement the EU WFD in Turkey and to this end, 45 priority substances defined by the WFD and 250 river basin specific pollutants defined by the SWQR had to be monitored in surface waters and point sources across Turkey. This action requires a substantial labor force and is financially demanding. Analysis of the above-mentioned micropollutants requires mostly advanced analytical equipment, which is costly. Additionally, the control of micropollutants in surface waters is a complicated task since the implementation of water quality-based discharge limitations in controlling point sources remains to be a challenging task. Water quality-based discharge limitations require long-term monitoring data of upstream flow rates, and concentration of micropollutants in both surface water and point source effluents. There is a need for the development of a methodology for monitoring and assessing the water quality of surface waters cost-effectively, and for controlling micropollutant discharges from point sources.

The present study was carried out to fill this gap in the literature. The overall goal of this thesis is to develop a cost-effective monitoring and control strategy for micropollutants in surface waters by prioritizing micropollutants according to their potential hazard and exposure levels in the Yeşilırmak River Basin (YRB). The objectives of the thesis that focus on the above-mentioned motivations are:

- to develop a screening methodology to identify the cause of concern micropollutants in the YRB, which are of priority concern due to their hazard and exposure levels
- to contribute to the development of a water quality-based point source control strategy by evaluating the DF of point sources in the YRB
- to develop a risk assessment methodology to identify high-risk areas in the YRB and propose point source management strategies

To achieve these objectives, for the first time in the YRB, a comprehensive water quality monitoring study was conducted to assess the chemical status of surface waters within the framework of the project titled “Management of Point and Diffuse Pollutant Sources in Yeşilirmak River Basin (115Y013)” (TUBITAK, 2019). The results of the surface water monitoring study were used to develop an occurrence and risk-based micropollutant screening methodology to identify pollutants that are the cause of concern in the YRB, and the spatio-temporal distributions of these pollutants were evaluated to propose a cost-effective monitoring strategy to be used in the YRB. The results of the point source monitoring study were evaluated by conducting a DF assessment for three cases. These cases were selected as “business as usual”, “full commitment to the EU WFD”, and “the fixed DF approach of the revised WPCR”. A point source inventory was built, and the flow rates of receiving surface waters at the point of discharge were calculated. The results of the DF assessment contributed to the development of a point source control strategy, and to the identification of additional micropollutants that are the cause of concern at point source discharges. Finally, a statistical methodology was developed to identify potential sources of the cause of concern micropollutants in the YRB, and a risk assessment methodology was developed to identify high-risk sub-basins in the YRB. The results of the risk assessment and source identification were interpreted together to develop point source management strategies in the YRB. The framework of the present study is provided in Figure 4.

This thesis is written in "three papers format", which incorporates three separate and free-standing chapters that can be read and understood independently. These three chapters form the body of the work that supports "A Risk-Based Monitoring and Control Strategy for Micropollutants in a River Basin". In Chapter 2, the study site, point and diffuse sources in the YRB were summarised in addition to the details of the monitoring study. The limitations and assumptions of the proposed study were discussed with a focus on the assessment of the results. In Chapter 3, the first paper is provided, where the results of the surface water monitoring study were discussed with a focus on developing a screening methodology to identify micropollutants that are the cause of concern in the YRB. The key findings were discussed with similar studies in the literature. In Chapter 4, the second paper is provided, where a DF assessment methodology was proposed and the key findings were provided with a focus on contributing to the development of a water quality-based point source control strategy. For this purpose, low-flow stream flowrates were estimated and DF calculation methodologies were developed to calculate the DF of all point sources in the YRB. The DFs were evaluated and the risks of adopting a fixed DF approach to control point sources were quantified. In Chapter 5, the third paper is provided, where an ecotoxicological risk assessment was conducted for pollutants that are the cause of concern in the YRB, and a point source control strategy was proposed. To this end, potential sources of micropollutants were identified by conducting a bivariate correlation analysis and evaluated together with the results of the ecotoxicological risk assessments. Finally, in Chapter 6, the overall findings of this study are summarised and recommendations are made for future studies.

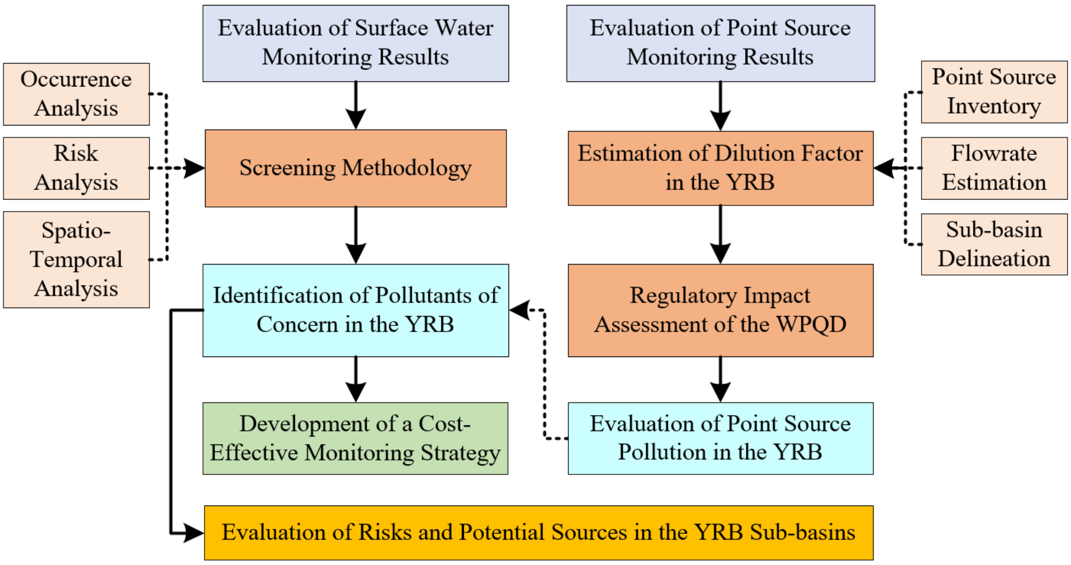

Figure 4. The Framework of the Study

CHAPTER 2

STUDY SITE AND BACKGROUND

The project named “Management of Point and Diffuse Pollutant Sources in Yeşilirmak River Basin (115Y013)” was implemented from 2016 to 2019 with the objective of developing a strategy for the management of point and diffuse pollution sources in the YRB. Additionally, the outcomes of the study provided technical support to the MoAF[1] in the adaptation of WFD for YRB and provided a basis for the preparation of RBMP for Yeşilırmak. This study is the first systematic monitoring campaign in YRB, which provides valuable information on the occurrence and concentration levels of 45 priority substances and 250 river basin specific pollutants listed in the national SWQR. This study can be regarded as the starting point for building micropollutant inventory in the Yeşilırmak River, which generated the initial dataset for the establishment of an inventory and laid out management strategies for the control of micropollutants.

2.1 Study Site

The YRB is located in Turkey between 39°30′ and 41°21′N latitude and 34°40′ and 39°48′E longitude (Figure 5). YRB is the third-largest river basin in Turkey, with a total catchment area of 36,129 km^2, which is approximately 5% of the county’s total land area (MoAF, 2010). YRB remains within the boundaries of eleven cities, which are Tokat, Samsun, Amasya, Çorum, Sivas, Yozgat, Gümüşhane, Giresun, Erzincan, Ordu and Bayburt. Among these cities, the city centers of Amasya, Çorum, Tokat, and Samsun remain within the river basin. However, the wastewater from Samsun is discharged into the Black Sea by deep-sea discharge after treatment.

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[1] Former Ministry of Water Affairs and Forestry

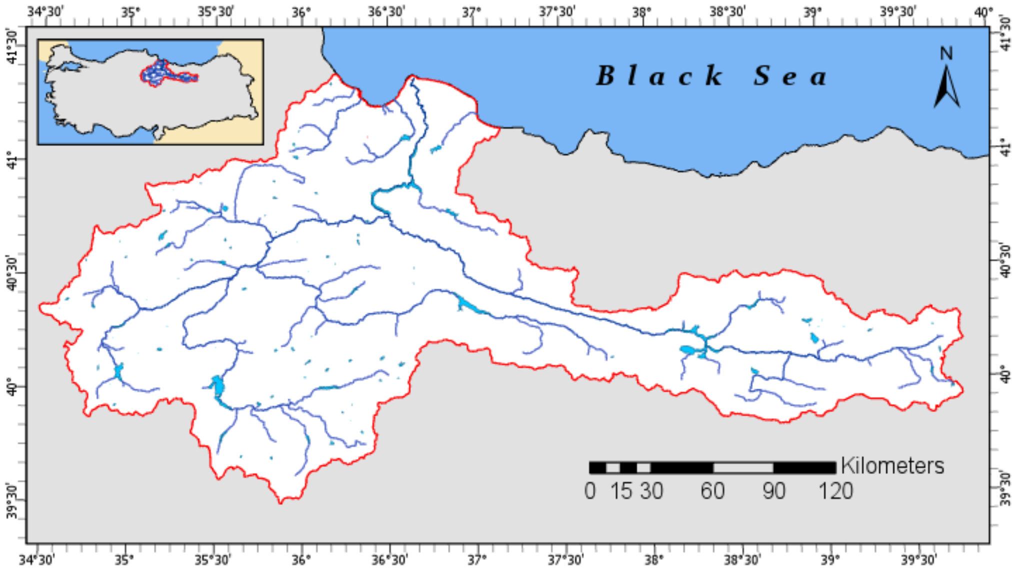

Figure 5 Location of the study site, Yeşilırmak River Basin

The Yeşilırmak River, which originates from Köse Mountain in Sivas, has a total length of 519 km and drains into the Black Sea at Çarşamba Plain in Samsun. Its three main tributaries are the Kelkit River, Çekerek River, and Tersakan River, and it reaches an annual total flow of 5.7 x 10^9 m^3 (Table 2) (MoAF, 2010). The most recent flow rate statistics available for Yeşilırmak River and its tributaries are dated 2010, and it has a mean annual flow of 121 m^3/s, while the minimum and maximum flows reported are 1.83 m^3/s and 1,914 m^3/s, respectively (MoAF, 2010).

Table 2. Flow Statistics of Yeşilırmak River and its tributaries (MoAF, 2010)

River	***Length (km)***	***Maximum Flow Rate (m^3/s)***	***Minimum Flow Rate (m^3/s)***	***Average Flow Rate (m^3/s)***	***Annual Total Flow Rate (m^3)***
Yeşilırmak	519	1,914	1.83	121	5.70 x 10^9
Kelkit	400	905	47	70.5	2.53 x 10^9
Çekerek	200	362	0.09	20	0.80 x 10^9
Tersakan	10	317	0.02	3.96	0.13 x 10^9

The river basin is characterized by a subtropical, semi-arid climate with an average annual precipitation of 497 mm and a temperature of 12 °C (MoAF, 2010), where there is a considerable spatial and temporal variation in temperature and precipitation. In winter, the average temperature is less than 0 °C in central regions, and the average winter temperature is 2 °C in the basin (MoAF, 2010). The average annual precipitation in the coastal regions close to the Black Sea coast reaches 1000-1500 mm and decreases to 350-400 mm in central regions (MoAF, 2010). Low flow conditions in the Yeşilırmak River are observed from July to February, and high flow conditions occur from March to May as a result of snowmelt and surface run-off (Kurunç et al., 2005).

The majority of the population in the basin depends on agriculture for livelihood and withdraws water from the river for irrigation. Inorganic fertilizers and pesticides are widely used for agricultural purposes (Tiril & Memis, 2018) and they are commonly found in the surface water (MoEF, 2008). The increased industrialization and urbanization in the basin led to significant increases in runoff water with substantially low quality due to excessive use of fertilizers and untreated point sources (Hadjikakou et al., 2011; Maraşlıoğlu & Öbekcan, 2017; MoAF, 2021; Ustaoğlu et al., 2021).

2.2 Point and Diffuse Sources in the Yeşilırmak River Basin

The point and diffuse source inventory of the YRB were built by merging information from various sources. The MoAF prepared the baseline for building pollution source inventory with Yeşilırmak Basin Protection Action Plan (MoAF, 2010). This plan can be considered the initial step toward the preparation of RBMP for YRB. Although this plan does not cover any information regarding micropollutants, it provides valuable information regarding major point sources and sources of pressure on water resources. The second source of information was the Provincial Environmental Status Reports published by the MoEUCC(MoEUCC, 2021). These reports are prepared annually for each city in Turkey, and information regarding point sources was updated according to these reports. Finally, the inventory of the recent Yeşilırmak RBMP was used for the final update of the inventory (MoAF, 2021). The Yeşilırmak RBMP was prepared in accordance with the Technical Assistance on Economic Analyses within River Basin Management Plans and Water Efficiency Aspects in Three Pilot River Basins in Turkey Project and provided valuable information regarding point sources and concentrations of micropollutants at urban and industrial wastewater discharges. The final point source inventory is summarized in Table 3. The complete list of all point source discharges in the YRB is given in Appendix A - Table A 1.

Table 3. Summary of total point source discharges in YRB by the industrial sector

Industrial Sector	**# of Facilities**	**Total Wastewater Discharge (m^3/day)**	**Total Treatment Capacity (m^3/day)**
Deep Sea Discharges			
Chemical Industry	1	300.0	300.0
Domestic & Urban Wastewater	2	112,750.0	113,878.0
Metal Industry	2	1,755.0	3,195.0
Mixed Industrial Wastewater	2	2,205.0	2,310.0
Oil Industry	2	24.0	24.0
Sub-Total	9	117,034.0	119,707.0
Surface Water Discharges			
Beverage Industry	5	43.9	57.9
Cellulose and Paper Industry	2	893.0	1,100.0
Chemical Industry	1	0.6	0.6
Coal Preparation, Processing, and Energy Production Industry	1	37.0	37.0
Domestic & Urban Wastewater	33	154,522.1	182,362.2
Food Industry	33	20,396.3	28,983.3
Metal Industry	2	20.5	20.5
Mining Industry	1	1,200.0	3,000.0
Mixed Industrial Wastewater	3	1,192.8	1,192.8
Other Industrial Wastewaters (Cooling)	1	1,080.0	2,000.0
Other Industry	1	480.0	770.0
Textile Industry	2	10.3	10.3
Vehicle Manufacturing and Repair Industry	1	1.8	1.8
Wood Products and Furniture Industry	1	40.0	50.0
Sub-Total	86	179,918.2	219,586.3
Grand Total	95	296,952.2	339,293.3

The total number of domestic, urban, and industrial wastewater treatment plants is identified as 95. The domestic and urban WWTPs have the highest count and are responsible for approximately 90% of total discharges. However, two urban WWTPS (Terme and Samsun Doğu), which are equipped with deep-sea discharge systems, are responsible for 38% of the total wastewater discharges. Among WWTPs with deep-sea discharges, domestic and urban wastewaters constitute 96% of the total, followed by mixed industrial WWTPs (1.9%) and metal industry (1.5%). Since the deep-sea discharges are not counted towards discharges to the YRB, the total daily wastewater flow can be regarded as approximately 180,000 m^3.

When the deep-sea discharges are excluded, the domestic and urban WWTPs have a combined wastewater flow of 154,522 m^3/day, which is approximately 86% of the total discharges to the YRB. The food industry follows the domestic and urban wastewater sector with 33 WWTP discharges and is responsible for 11% of the wastewater flows to the YRB. The four sugar factories in the YRB are responsible for 82% of all food industry discharges (16,760 m^3/day). The remaining 12 industries have a share of less than 1% individually, and constitute 3% of the total. It is important to note that the wastewater discharges from sugar factories are seasonal and the exact wastewater discharge during the production period is unknown. The flow rates are based on declared annual average values.

The distribution of point sources in the YRB is given in Figure 6. It is seen that the Tersakan River in Amasya has the highest number of point source discharges per river length, where four domestic WWTPs, seven food industry WWTPs, and one mining industry WWTP discharge into the river in less than 10 km. The total daily wastewater flow discharging into the Tersakan River was calculated as 9,350 m^3, which is approximately 2% of the average flow. However, during low flow conditions, it is five times greater than the river flow.

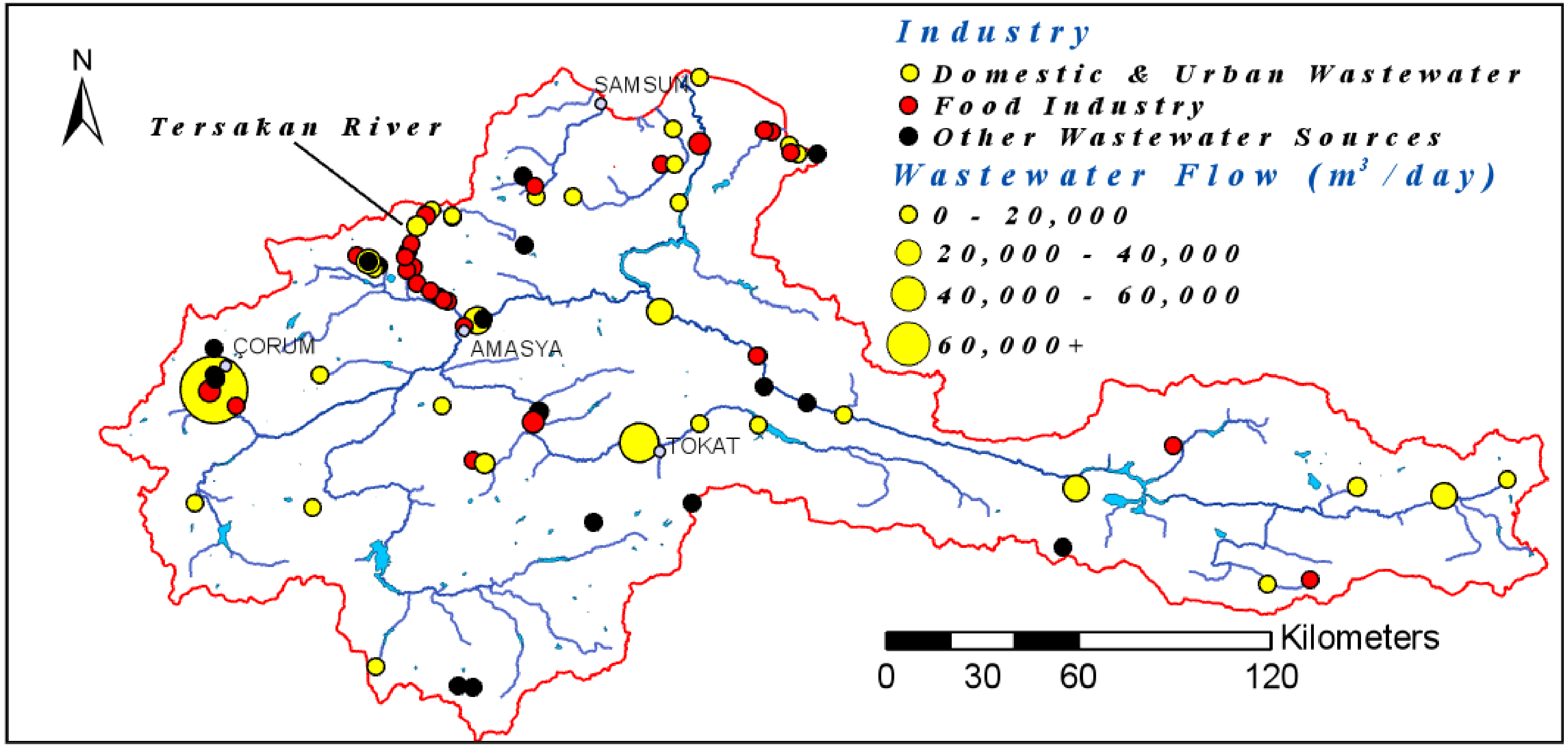

Figure 6. Point sources in the YRB

The minimum, maximum and average flow rates of wastewater discharges in the YRB are given in Table 4. Following the pattern in total point source discharges in by industrial sector, domestic and urban WWTPs have the highest individual flow rates, followed by the food industry discharges. The greatest single wastewater flow to the YRB is from Çorum municipality WWTP with a daily flow rate of 60,000 m^3, followed by Tokat municipality WWTP with a daily flow rate of 25,800 m^3. Other notable wastewater discharges are from Amasya WWTP, Tokat Erbaa WWTP, Gümüşhane Kelkit WWTP, Sivas Suşehri WWTP, and Merzifon WWTP, with daily flow rates decreasing from 11,500 m^3 to 8,900 m^3. When industrial wastewater discharges are evaluated, it is seen that average flow rates are less than expected sectoral values (Appendix B - Figure A 1 and Figure A 2). This shows that the size and capacity of industrial facilities in the YRB are relatively smaller than similar facilities in Turkey. Out of 86 point source discharges, 42 sources have a flow rate of less than 50 m^3/day, and 19 sources have a flow rate of greater than 1,000 m^3/day.

Table 4. Minimum, Maximum, and Average Flow Rates of Wastewater Discharges

Industrial Sector	**Wastewater Discharge (m^3/day)**			
	Min.	**Max.**	**Avg.**	**TR Avg.** **(**Figure A 1**)**
Beverage Industry	0.002	36.0	8.8	151.6
Cellulose and Paper Industry	43.0	850.0	446.5	1,724.3
Chemical Industry	0.6	0.6	0.6	145.2
Coal Preparation, Processing, and Energy Production Industry	37.0	37.0	37.0	548.5
Domestic & Urban Wastewater	1.5	60,000.0	4,828.8	4,014.5
Food Industry	3.9	4,800.0	635.5	1,074.8
Metal Industry	0.5	20.0	10.2	253.3
Mining Industry	1,200.0	1,200.0	1,200.0	693.1
Mixed Industrial Wastewater	289.4	480.0	397.6	1,3875.2
Other Industrial Wastewaters (Cooling)	1,080.0	1,080.0	1,080.0	117.8
Other Industry	480.0	480.0	480.0	520.3
Textile Industry	1.9	8.4	5.1	1,447.1
Vehicle Manufacturing & Repair Industry	1.8	1.8	1.8	606.1
Wood Products and Furniture Industry	40.0	40.0	40.0	241.5

In addition to point sources with WWTPs, untreated point wastewater discharges are significant sources of wastewater in the YRB. These sources were identified from Yeşilırmak Basin Protection Action Plan and 19 sources were removed from the database since they were connected to a WWTP after the action plan was published. The active untreated point wastewater sources, their population, and wastewater flows are provided in Appendix A - Table A 2. In addition to domestic wastewater sources, 148 industrial facilities discharge their wastewater without treatment. The list of these facilities, their discharge point, and wastewater flows are provided in Appendix A - Table A 3. Due to the nature of untreated domestic sources, information regarding their wastewater flow rate is unavailable. In order to calculate their flow rate, per capita daily wastewater statistics released by TUIK were used. The recent statistics show that per capita daily wastewater flow in Turkey is 189 L (TUIK, 2020), and wastewater discharges were calculated based on this value using Equation -1 and summarized in Table 5 along with industrial discharges.

$$Wastewater\ Discharge\ \left(\frac{m^3}{day}\right) = Population\ x\ \frac{0.189\ m^3}{cap.day} \qquad (Equation - 1)$$

The daily flow rate of untreated point domestic wastewater discharges is approximately 121,000 m^3, which is equal to 78% of treated domestic and urban wastewater sources in the YRB. This means that 44% of total domestic & urban wastewater in the basin is discharged without any treatment, which shows the significance of untreated domestic wastewater flows in the YRB. Tokat has 68 untreated point discharge sources, which account for 38.2% of total untreated urban wastewater in the YRB, followed by Samsun (20.7%) and Amasya (14.3%). The share of industrial discharges in urban wastewater is quite low (1%). When compared with industrial WWTP discharges, untreated industrial wastewaters constitute less than 5% of total industrial discharges.

Table 5. Untreated Point Wastewater Discharges in the YRB

City	**# of Discharges**	**Domestic Wastewater (m^3/day)**	**Industrial Wastewater (m^3/day)**	**Total Wastewater**	
				m^3/day	**%**
Amasya	24	17,005	451	17,456	14.3
Çorum	10	7,073	1	7,073	5.8
Giresun	3	3,266	3	3,270	2.7
Gümüşhane	8	3,563		3,563	2.9
Ordu	4	2,962		2,962	2.4
Samsun	12	24,884	494	25,378	20.7
Sivas	8	2,976		2,976	2.4
Tokat	68	46,499	296	46,795	38.2
Yozgat	21	12,975	5	12,980	10.6
Total	**158**	**121,204**	**1,250**	**122,454**	100.0

Table 6. Distribution of Untreated Industrial Discharges in the YRB

Industrial Sector	**Untreated Wastewater Discharge (m^3/day)**	**Percentage in Total Untreated Industrial Wastewater Discharge (%)**
Beverage Industry	0.14	0.01
Chemical Industry	274.06	21.93
Food Industry	281.83	22.55
Glass Industry	13.74	1.10
Machinery and Spare Parts Industry	71.12	5.69
Metal Industry	60.64	4.85
Mining Industry	0.65	0.05
Mixed Industrial Wastewater	376.54	30.13
Oil Industry	1.83	0.15
Textile Industry	8.47	0.68
Domestic Wastewater*	158.58	12.69
Vehicle Manufacturing and Repair Industry	2.14	0.17
Wood Products and Furniture Industry	0.14	0.01
Grand Total	**1,249.88**	**100.00**

* 19 industrial facilities reported only domestic wastewater, which accounts for approximately 13% of total untreated industrial discharges

The distribution of untreated industrial discharges by sector in the YRB is given in Table 6. Mixed industrial wastewaters constitute 30% of the total untreated wastewater, followed by the food industry (23%) and the chemical industry (22%). It is seen that 13% of industrial wastewater discharges are domestic wastewater from these industries. The majority of untreated industrial wastewater is discharged into domestic wastewater sewerage systems, which do not have any kind of end-of-pipe treatment. Among 148 industrial facilities discharging without treatment, 121 facilities discharge into these sewerage systems. The remaining 27 facilities discharge into YRB using the sewerage systems of Amasya KSS, Amasya OSB, Niksar OSB, Suluova OSB and Turhal OSB. These five organized industrial zones represent 43% of total untreated industrial wastewater.

The distribution of untreated wastewater discharges in the YRB is given in Figure 7. When compared with locations of urban and domestic WWTPs in the YRB (Figure 6), it is seen that untreated domestic wastewater discharges co-exist in many districts with urban WWTPs. In addition to urban WWTP discharges to the Tersakan River, the fourth highest untreated point discharge is from Suluova City (7,230 m^3/day). Another wastewater discharge into the YRB is from Suluova OSB, which discharges 179.3 m^3 of wastewater per day without any treatment.

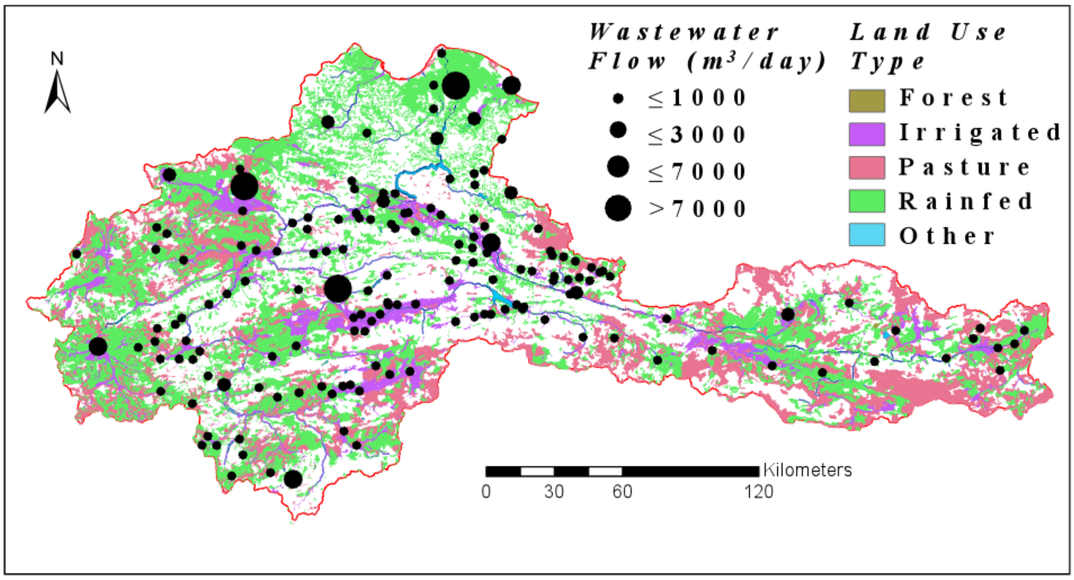

Figure 7. Untreated Direct Wastewater Discharges and Land Use Types in the YRB

Unlike point sources, it is quite challenging to identify all diffuse sources (non-point sources) in a river basin. Irrigation return flows and surface runoff from agricultural areas are among the first examples of diffuse sources. However, diffuse sources are identified as any non-point sources such as oil, grease, and chemical runoff from urban areas, salt from irrigation practices, acid and metal drainage from mines, atmospheric deposition, and leakages from septic systems (USEPA, 2021a). Due to varieties in the temporal and spatial distribution of diffuse sources, it is more challenging to identify and control them like point sources.

In this study, agricultural diffuse sources were taken into account since they are identified as major sources of diffuse pollution in the YRB. According to MoAF, agricultural activities within Samsun, Amasya, Tokat, and Çorum have the highest impact on the water quality of the basin (MoAF, 2010). The agricultural areas in the YRB were identified using the Yeşilırmak River Basin Master Plan prepared by Temelsu International Engineering Services Inc (MoAF, 2016). The land use map of the YRB is given in Figure 7, and detailed land use types are provided in Appendix C - Table A 4. Primary land use types and their area is summarized in Table 7. The largest agricultural land use in the YRB is identified as rainfed agricultural zones and constitutes 55% of total agricultural areas. The second largest land use is pastures (31%), followed by irrigated agricultural areas (13%). Pastures are found predominantly in the Eastern regions of the YRB. Rainfed agriculture is applied throughout the YRB, while irrigated agriculture is applied predominantly in Suluova district of Amasya, Erbaa, Zile, Turhal, Yeşilyurt, Niksar and central districts of Tokat, Alaca and central districts of Çorum, Aydıncık district of Yozgat, Suşehri, Koyulhisar and Akıncılar districts of Sivas, Şebinkarahisar district of Giresun, Şiran and Kelkit district of Gümüşhane (MoAF, 2016). Irrigation is a significant mechanism for shifts in crop productivity as well as water quality and quantity. A recent study shows that alternating from rainfed agriculture to irrigated agriculture increases the annual base flow and fertilizer demand of crops, resulting in an increase in concentrations of nutrients, sediment, and salt (Merchán et al., 2018). While agricultural diffuse pollution can be controlled by best management practices, other diffuse sources such as atmospheric deposition are more difficult to take direct control measures. In this regard, only agricultural activities were taken into account during this study since data relevant to other diffuse sources are not available.

Table 7. Primary Land Use Types and Total Areas in the YRB

Land Use	**Area (hm^2)**	**Percentage (%)**
Forest	650	0.03
Irrigated	307,192	13.32
Pasture	729,849	31.65
Rainfed	1,268,069	54.99
Other	120	0.01
Total	2,305,879	100.00

2.3 Monitoring Studies in the Yeşilırmak River Basin

Monitoring network design is a crucial step in collecting high-quality data from a monitoring study. Although one fit for all type of monitoring networks are cost and time efficient, the best monitoring networks are the dedicated fit-for-purpose type of networks (Guigues et al., 2013). In order to evaluate the environmental impact of human activities and to characterize a river basin, WFD requires the establishment of surveillance and operational monitoring programs in accordance with Article 5 and Annex II of WFD. WFD Guidance Document No: 7 provides further guidance on establishing the design of monitoring programs (European Commission, 2003b). Surveillance monitoring is an important part of the RBMPs, where initial monitoring information and data are collected to identify water bodies at risk. Surveillance monitoring is done in order to provide information regarding the overall surface water status within each catchment and sub-catchment of the river basin. River basins can be classified as homogeneous and heterogeneous in terms of water body characteristics and anthropogenic pressures, and heterogeneous river basins require more monitoring stations. In both cases, monitoring results of a statistically representative water body can be extrapolated to assess the surface water status of unmonitored water bodies. Additionally, surveillance monitoring also provides information regarding the identification of reference conditions and long-term changes resulting from anthropogenic activities. Operational monitoring is complimentary to surveillance monitoring and establishes the status of water bodies identified as being at risk of failing to meet their environmental objectives. Investigative monitoring is applied for specified cases where the reason for poor water status is unknown or when operational monitoring could not be established in water bodies with poor water status risk.

As part of this study, a monitoring network was established in the YRB and eight monitoring campaigns were carried out between 2016 and 2018: August and October of 2016, February, April, June, August, and November of 2017, and January of 2018. During the selection of monitoring station locations, point and diffuse sources throughout the basin were evaluated in order to identify water bodies with high anthropogenic pressure. The determination of the initial set of monitoring stations was based on these point and diffuse pressures in the YRB, where surface water monitoring stations were placed before and after the pressures that were considered significant. The significance of pressures in the YRB was identified in accordance with the previous studies in the basin (MoAF, 2010). During this placement, considering the accessibility of the monitoring stations during field studies, the flow observation and/or water quality stations of the State Hydraulic Works (SHW) and the operational monitoring stations of the MoAF were used when available. Since the MoAF stations were determined based on WFD Guidance Document No: 19 - Guidance on Surface Water Chemical Monitoring (European Commission, 2009b), the results contributed to the water quality inventory of the Yeşilırmak RBMP. In addition to surface water monitoring stations determined with a scope to identify pressures in the YRB, in accordance with WFD Guidance Document No: 7, additional surface water monitoring stations were placed at locations that are unlikely to be impacted by anthropogenic sources. The monitoring results from these stations were used to determine natural background concentrations of metals.

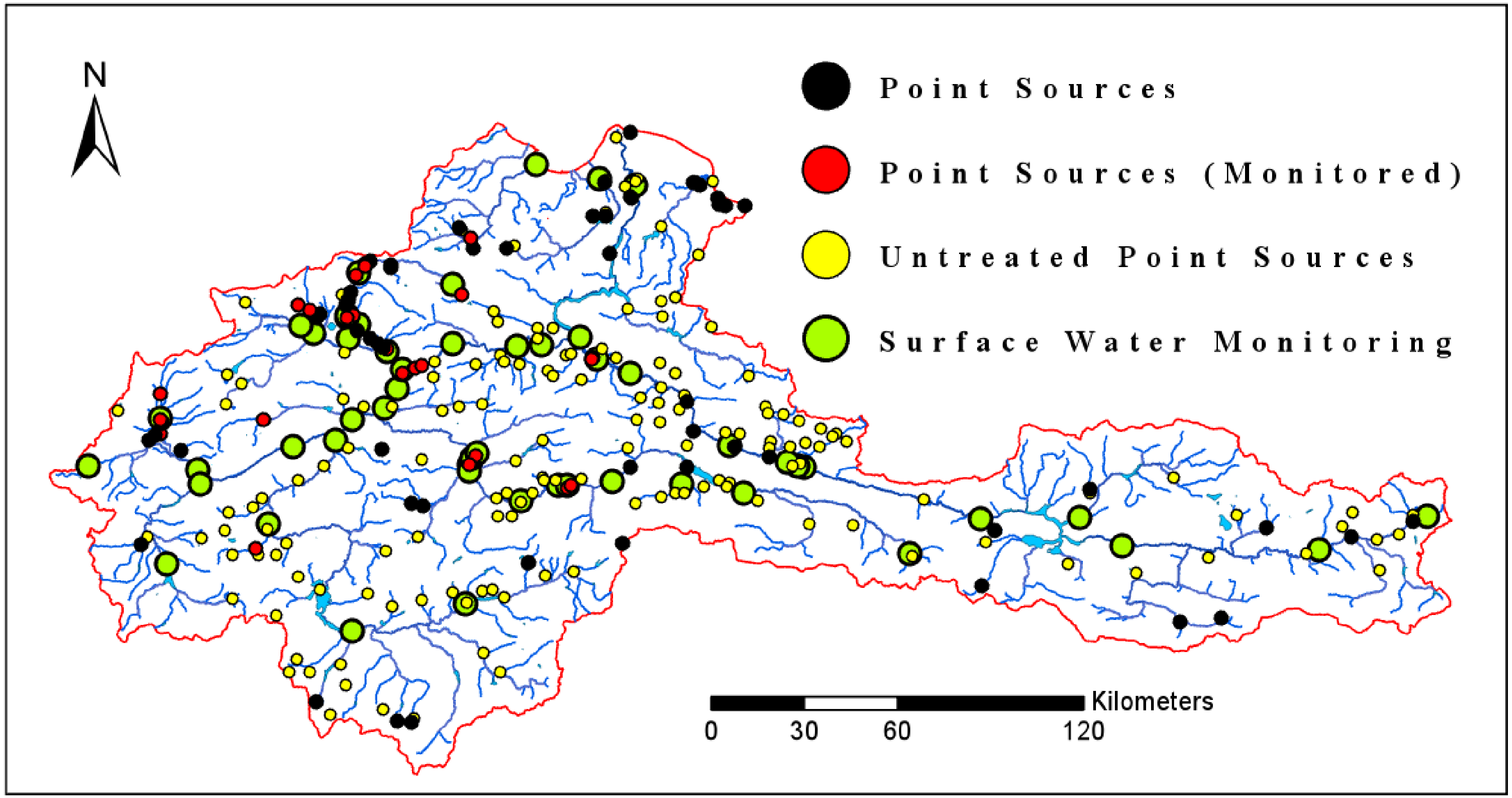

Figure 8. Point Sources and Surface Water Monitoring Stations

In order to fully evaluate the effects of point pressures, 43 surface water monitoring stations were identified initially (Figure 8). Thirteen of these stations were determined at locations, where neither SHW nor MoAF stations exist. The pollution profile of the YRB was determined using the monitoring results from these 43 stations and after two surface water monitoring campaigns, industrial and urban/domestic WWTP monitoring studies had started in addition to surface water monitoring.

Other than pollution indicators in the surface waters, the first selection criteria of these industries were based on their industrial sector (NACE codes) to cover as many types of manufacturing activities in the YRB as possible. The second selection criteria were capacity and generation of wastewater during production activities, where facilities with relatively high wastewater discharge and production capacity were included in the monitoring studies. The main reason why these point sources were included in monitoring studies performed in the basin is to reveal the link between pollutants discharged from these sources and monitored in the receiving environment, with the ultimate goal of determining pollution control measures. The major industrial point sources in the basin were identified as the manufacture of sugar, processing and preserving food, manufacture of paper and paper products, mining of non-ferrous metal ores, and mixed manufacturing activities, which mainly include the manufacture of machinery, basic metals, and fabricated metal products.

New surface water monitoring stations were added after the sixth monitoring campaign to further investigate the impact of point source pressures in the YRB. The complete list of surface water monitoring stations (Table A 5), urban and domestic wastewater treatment plants (Table A 6), and industrial wastewater treatment plants (Table A 7) are provided in Appendix D. Some of these monitoring stations were canceled at various monitoring studies due to one of the reasons given below:

- Limited accessibility to the station due to floods and harsh winter conditions
- No-flow conditions
- Ending of a point source monitoring

- Being under construction
- Deep sea discharge
- The facility was closed during all monitoring campaigns
- The facility was closed permanently

In the scope of the monitoring study in the YRB, 82 sampling stations were used at the end of the monitoring campaign (Table 8 and Figure 8). For surface water monitoring, 52 sampling points were used, while 16 sampling points were used for industrial wastewater monitoring, and six sampling points were used for urban and domestic wastewater monitoring. The samples from industrial, urban, and domestic WWTPs were collected from the plant outfall before mixing with the surface water.

Table 8. Number of Sampling Stations and Total Samples Collected in the YRB

Sampling Station Type	# of Stations	# of Samples Collected
Surface Water	52	345
Industry	16	61
Industry Influent	2	5
Urban & Domestic	6	28
Urban Influent	3	9
Untreated	2	3
Total	82	451

Towards the end of the monitoring campaign, samples were collected from two industrial WWTP influents and three urban WWTP influents to evaluate the treatability of micropollutants. WWTP influent samples were collected from Merzifon OSB and Meray Yağ San ve Tic A.Ş. for three consecutive monitoring campaigns. For urban WWTPs, Tokat WWTP, Çorum WWTP, and Amasya WWTP were selected to collect influent samples.

Aydıncık and Ozan WWTPs were initially identified for domestic WWTP monitoring studies; however, field studies revealed that those WWTPs were under construction during monitoring studies and the wastewater from these settlements was being discharged without any treatment. The monitoring results of these two WWTPs were determined to be used as reference samples for untreated direct discharges in the YRB. In this regard, during eight monitoring studies, 345 samples were collected from surface water monitoring stations, 89 samples were collected from WWTP discharges and three samples were collected from untreated point source discharges.

The average sample size for each station type is given in Figure 9. On average, seven samples were collected from each surface water monitoring station, where eight samples were collected from the initial set of monitoring stations, and only one sample could be collected for investigative samplings. For industrial wastewater discharges, four samples were collected from each industrial WWTP discharge, on average. Six samples were collected from Merzifon OSB, Dimes Tokat Taşlıçiftlik and Özdemir Antimuan Madenleri A.Ş. Five samples were collected from Olmuksan International Paper Ambalaj Sanayi ve Ticaret A.Ş. and Lesaffre Turquie Mayacılık Üretim ve Ticaret A.Ş. (Özmaya). Less than three samples were collected from Amasya Şeker Fabrikaları A.Ş. and Turhal Şeker Fabrikaları A.Ş. since these facilities were closed during the remaining monitoring studies. For urban wastewater discharges, five samples were collected from each WWTP discharge, on average. Six samples were collected from Tokat Central WWTP, Tokat Erbaa WWTP and Çorum WWTP. Four samples were collected from Çorum Mecitözü WWTP, while three samples were collected from Amasya Central WWTP and Samsun Havza WWTP. All six WWTPs have physical and biological treatment with limited nutrient removal capabilities. Monitored and unmonitored point sources, untreated point sources, and surface water monitoring stations in the YRB are given in Figure 8.

Surface water and point source monitoring samples were collected by a group of researchers from Fırat University and Munzur University. During the collection of samples, in-situ monitoring of temperature, pH, dissolved oxygen, conductivity, and total dissolved solids (TDS) was carried out. The samples were delivered to the Environmental and Cleaner Production Institute of the Scientific and Technological Research Council of Turkey (TUBITAK) Marmara Research Center for further analysis. All collected samples were analyzed for general chemical and physicochemical parameters given in Table 2 of SWQR (Table A 8).

For the first time in the YRB, the collected samples were also analyzed for 45 priority substances (Appendix E - Table A 9) and 250 river basin specific pollutants (Appendix E - Table A 10) at the TUBITAK Marmara Research Center. In addition to analyses of chemical and physicochemical parameters, the flow rate of surface waters and point discharges in the YRB were measured in the scope of the monitoring studies.

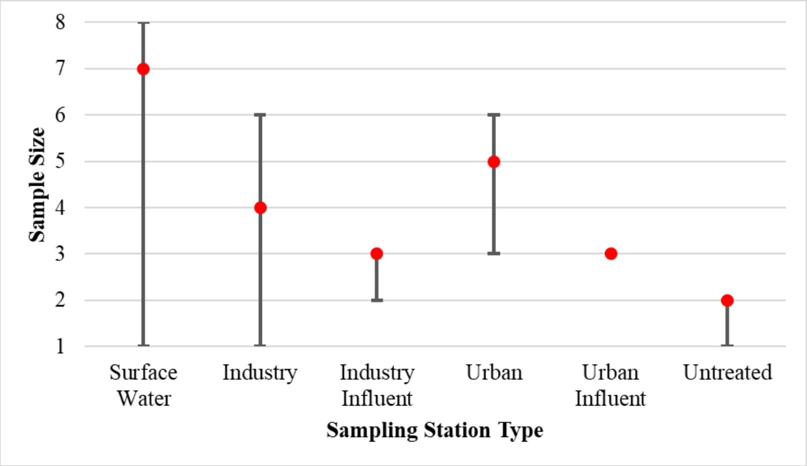

Figure 9. Average Number of Samples Collected from Each Station Type

According to EQSD (2008/105/EC) and SWQR (Official Gazette No: 29797, Date: August 10, 2016), the environmental concentrations of priority substances and river basin specific pollutants should not exceed their EQS. The EQSs for priority substances are provided in Annex V Table 5 of the SWQR, and EQS for river basin specific pollutants are provided in Annex V Table 4 of the SWQR. The EQS are expressed in annual average EQS (AA-EQS) or maximum allowable concentration EQS (MAC-EQS) (Table 9). The AA-EQS is the annual average value of a pollutant concentration established to provide protection against long-term exposure, while MAC-EQS is the concentration limit established to protect against short-term exposure. Some exceptions are possible for MAC-EQS. For example, Di(2-ethylhexyl)-phthalate (DEHP) does not have any MAC-EQS identified. In this situation, AA-EQS values are considered protective against short-term pollution peaks in continuous discharges since they are significantly lower than the values derived based on acute toxicity.

Table 9. Environmental Quality Standards of Alachlor, Benzene, and DEHP

Pollutant	**CAS No**	**Inland Surface Waters**		**Other Surface Waters**	
		AA-EQS (µg/L)	**MAC-EQS (µg/L)**	**AA-EQS (µg/L)**	**MAC-EQS (µg/L)**
Alachlor	15972-60-8	0.3	0.7	0.3	0.7
Benzene	71-43-2	10	50	8	50
Di(2-ethylhexyl)-phthalate (DEHP)	117-81-7	1.3	N/A	1.3	N/A

In this regard, the long-term pollution evaluation of 45 priority substances and 250 river basin specific pollutants in the YRB was based on their AA-EQS values. When the sampling results of eight monitoring studies were evaluated, it was seen that the concentrations of metals were very high[2] in the YRB. It was concluded that high metal concentration could be due to the presence of natural formations in the river basin, such as soil type and rock formations. According to SWQR (Official Gazette No: 29797, Date: August 10, 2016), background concentrations should be taken into account during water resources management, and the environmental targets are accepted as the sum of background concentration and the EQS if the background concentrations are higher than the EQS. A background concentration determination study was carried out for the metals detected in the YRB, and out of 28 metals detected in the YRB, Aluminum (Al), Copper (Cu) and Iron (Fe) were determined to have the background concentrations added to their environmental targets and provided in Table 10.

Table 10. Background Concentrations of Metals in the YRB (TUBITAK, 2019)

Metals	**Background Concentration (µg/L)**	**EQS (µg/L)**	**Environmental Target (µg/L)**
Aluminum (Al)	45.6	2.2	47.8
Copper (Cu)	11.6	1.6	13.2
Iron (Fe)	62.6	36	98.6

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[2] A discussion on metal concentrations in the YRB is provided in Chapter 3.3.1.

Although SWQR (Official Gazette No: 29797, Date: August 10, 2016) came into force in 2016, the laboratory infrastructure in Turkey was not ready for analysis of some pollutants. Only two laboratories in Turkey, the Environment Reference Laboratory of the Ministry of Environment, Urbanization and Climate Change, and the Environmental and Cleaner Production Institute Laboratory of the TUBITAK Marmara Research Center were able to analyze micropollutants.

Although most of the micropollutants were analyzed during monitoring studies, two priority substances (C10-13 chloroalkanes, Tributyltin compounds) and seven river basin specific pollutants (Dibutyltin oxide, EDTA, Chloroacetic acid, n-butyltin trichloride, tert-butyl-4-methoxyphenol, Triphenyltin; fentin and 2,4-d isooctyl ester) could not be analyzed during the first four monitoring studies. Additionally, EDTA, Chloroacetic acid, and tert-butyl-4-methoxyphenol could not be analyzed during the complete monitoring campaign and 2,4-d isooctyl ester could only be analyzed for only two sampling periods.

According to Commission Directive 2009/90/EC - Technical Specifications for Chemical Analysis and Monitoring of Water Status (European Commission, 2009a), if the measured environmental concentration of a substance is below the limit of quantification (LoQ), half of the LoQ value is used for calculation of the annual average value of that substance. One minor difference of this study was that the limit of detection (LoD) values of all pollutants were accepted as LoQ since LoD was provided instead of the LoQ values by the TUBITAK Marmara Research Center laboratory (LoD is hereon referred to as LoQ while discussing results of the monitoring study). LoQ is the minimum level at which the analyte can be quantified with acceptable accuracy and precision, while LoD is the lowest amount of analyte in a sample that can be detected but not necessarily quantitated as an exact value. The major drawback of using LoQ or LoD value while calculating the annual mean is that the confidence level of reporting true positive value decreases, and consequently, the risk of reporting a false positive or failing to detect the presence of a substance increases (European Commission, 2009b).

When the results of the analyses conducted on samples collected from the YRB were evaluated, it was seen that 160,486 measurements were reported during the monitoring campaign and approximately 88% of the total measurement were reported as less than or equal to the LoQ value. When the LoQ value of each micropollutant was compared to its EQS, it was seen that half of the LoQ value of five priority substances (Tributyltin compounds, Perfluorooctane sulfonic acid and derivatives (PFOS), Cypermethrin, Hexabromocyclododecane (HBCDD), Heptachlor and heptachlor epoxide), and three river basin specific pollutants (Clofibric acid, Cyfluthrin, Tefluthrin) were greater than their EQS. Also, half of the LoQ value of Bromine (Br) was greater than its EQS for three monitoring studies. This situation led to the false exceedance of EQS in all samples for these pollutants. In addition, the LoQ value of two priority substances (Endosulfan and Mercury), and 18 river basin specific pollutants were equal to their EQS value.

Due to the above-mentioned problems in analyses of micropollutants and low LoQ values, the micropollutants given in Table 11 were excluded from the evaluation of micropollutants in the YRB samples. Among these micropollutants, Tributyltin compounds, PFOS, Cypermethrin, HBCDD, Heptachlor and heptachlor epoxide, Clofibric acid, Cyfluthrin, and Tefluthrin were excluded from the calculation of annual mean in the surface water monitoring stations and WWTP effluents. The concentration and occurrence of these pollutants in the YRB were evaluated in Chapter 3. On the other hand, EDTA, Chloroacetic acid, tert-butyl-4-methoxyphenol, and 2,4-d isooctyl ester were excluded from any kind of evaluation. For evaluation of Polyaromatic hydrocarbons (PAH), the corresponding AA-EQS in water refers to the concentration of benzo(a)pyrene, since it can be considered a marker for the other PAHs.

Table 11. List of Pollutants Excluded from Evaluation

Pollutant	**Pollutant Type**	**Reason for Exclusion**	**Extent of Exclusion**
Tributyltin compounds	Priority substance	½ * LoQ is greater than the EQS	Excluded from calculation of annual mean concentration
PFOS	Priority substance		
Cypermethrin	Priority substance		
HBCDD	Priority substance		
Heptachlor and heptachlor epoxide	Priority substance		
Clofibric acid	Specific pollutant		
Cyfluthrin	Specific pollutant		
Tefluthrin	Specific pollutant		
EDTA	Specific pollutant	Analyses unavailable during the whole monitoring campaign	Excluded from all evaluations
Chloroacetic acid	Specific pollutant		
tert-butyl-4-methoxyphenol	Specific pollutant		
2,4-d isooctyl ester	Specific pollutant	Analyses unavailable during six monitoring studies	
Polyaromatic hydrocarbons (PAH)	Priority substance	(PAHs) are a class of chemicals. benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene were monitored as indicators.	Benzo(a)pyrene and other PAHs were monitored

CHAPTER 3

OCCURRENCE OF MICROPOLLUTANTS IN THE YEŞİLIRMAK RIVER BASIN

The major environmental pressures on the surface water bodies of the YRB were discussed in Chapter 2.2. Domestic and urban wastewater discharges (both treated and untreated) were determined as the highest impact anthropogenic sources, while industrial activities such as the manufacture of sugar, processing and preserving food, manufacture of paper and paper products, mining of non-ferrous metal ores, mixed manufacturing activities and agricultural practices were determined as other sources of pollution in the YRB. Both the EQSD (2008/105/EC) and SWQR (Official Gazette No: 29797, Date: August 10, 2016) require monitoring of 45 priority substances (Directive 2013/39/EU) and river basin specific pollutants to assess the chemical status of water bodies.

As discussed in Chapter 2.3, it is technically and financially challenging to monitor micropollutants in a river basin for such a large number of pollutants however, it is necessary to establish an inventory of micropollutant pollution for the preparation of RBMPs and developing management strategies. This is the first comprehensive study shifting the focus from conventional water quality monitoring to micropollutant monitoring in the YRB. The results presented in this chapter[3] will help screen the national list of river basin specific pollutants in the YRB and develop a cost-effective monitoring strategy by statistical evaluation of the monitoring data.

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[3] Parts of this chapter was published as the following article: Kucuk, E., Pilevneli, T., Onder Erguven, G. et al. Occurrence of micropollutants in the Yesilirmak River Basin, Turkey. Environ Sci Pollut Res 28, 24830–24846 (2021). https://doi.org/10.1007/s11356-021-13013-6

3.1 Introduction

3.1.1 Background

The EU WFD (2000/60/EC) is regarded as the most significant and far-reaching legislation in the EU published by the European Commission, which adopts a river basin management approach (European Commission, 2000). The ultimate aim of the WFD is to reach "good status" in all European waters by reducing contamination by chemicals while ensuring a flourishing ecosystem. An RBMP is an important part of WFD implementation, which requires characterization of the basin, establishing a water quality monitoring program, setting environmental objectives, and a program of measures to reach and sustain the good status in all water bodies within the river basin.

The chemical status assessment is done in accordance with the environmental pollution caused by "hazardous substances", which are defined as substances or groups of substances that are toxic, persistent, and bio-accumulative. These pollutants are defined in Annex VIII of the WFD (2000/60/EC) as the following:

- Organohalogen compounds and substances which may form such compounds in the aquatic environment,
- Organophosphorous compounds,
- Organotin compounds,
- Substances and preparations, or the breakdown products of such, which have been proved to possess carcinogenic or mutagenic properties or properties that may affect steroidogenic, thyroid, reproduction, or other endocrine-related functions in or via the aquatic environment,
- Persistent hydrocarbons and persistent and bioaccumulative organic toxic substances,
- Cyanides,
- Metals and their compounds,

- Arsenic and its compounds,
- Biocides and plant protection products (PPPs).

According to Eurostat, both production and consumption of hazardous chemicals since 2004 had reached their minimum in 2009 and the total production and consumption increased since then to a new peak in 2020, which is approximately 95% of the reference year (Eurostat, 2021). A recent publication notes that more than 140,000 chemicals were produced by humans, while on average, 1,500 new chemical substances are produced in the USA alone, and many of these substances are known to be toxic (Naidu et al., 2021). Since it is practically impossible to regulate all chemicals on the market due to budget and time constraints, WFD brings a practical perspective and sub-categorizes hazardous substances as “priority hazardous substances”, “hazardous substances” and “river basin specific pollutants”. The WFD defines 45 substances and a group of substances as “priority”, and the Member States are required to implement the necessary measures to eliminate pollution of surface water by these substances. These measures should reverse any significant and sustained upward trend in the concentration of those pollutants in the receiving environment, and the concentrations must be reduced progressively by ceasing or phasing out emissions, discharges, and losses of priority substances. The target concentrations to be reached in the receiving environment are set by the EQSD (2013/39/EU). The EQS is defined as “the concentration of a particular pollutant or group of pollutants in water, sediment or biota, which should not be exceeded in order to protect human health and the environment”.

In addition to priority pollutants, the WFD adds the necessity for all Member States to identify river basin specific pollutants by following the generic approach provided in WFD Guidance Document No: 3 – Analysis of Pressures and Impacts (European Commission, 2003a). In Turkey, 45 priority substances and their EQS were adopted in the SWQR (Official Gazette No: 29797, Date: August 10, 2016). A big effort was put into the identification of the river basin specific pollutants. Three large-scale projects had been carried out to create an inventory of chemical substances used in Turkey:

- Project on the Control of Hazardous Substance Pollution (TMKK) (MoAF, 2013)
- Identification of Hazardous Chemicals in Coastal and Transitional Waters and Ecological Shore Dynamics Project (KIYITEMA) (MoAF, 2014a)
- Identification of Water Pollution due to Usage of Crop Protection Products and Identification of Environmental Quality Standards of Chemicals or Chemical Groups Project (BIKOP) (MoAF, 2014b)

A top-down methodology was applied to the inventories created in projects TMKK, KIYITEMA, and BIKOP. A total of 3102 chemicals in TMKK, 3300 chemicals in KIYITEMA, and 462 chemicals in BİKOP were added to the chemical inventory of Turkey. Combined Monitoring Based and Modeling Based Priority Setting (COMMPS) and Total Hazard Value Score (THVS) methods were applied by TUBITAK MAM in order to eliminate and prioritize these chemicals (MoAF, 2014b). The outcome of the total prioritization procedure was 116 point-sourced parameters and 160 diffuse-sourced parameters. These pollutants were refined as 250 river basin specific pollutants and covered in the 2015 amendment of the SWQR. Approximately 60% of these pollutants are crop protection products, including herbicides (15.7%), insecticides (27.2%), fungicides (18.1%), and growth regulators (1.6%) (Figure 10). Pharmaceuticals and personal care products constitute 7.5% of all pollutants and 7.1% is metals, metalloids, and halogens. The remaining 22.8% of pollutants are defined as industrial organic compounds, which are commonly used in the manufacturing of commercial products.

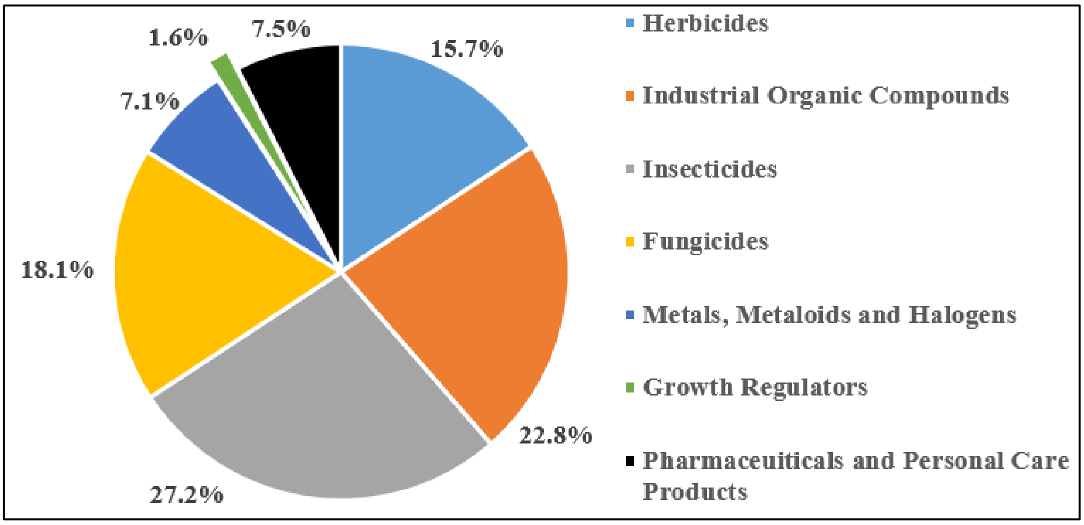

Figure 10. Distribution of River Basin Specific Pollutants Defined in SWQR

SWQR (Official Gazette No: 29797, Date: August 10, 2016) require monitoring of 45 priority substances (Directive 2013/39/EU) and 250 river basin specific pollutants to assess the chemical status of water bodies. The list of 250 river basin specific pollutants is shared across 25 river basins of Turkey since a top-down methodology was adopted during the identification of these substances. In the EU, the total number of river basin specific pollutants monitored by the 14 Member States was reported as 452 substances, and the average substance count of Member States was 55 (Irmer et al., 2014). Bottom-up, targeted chemical surface water assessments are required in order to determine river basin specific pollutants and their ecotoxicological properties. In addition, it is not possible to monitor all chemical substances for prolonged durations and it is almost necessary to identify the chemicals posing the highest risk to human and environmental health due to limited time and resources (Donnachie et al., 2016).

Several chemical screening tools were developed for identifying, classifying, and ranking chemical substances (Bu et al., 2013; Johnson et al., 2017; Kuzmanović et al., 2015), but beyond time and resource limitations, there are major technical obstacles behind chemical status monitoring. The micropollutants are diverse, persistent, and present at very low concentrations in the environment. The EQSs of many micropollutants are lower than or very close to their LoQ values. As a result, even after 14 years since the EQSD (Directive 2008/105/EC) came into force in the EU, the chemical status assessment concept introduced by the WFD remains to be criticized (Loga & Przeździecki, 2021). Analytically determining concentrations of some priority substances is found “virtually impossible” and improvements leading to lower detection limits are in need (Altenburger et al., 2015). The limitations of this study were discussed in Chapter 2.3, and the LoQs of eight micropollutants were reported to be inadequate. Cost-intensive measurements of priority substances and river basin specific pollutants, and infrastructure requirements remain a burden before achieving monitoring goals. A recent study conducted in Boğazköy Dam in the Sakarya River Basin by one of the leading research institutions in Turkey is a prime example of this situation. The laboratory analyses carried out for only six priority substances could not satisfy the LoQ values required for environmental pollution assessment, since their LoQ is higher than the EQS (Yılmaz & Erdoğan, 2020). The ratio of censored data (the ratio of test results less than or equal to the LoQ value in all samples) is also a common problem among EU countries (Merrington et al., 2021). The censored data percentage in the EU is quite similar to the findings in this study with minor exceptions (Table 12). The LoQ reported for Diclofenac and Imidacloprid is approximately 2-2.5 times lower than the value reported in this study, while the LoQ of Thiamethoxam is 25 times higher. The relationship between the LoQ and censored data is also tied to its environmental concentration, such that if the environmental concentration is higher than the LoQ, it is not counted towards censored data. For example, the LoQ of Thiamethoxam is in the range of 0-0.05 µg/L in the EU and while Austria and France report 99% censored data, the UK reports only 37% with the same LoQ. This shows that 63% of all measurements in the UK are greater than 0.05 µg/L; however, it is not possible to report concentrations of Thiamethoxam in the rest of the EU with high confidence, such that if it is actually zero or not. On the other hand, 95% of all Thiamethoxam measurement results in this study were reported as censored, even though the LoQ in this study was determined as 0.002 µg/L. Until the capabilities of the analytical techniques improve, passive sampling and monitoring of the biota is the recommended methodology to evaluate the environmental compliance of these substances (Brack et al., 2017).

Table 12. Comparison of Censored Data Ratios of Diclofenac, Imidacloprid, and Thiamethoxam in the EU with Study Results

Country	**Diclofenac**		**Imidacloprid**		**Thiamethoxam**	
	Censored Data	**LoQ (µg/L)**	**Censored Data**	**LoQ (µg/L)**	**Censored Data**	**LoQ (µg/L)**
Austria	31 %	0 – 0.05	93 %	0 – 0.0085	100 %	0 – 0.05
France	64 %		72 %		99 %	
Netherlands	46 %		56 %		86 %	
UK	44 %		10 %		37 %	
EU Average	52 %		69 %		97 %	
This Study	97 %	0.1	89 %	0.02	95 %	0.002

In the last decade, extensive surface water sampling campaigns were carried out to evaluate the extent of micropollutant pollution (Bradley et al., 2017; Sousa et al., 2018), which aimed to analyze only the target chemicals (Wood et al., 2017). A targeted monitoring program is essential to reveal emission patterns and track pollution sources (Pistocchi et al., 2019); however, there is always a possibility of not being able to characterize the sources or failing to identify indicators of source specificity (Du et al., 2020). The advances in the use of liquid or gas chromatography coupled with high-resolution mass spectrometry (LC-HRMS, GC-HRMS) allowed the development of non-target screening (NTS), which can detect hundreds to thousands of known and unidentified chemical substances with ease (Du et al., 2020). The NTS introduced a substantial amount of new chemicals and shifted the focus from target chemical monitoring to the identification of representative substances (Emadian et al., 2021). Researchers have developed statistical methods to classify these new pollutants and tried to describe their occurrences, sources, concentration patterns, and load contributions, as well as to prioritize these substances based on their associated risks in the aquatic environment (Carpenter et al., 2019; Carpenter & Helbling, 2018b; Du et al., 2020; Emadian et al., 2021; Hollender et al., 2019; Krauss et al., 2019; Tian et al., 2020). Despite all these advantages, it should be remembered that targeted chemical monitoring is more sensitive, much faster and more importantly the number of laboratories that can conduct this type of analysis is more common (Hollender et al., 2019).

3.1.2 Objective and Scope

The aim of this study is to investigate the occurrence of micropollutants in the Yesilirmak River and to develop a cost-effective monitoring strategy based on spatio-temporal occurrence patterns. Although this study is part of a targeted chemical monitoring assessment, the monitoring data is large enough to conduct descriptive statistical analyses to evaluate priority substances and river basin specific pollutants in the YRB and their spatio-temporal variances. In this regard, a statistical screening approach was adopted to identify the cause of concern for micropollutants in the YRB, and spatio-temporal patterns of these pollutants were evaluated to determine sampling locations and sampling seasons under three main pollutant categories, i.e. metal and metallic substances, PPPs, and industrial organic compounds.

3.2 Methodology

3.2.1 Occurrence Frequency of Micropollutants in the Yeşilırmak River Basin

In order to determine the environmental significance of micropollutants in the YRB, sampling results from 52 surface water monitoring stations designated in the Yeşilırmak River and its tributaries were used. The sampling points and location of anthropogenic pressure are given in Figure 8. The location of significant anthropogenic pressures was the main factor in the determination of surface water monitoring stations. In accordance with the SWQR (Official Gazette No: 29797, Date: August 10, 2016), 45 priority substances and 250 river basin specific pollutants, including biocides, pharmaceuticals, hormones, personal care products, metals, metalloids, halogens and other industrial organic compounds were selected as target chemicals. From 52 surface water monitoring stations, 345 samples were collected and 100,291 analyses were conducted to assess priority substances, river basin specific pollutants, and their indicator groups. In addition, general physico-chemical parameters, temperature, pH, conductivity, dissolved oxygen, oxygen saturation, total dissolved solids, chemical oxygen demand, total organic carbon, ammonia, nitrate, nitrite, total Kjeldahl nitrogen, and total phosphorus were measured for all samples.

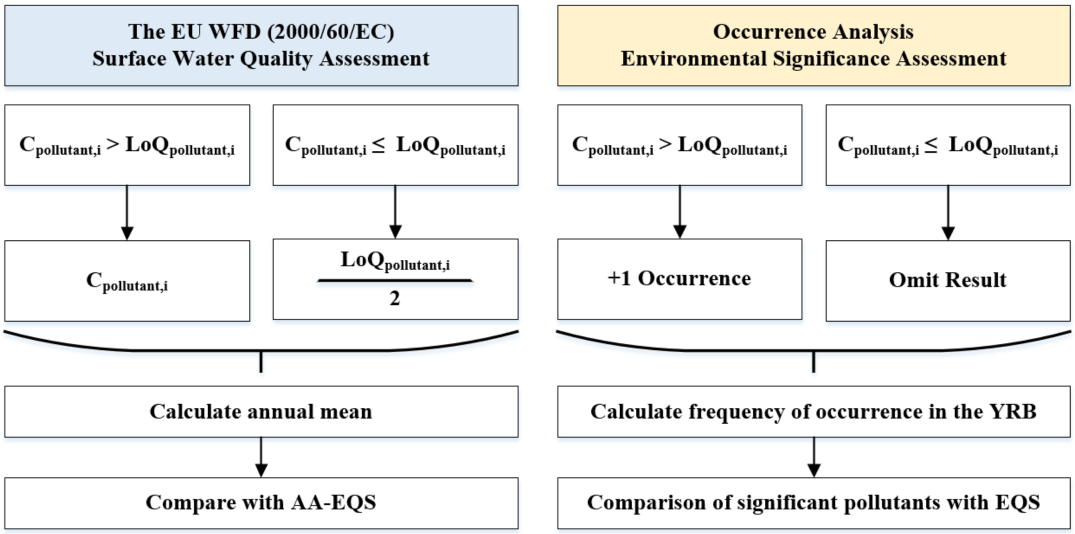

Figure 11. Differences between Surface Water Quality Assessment and Occurrence Analysis

According to the WFD, the status of a water body is evaluated according to the mean annual concentrations of priority substances and river basin specific pollutants (Figure 11). However, while determining river basin-specific pollutants, according to the generic approach (Figure 1), the concentration of pollutants in surface waters should be compared with benchmarks such as Lethal Concentration 50 (LC50), No Observed Effect Concentration (NOEC), critical load and EQS. Since the EQS of river basin specific pollutants are already identified with the SWQR, the frequency of occurrence and sample size of each micropollutant were taken as criteria to identify significant pollutants of the YRB.

The occurrence analyses were based on the number of times a pollutant measurement was quantified above its LoQ value. Although priority substances do not undergo any significance tests, the same methodology was also applied to them to identify their significance in the YRB. In order to be statistically representative, the minimum sample size threshold for each micropollutant was determined as 20. This threshold was determined based on the concentrations of pollutants, where each pollutant should have a concentration above its LoQ value in at least 20 samples. This corresponded to a frequency of 5.5% in all samples. The frequency of occurrence was calculated for all pollutants and any pollutant with a frequency of less than 5.5% was screened out. The frequency of occurrence was calculated according to Equation-2.

$$\begin{matrix} Frequency\ of \\ Occurrence\ (\%) \end{matrix} = \frac{\#\ of\ samples\ Pollutant_i\ Quantified}{\#\ of\ samples\ Pollutant_i\ Analyzed} \qquad (Equation - 2)$$

where;

i: Micropollutants

Pollutant$_i$ Quantified: Total number of samples where the concentration of pollutant i is greater than the LoQ value

Pollutant$_i$ Analyzed: Total number of samples analyzed for pollutant i

3.2.2 Removal of Outlier Values in the Dataset

An outlier is a data point, which differs significantly from other observations. The outliers were removed from the data set of each micropollutant with a frequency of occurrence greater than 5.5%. The outliers generally occur due to errors during measurement or sample collection. Outliers are generally extremities in a dataset, which heavily influence the mean and causes skewness in the distribution of data

(Mohr et al., 2021). The interquartile range (IQR) method of outlier detection was used for removing outlier values. Box & Whisker Plot was used to visualize the distribution of each micropollutant data (Figure 12).

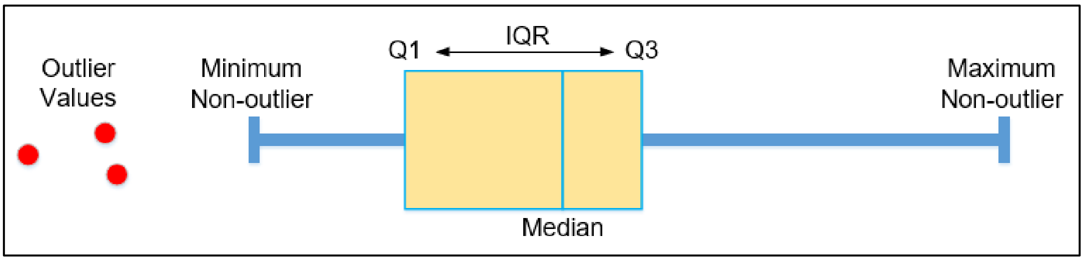

Figure 12. Box & Whisker Plot and Interquartile Range

Q1 is the first quartile of the data, which corresponds to the 25th percentile, where 25% of the data lies between minimum and Q1. Q3 is the third quartile of the data, which corresponds to the 75th percentile, where 75% of the data lies between minimum and Q3, or where 25% of the data lies between maximum and Q3. The IQR is the length of the interval between the 25th and 75th percentiles and describes the range of the middle half of the distribution (Equation-3). The median is the center point, which is also called the second quartile and corresponds to the 50th percentile. The outlier range is then determined by calculating the lower and upper bounds (Equation-4). Any data point less than the lower bound or more than the upper bound was considered an outlier and removed from the dataset.

$$IQR = Q3 - Q1 \qquad (Equation - 3)$$

$$Outlier\ Range = \begin{cases} Lower\ Bound = Q1 - 1.5\ x\ IQR \\ Upper\ Bound = Q3 + 1.5\ x\ IQR \end{cases} \qquad (Equation - 4)$$

3.2.3 Identification of Pollutants of Concern

The significance of frequent micropollutants was evaluated based on EQS concentrations. The extent of AA-EQS exceedance for each micropollutant was calculated using Equation-5, where $C_{Average,i}$ is the mean annual environmental concentration of micropollutant i, and AA-EQS is the annual average EQS of the same micropollutant.

$$Ratio\ of\ AA - EQS\ _{i}(\%) = \frac{C_{Average,i}}{AA - EQS_{i}} \times 100 \qquad (Equation - 5)$$

$C_{Average,i}$ of each micropollutant was calculated as the average of surface water concentrations across all monitoring stations, which are greater than the LoQ values. After calculating the ratio of AA-EQS, all micropollutants with a ratio of greater than 100% were identified as the "cause of concern" micropollutants. A threshold of 100% was selected to follow a regulatory context since a ratio of greater than 100% across all monitoring stations shows that the concentration of that pollutant in the YRB is higher than the limit value to provide protection against long-term exposure. MAC-EQS was not used during the evaluation of significant micropollutants in the YRB since AA-EQS is always lower than MAC-EQS and a conservative approach was aimed in this study. The ratios of MAC-EQS to AA-EQS for priority substances and river basin specific pollutants are provided in Table 13. The AA-EQS of 66 micropollutants is equal to their MAC-EQS. The MAC-EQS of 98 micropollutants is 1 to 10 times higher than their AA-EQS, and the MAC-EQS of 108 micropollutants is at least 10 times higher than their AA-EQS. According to these values, evaluating using AA-EQS satisfies the conservative approach.

Table 13. The ratio of MAC-EQS to AA-EQS for Priority Substances and River Basin Specific Pollutants Defined in SWQR

MAC-EQS/AA-EQS Ratio	**# of Pollutants**
x =1 *	66 + 51
$1 < x \leq 10$	98
$10 < x \leq 100$	89
≥ 100	19

* The MAC-EQS/AA-EQS of 51 micropollutants/micropollutant groups could not be calculated since either of them is missing. According to WFD, AA-EQS and MAC-EQS are used in place of each other when either of them is missing.

3.3 Results and Discussion

3.3.1 Occurrence of Micropollutants in the Yeşilırmak River Basin

The frequency of occurrence of micropollutants in the YRB was calculated according to Equation – 2 and detailed results are provided in Appendix F - Table A 11 and summarized in Table 14. Less than 10% of all PPPs (including fungicides, herbicides, insecticides, and growth regulators), which are expected to be diffused sourced had a frequency of greater than 5.5%. Similarly, 16% of pharmaceuticals and personal care products (PCPs) and 22% of industrial organic compounds had a frequency of greater than 5.5%. On the other hand, 90% of metals, metalloids, and halogens had a frequency of greater than 5.5%. Only metals were detected with a frequency of greater than 71%. Among all micropollutants, 93% of them had an occurrence between 0-30 percent in the YRB water bodies.

Table 14. Frequency of Occurrence Distribution of Pollutant Groups in the YRB Surface Waters

Pollutant Group	**0 - 5.5%**	**5.5 - 30%**	**30 - 60%**	**60 - 90%**	**+ 90%**
Fungicides	45	4	0	0	0
Herbicides	46	3	0	0	0
Insecticides	64	9	0	0	0
Growth Regulators	4	0	0	0	0
Metals/Metalloids/Halogens	2	0	4	0	15
Industrial Organic Compounds	67	16	2	1	0
Pharmaceuticals/PCPs	16	3	0	0	0

Two-hundredth-and-forty-four micropollutants had a frequency of less than 5.5%, whereas 128 of them were not detected in any sample. Among undetected micropollutants, 16 of them are priority substances and 112 of them are river basin specific pollutants. Six of these priority substances are industrial organic compounds (C10-13 Chloroalkanes, Tributyltin compounds, Brominated diphenyl ethers, Pentachlorophenol, PFOS, HBCDD), and ten of them are PPPs (Quinoxyfen, Cybutryne, Alachlor, Atrazine, Simazine, Trifluralin, Terbutryn, Chlorfenvinphos, Endosulfan, Dicofol). Eighty-two of the undetected river basin specific pollutants are PPPs, 23 of them are industrial organic compounds and seven pollutants are pharmaceutical and personal care products.

Micropollutants with a frequency of occurrence of more than 5.5% were selected for further evaluation and the distribution of these pollutants among pollutant groups is summarized in Figure 13. Xylene (m), Chlorsulphuron, and Free CN were identified as pollutants with a frequency of more than 5.5% but removed from the list since they have less than 20 samples quantified. The majority of selected micropollutants were identified as industrial organic compounds (17), metals (15), metalloids (3), and halogens (1). Among PPPs, insecticides (8) were identified more than fungicides (4) and herbicides (3). Only three pharmaceuticals and personal care products were identified as selected micropollutants.

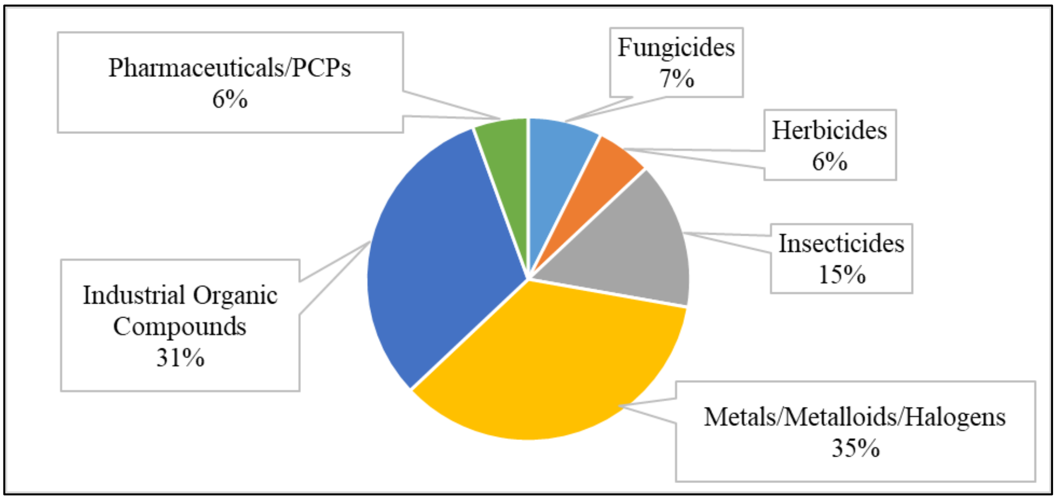

Figure 13. Distribution of Selected Micropollutants among Pollutant Groups

The outlier values were removed by the IQR method of outlier detection and the median, average, minimum, and maximum concentrations in 52 surface water sampling stations were calculated for all selected micropollutants. The median, mean, minimum, and maximum concentrations of 54 selected micropollutants and their frequency of occurrence in the YRB surface water sampling stations are given in Table 15. Only metals (Ni, Al, As, Ba, Co, Cu, Fe, V, Zn, Pb, Cr) and metalloids (B, Si) were consistently detected in almost all of the surface water samples collected from the YRB, with a detection frequency of greater than 99%. They were followed by other metals and metalloids (Ag, Sb) and petroleum hydrocarbons (PHCs) with occurrence frequencies varying between 87 to 97%. The metals and metalloids were detected in at least 333 surface water samples out of 346 collected throughout the monitoring campaign. PHCs could only be analyzed in 217 surface water samples and 190 of them had been quantified above LoQ value. Among 45 priority substances and 250 river basin specific pollutants monitored in the YRB, the above-mentioned 16 micropollutants had a significantly greater occurrence rate, whereas the remaining 38 micropollutants had occurrence frequencies varying between 5.5 to 36%. The metals and metalloids were detected with an average frequency of 6 times higher than industrial organic compounds and 11 times higher than PPPs. In the detection range of 10 to 36%, three metals and one halogen (Cd, Be, Ti and Br), ten industrial organic compounds (Dioxin-like compounds, Nonylphenols, Trichloromethane, Anthracene, Dioxin, Diethyl phthalate, Phenanthrene, Di(2-ethylhexyl)-phthalate (DEHP), Bisphenol-A (BPA), Fluorene), and six PPPs (Buprofezin, Dichlorvos, Piperonyl butoxide, Benzyl Benzoate, Cypermethrin, Hexachlorocyclohexane) were quantified in the YRB. The remaining 18 micropollutants had occurrence frequencies varying between 5.5 to 10%. Among these 18 micropollutants, nine of them were identified as PPPs (Hexachlorobenzene, Carbendazim, Diflubenzuron, Imidacloprid, Acetachlor, Epoxiconazole, Ethalfluralin, Flutriafol, Fluroxypyr), six of them were identified as industrial organic compounds (Dichloromethane (DCM), Acenaphthene, 1,1-Dichloroethane, 2,6 xylenol, Fluoranthene, PCB 28), and three of them were identified as pharmaceuticals and personal care products (Dibutyl phthalate (DBP), Diisobutyl adipate, Diphenyl ether).

Table 15. The Median Mean, Minimum, and Maximum Surface Water Monitoring Station Concentrations of Selected Pollutants in the YRB

Pollutants*	**Median (µg/L)**	**Mean (µg/L)**	**Min. (µg/L)**	**Max. (µg/L)**	**Freq. (%)**
Si	6.2E+03	6.7E+03	4.0E+02	3.0E+04	100.0
Al	2.6E+02	4.9E+02	2.5E+01	9.0E+03	100.0
Fe	3.9E+02	7.1E+02	3.6E+01	7.5E+03	100.0
B	2.0E+02	2.2E+02	1.8E+01	9.9E+02	100.0
Ba	6.5E+01	7.2E+01	2.1E+00	8.9E+02	100.0
Zn	1.3E+01	5.8E+01	6.7E-01	7.4E+02	100.0
Cu	1.7E+01	2.2E+01	5.8E-01	2.5E+02	100.0
As	3.8E+00	8.8E+00	3.1E-01	1.9E+02	100.0
Ni	4.2E+00	7.0E+00	1.8E-01	1.4E+02	100.0
V	3.8E+00	5.1E+00	5.8E-01	8.1E+01	100.0
Co	5.2E-01	1.3E+00	4.3E-02	3.5E+01	100.0
Pb	2.0E+00	4.3E+00	1.5E-01	1.1E+02	99.7
Cr	2.0E+00	3.4E+00	2.8E-01	4.4E+01	99.7
Ag	1.1E-01	1.8E-01	2.2E-02	2.5E+00	97.4
Sb	1.1E+00	5.5E+00	1.2E-01	8.0E+01	96.5
PHCs	2.1E+02	2.7E+02	5.2E+01	1.0E+03	87.6
Dioxin-like compounds	8.6E-05	2.2E-04	1.9E-05	2.0E-03	36.1
Cd	1.3E-01	6.7E-01	6.0E-02	1.3E+01	33.3
Br	9.6E+01	1.6E+02	3.1E+01	8.0E+02	29.6
Be	6.1E-02	1.1E-01	3.7E-02	1.0E+00	24.9
Nonylphenols	1.6E-01	2.4E-01	4.5E-03	2.8E+00	21.2
Ti	1.4E+01	3.0E+01	7.7E+00	5.2E+02	20.7
Trichloromethane	1.0E+00	1.2E+00	1.1E-01	5.6E+00	19.4
Anthracene	8.9E-03	1.2E-02	1.6E-03	4.0E-02	18.8
Buprofezin	2.0E-01	1.8E-01	1.0E-02	3.4E-01	17.1
Dichlorvos	1.1E-01	1.3E-01	1.3E-02	4.6E-01	16.2
Dioxin	4.0E-05	8.6E-05	6.0E-06	2.8E-04	14.8
Diethyl phthalate	8.3E-02	2.9E-01	1.9E-03	2.1E+00	13.6
Phenanthrene	5.2E-02	8.3E-02	1.5E-03	3.7E-01	13.6
Di(2-ethylhexyl)-phthalate (DEHP)	3.9E-01	9.8E-01	3.7E-02	8.9E+00	11.9
Piperonyl butoxide	3.2E-02	7.9E-02	1.3E-02	6.9E-01	11.0
Bisphenol-A (BPA)	7.2E-03	1.8E-02	1.1E-03	1.1E-01	11.0
Fluorene	8.1E-03	2.2E-02	1.5E-03	1.1E-01	11.0
Benzyl benzoate	6.4E-02	1.6E-01	3.8E-03	1.5E+00	10.7
Cypermethrin	8.3E-02	1.1E-01	3.1E-02	3.8E-01	10.5

Table 15. The Median Mean, Minimum, and Maximum Surface Water Monitoring Station Concentrations of Selected Pollutants in the YRB (Continued)

Pollutants*	**Median (µg/L)**	**Mean (µg/L)**	**Min. (µg/L)**	**Max. (µg/L)**	**Freq. (%)**
Hexachlorocyclohexane	2.4E-02	4.6E-02	5.6E-03	3.0E-01	10.1
Carbendazim	3.0E-02	1.2E-01	1.0E-02	8.0E-01	9.6
Acenaphthene	1.1E-02	1.3E-02	5.5E-03	3.4E-02	9.6
2,6 xylenol	1.8E-01	1.4E+00	1.4E-03	1.3E+01	9.0
1,1-Dichloroethane	3.0E-01	5.1E-01	1.1E-01	3.9E+00	9.0
Fluoranthene	4.9E-03	1.0E-02	1.2E-03	4.0E-02	8.4
Imidacloprid	3.6E-02	9.3E-02	2.5E-02	6.7E-01	8.1
Acetachlor	2.9E-02	3.3E-02	1.0E-02	9.3E-02	7.5
Ethalfluralin	6.5E-01	9.9E-01	1.3E-02	3.4E+00	7.2
Epoxiconazole	1.9E-02	5.5E-02	6.0E-03	3.2E-01	7.2
Dibutyl phthalate (DBP)	2.8E-02	7.4E-02	1.1E-02	4.7E-01	7.0
Flutriafol	1.2E-01	2.3E-01	5.8E-02	2.0E+00	6.7
Fluroxypyr	3.8E-01	4.3E-01	2.0E-01	9.6E-01	6.4
Diisobutyl adipate	4.9E-02	7.9E-02	1.3E-02	3.1E-01	6.4
PCB 28	2.7E-03	3.8E-03	1.1E-03	1.5E-02	6.4
Diflubenzuron	2.5E-01	4.3E-01	6.1E-02	2.4E+00	6.1
Diphenyl ether	1.6E+00	3.7E+00	1.2E-02	2.6E+01	5.8
Dichloromethane (DCM)	7.5E+00	8.3E+00	2.5E+00	1.7E+01	5.8
Carbendazim	3.0E-02	1.2E-01	1.0E-02	8.0E-01	9.6

** Priority substances are given in italic*

Similar to the occurrence of micropollutants, metals and metalloids had higher concentrations with respect to the concentration of organic micropollutants. Surface water monitoring study results showing the concentration distribution of selected micropollutants are given in Figure 14. Green dots show concentrations below AA-EQS, while red dots show concentrations exceeding the AA-EQS. The concentration of selected micropollutants ranged from $6x10^{-6}$ µg/L to 30 mg/L. The highest concentration was measured for Si, which had concentrations ranging from 0.4 mg/L to 30 mg/L. The lowest concentration was measured for Dioxin, which had concentrations ranging from $6x10^{-6}$ µg/L to $3x10^{-4}$ µg/L.

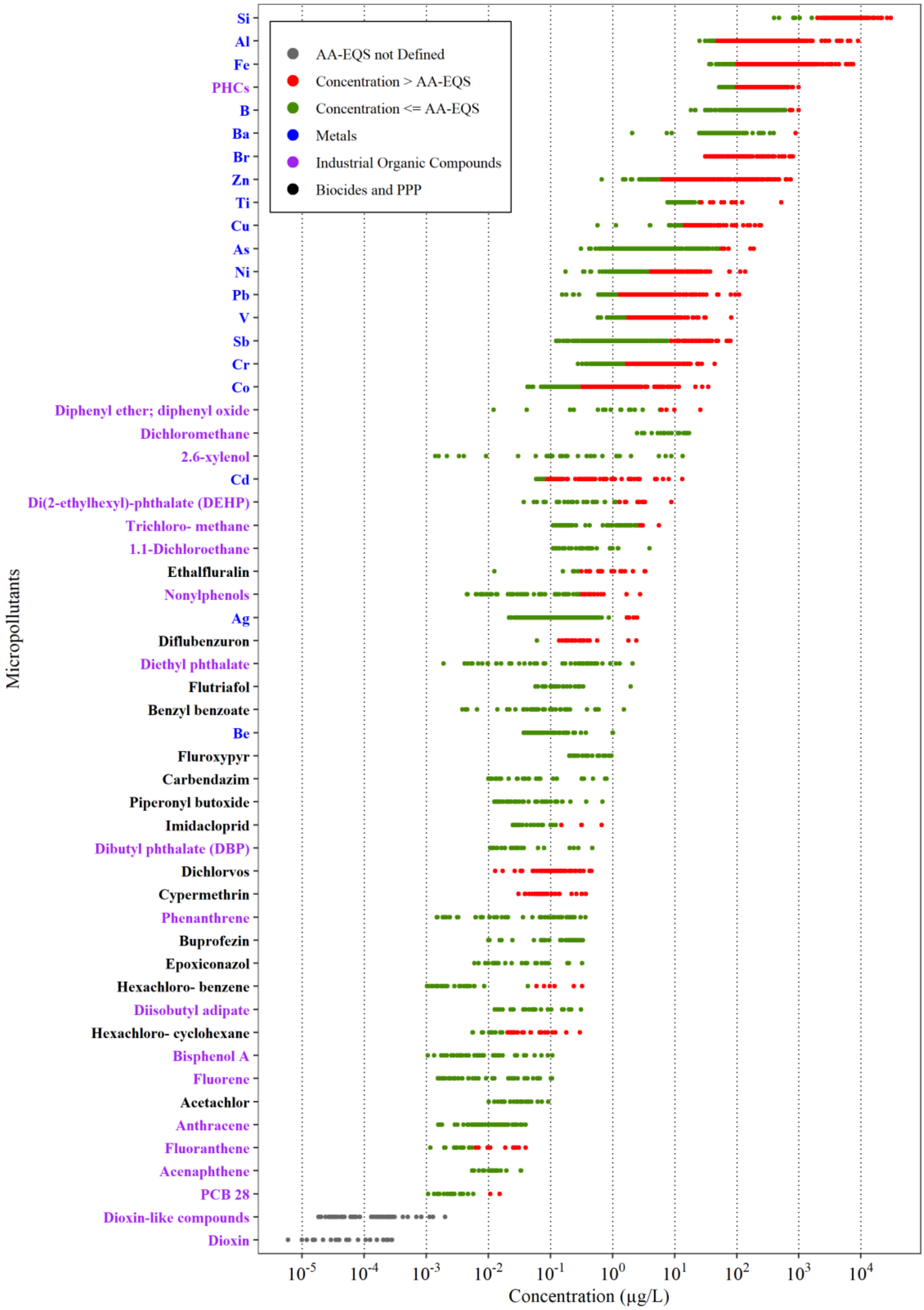

Figure 14. Sampling Results of 54 Selected Micropollutants in Surface Waters

Concentrations of Si, Al, Fe, PHCs, B, Ba, Br, Zn, Ti, Cu, As, Ni, Pb, V, Sb, Cr, Co, Diphenyl ether, Dichloromethane, and 2,6-xylenol, which are mostly metals and metalloids had the highest concentrations in the YRB. Since both the frequency and concentration of metal pollutants in the YRB are relatively high, their concentrations were compared with similar surface water monitoring data in the literature. The minimum, maximum, and median environmental monitoring data of Ag, Al, As, Cd, Co, Cr, Cu, Fe, Ni, Pb, and Zn from 27 countries were summarized in Appendix G - Table A 12 (Boarh & Misra, 2010; Cengiz et al., 2017; Donnachie et al., 2014; Harguinteguy et al., 2014; Johnson et al., 2017; Kumar et al., 2019; F. Liang et al., 2011; N. Liang et al., 2011; Rautenberg et al., 2015; Turgut, 2003). The minimum, maximum, and median concentrations of other countries were normalized by dividing by the results of this study and represented as a ratio in Figure 15, whereas this study was represented by the red line.

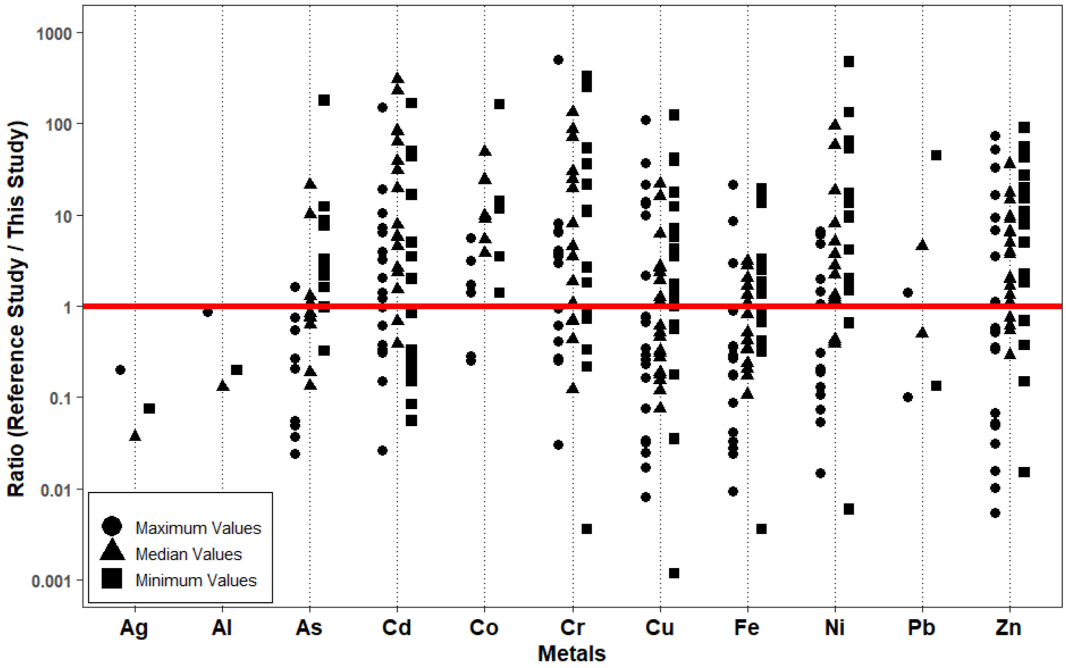

Figure 15. Comparison of Metal Concentrations in the YRB with Literature

The environmental concentrations of Pakistan, Bangladesh, and Nigeria were not used in this comparison since they were 10^3 to 10^6 times higher than the results of this study. These differences could not be explained by anthropogenic sources since even in conditions, where surface waters are polluted by heavy metal mining activities, the concentrations exceed the measurements in this study by one to eight times (N. Liang et al., 2011).

Data regarding Ag and Al could only be compared with findings in the UK. Both median and extreme values are 2 to 30 times higher than concentrations in the UK; however, it is not possible to generalize a high-concentration trend in the YRB. Similarly, the concentration of Pb could only be compared with findings in China and the UK. Surface water Pb concentrations were less than in this study in the UK, and four to 45 times higher in China. Environmental concentrations of As, Cd, Co, Cr, Cu, Fe, Ni, and Zn were compared to at least nine countries' data. The results showed that the surface water concentrations of metals in the YRB are generally on par with measurements from other countries, which indicates that they might be naturally occurring. The results of this study were also compared to surface water concentrations of Tigris, Boğaçayı and Küçük Menderes Rivers, and Atatürk, Seyfe and Beyşehir Lakes in Turkey (Cengiz et al., 2017; Kumar et al., 2019; Turgut, 2003). The median concentrations in this study were found to be lower than other national environmental concentrations however, maximum values were 2 to 3 times higher.

The frequency of occurrence of 54 selected micropollutants was classified according to their temporal variations in the YRB and pollution clusters were given in Figure 16. Except for Be, Br, Cd, and Ti, the metals and metalloids were detected in the YRB surface waters in all seasons, with maximum frequencies in the fall. A decreasing occurrence frequency trend was observed from fall to spring, which is correlated with the average flow rates in the Yeşilırmak River. Si is the only exception among metals and metalloids, which shows a relatively low detection frequency in the fall. Unlike metals and metalloids, PPPs were not quantified in all seasons. Cypermethrin was only quantified in spring, while Acetachlor, Diflubenzuron, and Fluroxypyr were quantified only in the fall. PPPs were quantified as lowest in the winter and highest in the fall, while an increasing trend from winter to fall could not be observed. This was related to low precipitation rates in the summer and high utilization of PPPs in the spring and summer.

Flutriafol, Hexachlorocyclohexane, Acetachlor, Carbendazim, Epoxiconazole, Diflubenzuron, Fluroxypyr, and Piperonyl butoxide were detected at the highest rate in the fall. A second peak was observed for Benzyl Benzoate, Cypermethrin, Ethalfluralin, and Hexachlorobenzene in the spring. In summer, Imidacloprid, Dichlorvos, and Buprofezin were detected at the highest rate. Industrial organic compounds and pharmaceuticals and PCPs were mostly detected in the fall, similar to PPPs. 1,1-Dichloroethane, Acenaphthene, Anthracene, Fluoranthene, Fluorene, PCB 28, Phenanthrene, Diisobutyl adipate, and Diphenyl ether were most frequently detected in the spring. One of the highest detected micropollutants in the YRB, PHCs was not detected in the summer. Dioxin, Trichloromethane, and PHCs were most frequently detected in the winter. 2,6 xylenol and Dioxin-like Compounds were most frequently detected in the fall, while BPA, DCM, DEHP, Diethyl phthalate, Nonylphenols, and DBP were mostly detected in the fall. The seasonality of these industrial organic compounds could not be explained since there is not any seasonality in their use or production. The results of the cluster analysis showed that in terms of occurrence in the YRB surface waters, except Br, Be, Cd and Ti, metals and metalloids are one major group among selected micropollutants. The results of the cluster analysis given in Figure 16 were refined for pollutants of concern in the YRB and discussed in the related section (Figure 18).

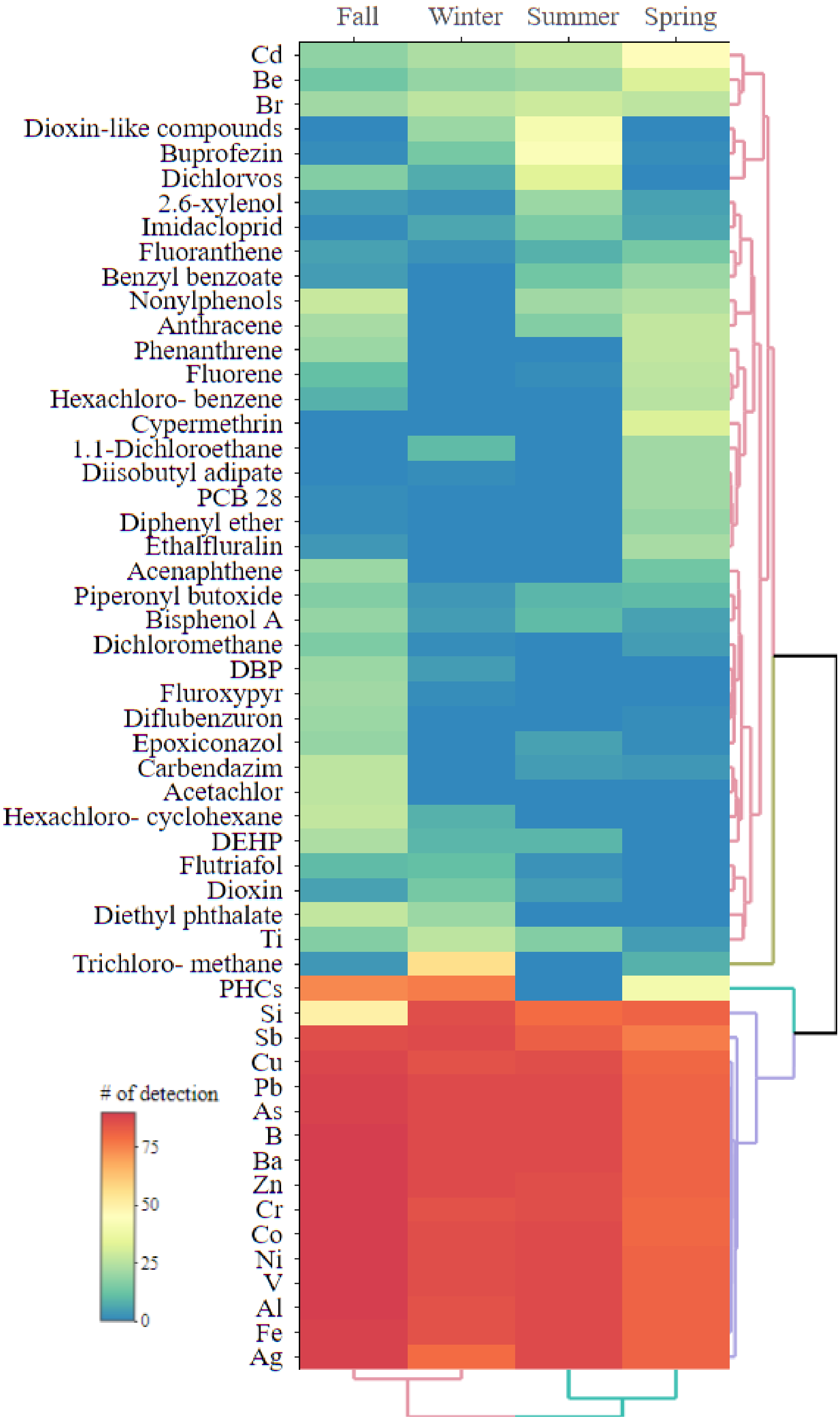

Figure 16. Seasonal Clustering and Occurrence Frequency of Selected Micropollutants

3.3.2 Determination of Pollutants of Concern in the Yeşilırmak River Basin

Although the surface water concentrations of other micropollutants are lower than metals and some of the industrial organic compounds, the occurrence of Cd, Di(2-ethylhexyl)-phthalate (DEHP), Ethalfluralin, Nonylphenols, Diflubenzuron, Dichlorvos, Cypermethrin, Hexachlorobenzene, and Fluoranthene were considered significant since their concentrations exceed the AA-EQS (Figure 14).

Among the micropollutants given in Table 15, the concentrations of 11 priority substances and 21 river basin specific pollutants exceeded the AA-EQS in receiving waters, including metals (Pb, Ag, Al, As, Ba, Cu, Zn, V, Fe, Co, Cr, Ni, Cd, Ti), metalloids (Si, Sb, B), halogen (Br), biocides (Dichlorvos, Cypermethrin, Diflubenzuron, Ethalfluralin, Hexachlorocyclohexane, Hexachlorobenzene, Imidacloprid) and industrial organic compounds (PHCs, Nonylphenols, Trichloromethane, DEHP, Diphenyl ether; Diphenyl oxide, Fluoranthene, PCB 28). The significance of selected micropollutants was evaluated based on their EQS and the extent of AA-EQS exceedance for each micropollutant using Equation-5. The average surface water concentration of each micropollutant across the YRB was calculated using the results of the monitoring study, where only results that are above the LoQ value were included in the calculation. Dioxin and Dioxin-like compounds could not be evaluated based on their surface water concentrations, since neither AA-EQS nor MAC-EQS is available for these pollutants. The selected micropollutants, which exceeded their relative AA-EQS in at least one surface water monitoring station, are given in Table 16. The minimum, maximum, and average AA-EQS ratios for each micropollutant and the number of monitoring stations where AA-EQS exceedance occurred are also provided in Table 16. The micropollutants that had an average AA-EQS ratio of 100 were identified as the pollutants of concern in the YRB, and these 20 micropollutants are highlighted in Table 16 and Figure 17.

Table 16. Number of Surface Water Monitoring Stations where Selected Pollutants' Concentration Exceeded the AA-EQS and Minimum, Average and Maximum Percentages of AA-EQS in the YRB

Pollutants[1]	**Number of stations[2]**	**Minimum (% of AA-EQS)**	**Average (% of AA-EQS)**	**Maximum (% of AA-EQS)**	**AA-EQS (µg/L)**
Al[3-4]	52	52.61	1024.98	18,620.56	48.07
Zn[3]	52	11.39	979.79	12,493.95	5.9
***Pb*[3]**	52	12.85	360.90	9,164.01	1.2
Fe[3-4]	52	38.14	744.88	7,874.83	95.22
V[3]	52	36.31	320.18	5,069.94	1.6
Cu[3-4]	52	4.43	168.24	1,902.90	12.99
Si[3]	52	21.91	368.43	1,649.18	1830
PHCs[3]	50	54.17	277.89	1,038.54	96
Co[3]	48	14.23	442.27	11,675.62	0.3
Cr[3]	45	17.46	213.98	2,748.60	1.6
Cd[3]	41	74.38	839.20	16,515.90	0.08
Dichlorvos[3]	40	2,155.56	22,492.52	76,986.93	6.00E-04
***Ni*[3]**	40	4.38	174.67	3,405.74	4
Br[3]	34	100.65	531.20	2,595.48	31
***Cypermethrin*[3]**	32	38,395.63	131,362.09	468,750.00	8.00E-05
Diflubenzuron[3]	20	47.05	333.51	1,871.05	0.13
***Hexachlorocyclohexane*[3]**	20	28.11	228.39	1,490.25	0.02
Ethalfluralin[3]	20	4.20	329.62	1,134.54	0.3
Nonylphenols	18	1.50	80.48	925.00	0.3
Sb	12	1.59	70.65	1,024.00	7.8
Ti[3]	10	29.69	116.36	2,002.83	26
***Fluoranthene*[3]**	10	18.69	159.88	636.01	0.0063
Di(2-ethylhexyl)-phthalate (DEHP) [1]	9	2.87	75.03	684.77	1.3
Trichloromethane	7	4.40	46.91	224.00	2.5
Hexachlorobenzene	6	2.08	62.86	646.75	0.05
Diphenyl ether; diphenyl oxide	4	0.20	61.42	430.80	6
As	3	0.58	16.56	355.16	53
Imidacloprid	2	17.86	66.12	479.29	0.14
Ag	2	1.45	12.32	165.38	1.5
PCB 28	2	10.71	38.39	151.72	0.01
B	2	2.58	31.23	139.90	707
Ba	1	0.30	10.61	130.46	680

[1] *Priority substances are given in italic*

[2] Number of surface water monitoring stations where pollutant concentration exceeded the AA-EQS

[3] Pollutants of concern in the YRB

[4] Background concentrations were considered when determining the AA-EQS exceedance

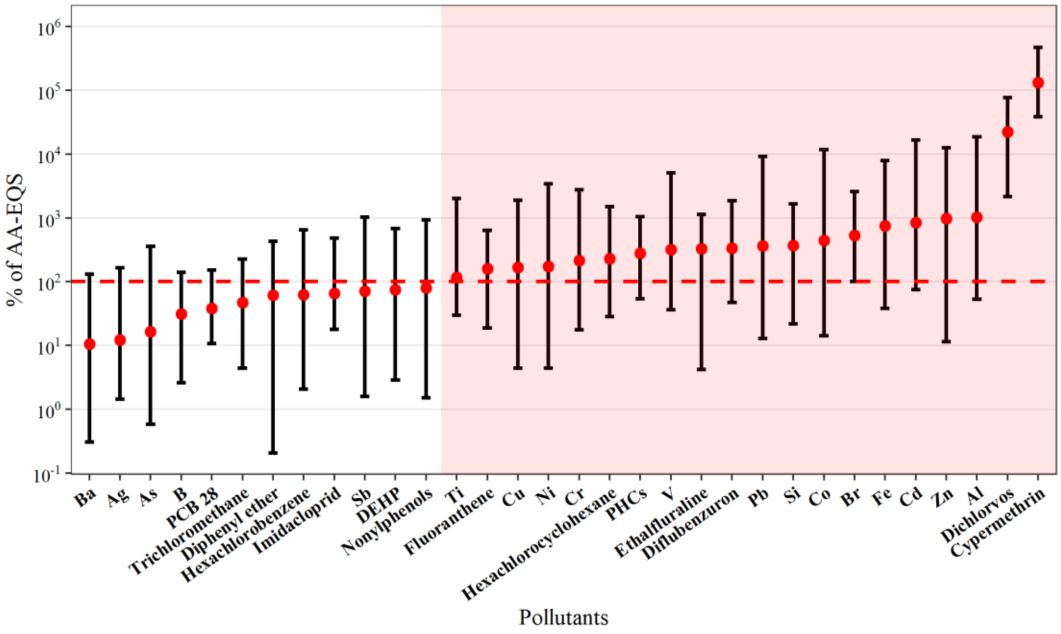

Figure 17. The Minimum, Maximum, and Average AA-EQS Ratios of Selected Micropollutants which Exceeded Their AA-EQS in Surface Water Samples

The surface water concentrations of seven micropollutants; Al, Zn, Pb, Fe, V, Cu, and Si had exceeded the AA-EQS in all sampling stations. They were followed mostly by other metals (Co, Cr, Cd, Ni, Br), PHCs, Dichlorvos, and Cypermethrin, where these pollutants exceeded the AA-EQS in at least 32 surface water sampling stations. The average concentration of Diflubenzuron, Hexachlorocyclohexane, Ethalfluralin, Ti, and Fluoranthene had exceeded the AA-EQS in less than 20 monitoring stations; however, their exceedance did not follow a spatial pattern. Their seasonal variations are discussed in Chapter 3.3.1.

The EQS exceedances show that metals, which had a high frequency of occurrence in the YRB, also had very high concentrations with respect to their EQS. Although the AA-EQS of Al, Fe, and Cu were revised by considering the background concentrations, their surface water concentrations still substantially exceeded the relevant limit values. Both natural sources and anthropogenic activities are attributed to environmental pollution by metals (Ismail et al., 2016; Kankiliç et al., 2013; Li et al., 2013; F. Xu et al., 2016). Their presence in the freshwater environment has become a key environmental problem due to their PBT properties both in the aqueous phase and in sediment and raised widespread concern in the last decade (Bastami et al., 2015; Ghaderi et al., 2012; Govind & Madhuri, 2014; Singh & Kumar, 2017; G. Xu, Pei, et al., 2015; C. Zhang et al., 2019).

Anthropogenic activities such as mining, metal industry, petroleum production, combustion of coal, chemical industry, and manufacture and use of PPPs are accepted as the main contributor to metal pollution in freshwater ecosystems (Begy et al., 2016; Guan et al., 2016; Ismail et al., 2016; Monferran et al., 2016; Neyestani et al., 2016). The mining activities, use of PPPs, textile, metal, petroleum, and chemical industry were determined as sources of pollution in the YRB. However, it is quite challenging to relate any surface water pollution directly to a source since several metals such as Cr, Cu, and Zn can also be released from sediments depending on their bioavailability (C. Zhang et al., 2019), and can travel long distances by sediment transport (Sponza & Karaoğlu, 2002). Metals such as As, Cd, and Ni have a lower risk of releasing from sediments and they are more likely attributed to mining and shipping activities (Fazlin Nazli & Rasidah Hashim, 2010; Nasrabadi, 2015). Cd and Pb are considered closely related to alloying, electroplating, and dyeing activities (G. Xu, Liu, et al., 2015) and intensive use of phosphate fertilizers (Jones & Johnston, 1989; Xia et al., 2011). Additionally, Pb was used in gasoline as an additive and contributed to the diffuse pollution from gasoline-powered machines and vehicles (H. Zhang & Shan, 2008). In accordance with these discussions, the metal pollution in the YRB was attributed primarily to mining activities, combustion of coal, and use of PPPs since the capacity of the textile industry, metal industry, petroleum production, and chemical industry in the YRB is substantially low.

PPPs are the second group of micropollutants among the pollutants of concern in the YRB, after metallic substances. Dichlorvos was detected in 40 surface water monitoring stations, followed by Cypermethrin in 32 monitoring stations. Diflubenzuron, Hexachlorocyclohexane, and Ethalfluralin were the least detected PPPs with a detection frequency of 20 monitoring stations (Table 16). Although their occurrence was less frequent than in metallic substances, the extent of AA-EQS exceedance is significantly greater than in metals. The observed concentration of Cypermethrin was 1300 times higher than its EQS on average and peaked at an exceedance of 4600 times. Dichlorvos exceeds its AA-EQS 225 times on average, followed by Diflubenzuron and Ethalfluralin with an exceedance ratio of approximately three times. Hexachlorocyclohexane was the least exceeded PPP, with an average exceedance ratio of two times.

Dichlorvos is an organophosphorus compound used as an insecticide on crops, animals, and in pest-strips (USEPA, 2000). Ethalfluralin is a synthetic herbicide with low aqueous solubility and it is used for the control of annual grasses and broadleaf weeds (Lewis et al., 2016; USEPA, 1995). Hexachlorocyclohexane is a synthetic broad-spectrum insecticide used mainly to control soil-inhabiting insects (Lewis et al., 2016), and it is one of the persistent organic pollutants (POPs) listed in Annex A of the Stockholm Convention. Stockholm Convention is an international treaty to protect human and environmental health from unintentional hazards of POPs. According to the Stockholm Convention, the production, utilization, and trade of chemicals listed in Annex A must be prohibited and necessary legal and administrative actions should be taken to eliminate these chemicals (UNEP, 2017). The manufacture and import of Dichlorvos and Ethalfluralin were banned in 2009 and 2011, respectively, and their utilization has not been allowed since 2011 and 2012, respectively (MoAF, 2022a). The manufacture, utilization, and import of Hexachlorocyclohexane have also been banned since 2010, as Turkey is a party to the Stockholm Convention. However, it can still be produced as an unintentional by-product of lindane (Lewis et al., 2016). The results of the monitoring study revealed that although Dichlorvos, Hexachlorocyclohexane, and Ethalfluralin usage in agricultural practices were banned in Turkey, they are still being detected in the aqueous phase of receiving water bodies. In the YRB, Dichlorvos had been primarily used during the production of maize, apples, and sunflowers, while Ethalfluralin had been used for the production of soybeans, dry beans, sunflowers, potato, and canola, and Hexachlorocyclohexane had been used during the production of fruits and vegetables.

Among pollutants of concern in the YRB, Diflubenzuron and Cypermethrin are the two legally used insecticides in Turkey. Diflubenzuron is an insecticide that is primarily used on cattle, citrus, cotton, mushrooms, standing water, forestry trees, and in programs to control mosquitoes and moths (USEPA, 1997). Cypermethrin is a highly toxic synthetic pyrethroid insecticide used in large-scale agricultural applications as well as a consumer product for domestic purposes (Williams et al., 2017). Both of them are primarily used for rainfed agricultural products. Diflubenzuron is used during the production of maize, hazelnuts, apples, pears, and peaches, while Cypermethrin is widely applied to wheat, barley, rye, beans, soybeans, potato, sugar beet, apples, pears, cherry, and grapes in the YRB. The surface water concentration of Diflubenzuran was measured between 0.061 µg/L and 2.4 µg/L, while Cypermethrin was measured between 0.031 µg/L and 0.38 µg/L (Table 15). In terms of aquatic toxicity, Cypermethrin had the highest risk factor in the YRB among 45 priority substances and 250 river basin specific pollutants, with a significantly high exceedance of the EQS, reaching a percentage of 468,000%. The PPPs reach surface waters through anthropogenic activities only by direct discharge from manufacturing processes or as a diffuse source of agricultural applications. The main contributor of Dichlorvos, Cypermethrin, Diflubenzuron, Hexachlorocyclohexane, and Ethalfluralin pollution was identified as agricultural applications since the manufacture of PPPs was not carried out in the YRB. Toros Tarım Sanayi ve Ticaret and Uğurlar Gübre Sebze Pazarlama ve Ticaret in Samsun, and Gaffaroğlu Organik Gübre Sanayi in Turhal were identified as manufacturers of agricultural fertilizers only. None of these facilities could be covered in the scope of the monitoring studies due to the following reasons: Toros Tarım Sanayi ve Ticaret discharges into the Black Sea with a deep sea discharge unit, and Uğurlar Gübre Sebze Pazarlama ve Ticaret facility is at the downstream of Çarşamba station, which is the last surface water monitoring station before transitional waters. Gaffaroğlu Organik Gübre Sanayi discharges a small amount of wastewater (3.16 m^3/day) to the Turhal wastewater sewerage system, which is discharged after Turhal without any treatment.

Among industrial organic compounds, PHCs and Fluoranthene were identified as the cause of concern pollutants in the YRB (Table 16). PHCs were detected in 50 of the 52 surface water monitoring stations, with an average exceedance ratio of approximately three times. PHCs concentrations in the YRB were measured between 52 µg/L and 997 µg/L, with an average of 266 µg/L. PHCs originally come from different chemicals in crude oil and refer to a large family of several hundred chemical compounds. In addition to hexane, benzene, fluorene, naphthalene, toluene, xylenes, jet fuels, mineral oils, petroleum products, and gasoline components, mixtures containing s combination of the above chemicals are among PHCs (USEPA, 2014). Therefore, instead of measuring each chemical found in crude oil separately, it is more practical to measure the total amount of PHCs. The common pathways for PHCs to aquatic ecosystems are through accidents, spills or leakages, industrial emissions to water and air, and as byproducts of commercial uses of crude oil products. The predominant sources of PHCs in freshwater were identified as accidental spills from road or rail tankers, leakages from oil pipelines, exploration or production of crude oil, spent lubricants, vehicular emissions, and incomplete combustion of coal, oil, and gas (Doble & Kumar, 2005; Vandana et al., 2022). The source of PHCs levels detected in the surface water monitoring stations of the YRB was attributed to accidental spills and diffuse emissions since the manufacturing of crude oil is not carried out within the basin boundaries.

Fluoranthene was detected in 10 surface water monitoring stations, with an average exceedance ratio of 159 times. Fluoranthene concentrations in the YRB were measured between 0.0012 µg/L and 0.04 µg/L, with an average of 0.01 µg/L. According to the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) (European Commission, 2006) list of substances supplied to the Turkish market, Fluoranthene is neither produced in nor imported to Turkey. Fluoranthene is a high molecular PAH, which has been mainly used as a binding agent in the production of carbon electrodes and anodes, refractories, clay pigeons, active carbon, coal briquette, road construction, roofing, and corrosion protection (WFD-WGE, 2011). Fluoranthene is categorized as a priority pollutant by the United States Environmental Protection Agency (USEPA) US Clean Water Act and EC WFD (2008/105/EC). Fluoranthene is not produced or used in its pure form but is produced during the combustion of many industrial processes, which makes it partly natural (European Commission, 2012). However, it is one of the most abundant PAHs; it can be easily detected and used as an indicator of other PAHs (Šepič et al., 2003). Fluoranthene was detected in air and water emissions of various anthropogenic activities, such as the energy sector, production, and processing of metals, mineral industry (mining activities), chemical industry, and waste and wastewater management (EEA, 2022). The existence of PAHs in WWTPs could be attributed to the use of dandruff shampoo, detergents, and mothballs, which are commonly found in households (Mohd-Towel et al., 2016). The major source of Fluoranthene pollution in the YRB was identified as urban and domestic WWTPs[4], since industrial processes responsible for its discharge are not available in the YRB, and it was detected in effluents of major urban WWTPs.

The seasonal clustering of selected micropollutants was refined for pollutants of concern in the YRB to further explain the relationship between occurrences of metal pollutants, and to find out any meaningful relationship between organic micropollutants. Seasonal variations were removed from the cluster and the correlation between their occurrences in the YRB is given in Figure 18. The cluster tree of metal micropollutants was exclusively given in Figure 19. The height of the lines shows the distance of each pollutant from each other in terms of occurrence. The metals were grouped according to their mutual presence in the YRB. The first group of metals was identified as Al and Fe, and the second group was identified as Co, Ni, and V. Cr is at equal distance to these two groups, and Al, Fe, Co, Ni, V, and Cr can be considered as a single group according to their occurrence in the YRB. Br and Cd can be considered as a third group, although their relationship is not as close as the previously mentioned metals. The presence of Ti could not be explained by the presence of any other metal in the YRB. A strong negative correlation was found

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[4] The Fluoranthene emissions from point sources are discussed in Chapter 4.6.3.

between Si and organic micropollutants Diflubenzuron and Hexachlorocyclohexane, while a weak negative correlation was also present between Si, PHCs, Dichlorvos, and Fluoranthene. Although the high concentration of Si in the YRB could not be explained by any anthropogenic activities, it is generally attributed to a natural weathering of silicates in the bedrock and soils (Neal et al., 2005). Silica (SiO_2) is an oxide of Si, which can be found in almost all minerals, and its concentration highly depends on the transport of surrounding sediments and soils (Ustaoğlu et al., 2017). This negative relationship might be due to the adsorption of organic pollutants onto the soil (He et al., 1995; Wadaskar et al., 2010).

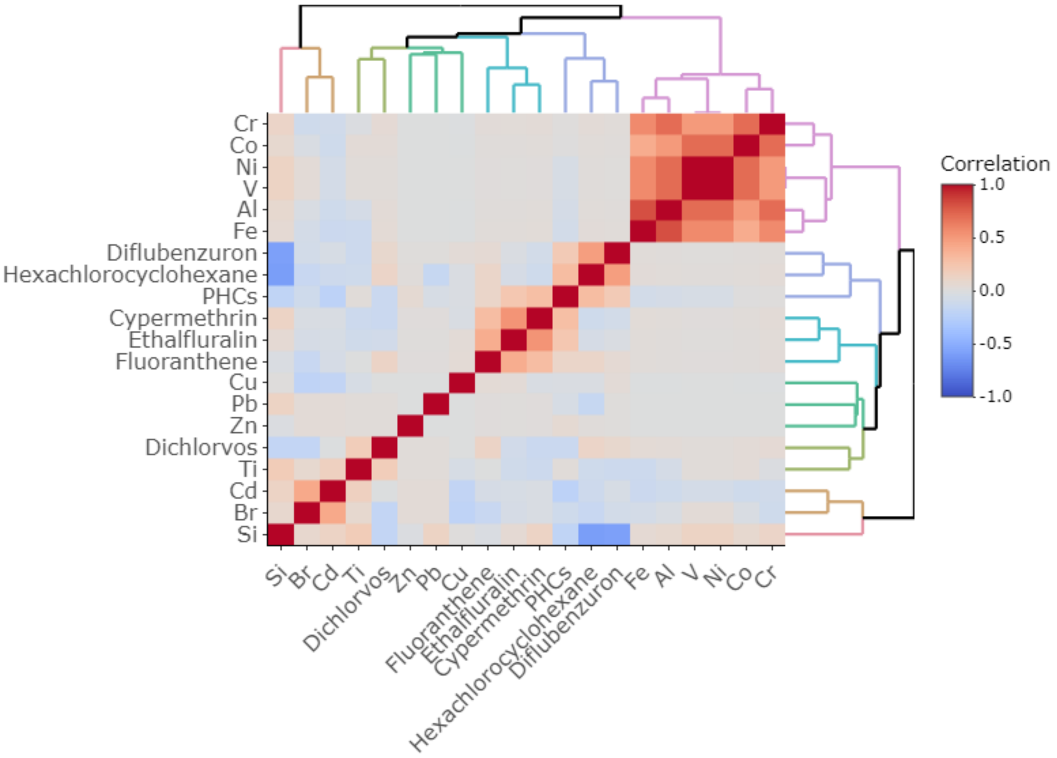


Figure 18. Occurrence Correlation Heatmap and Clusters of Pollutants of Concern

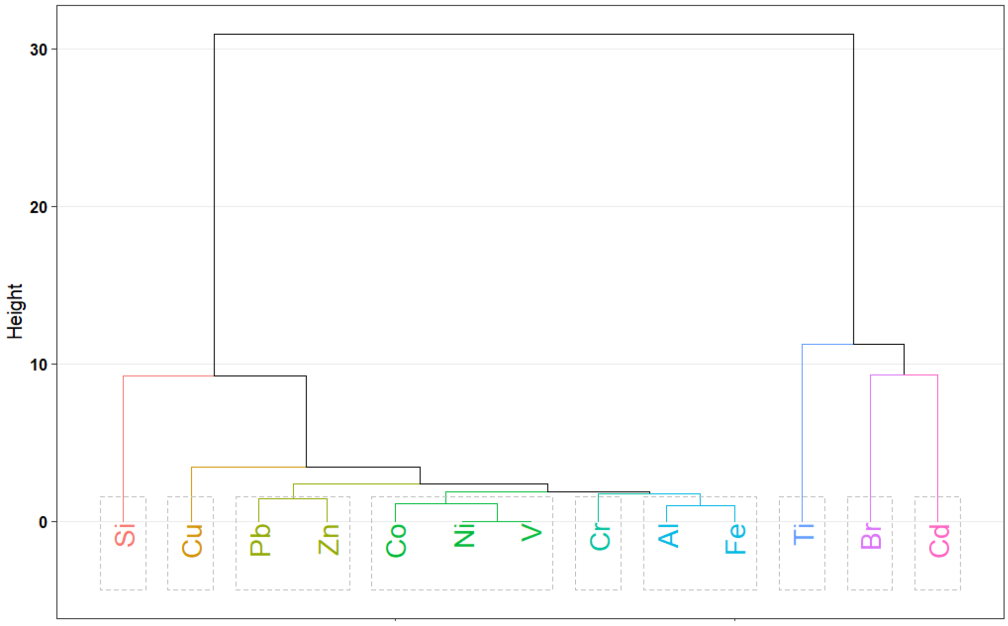


Figure 19. Clusters of Metal Micropollutants in the YRB

3.3.3 Spatio-Temporal Variance of Pollutants of Concern

The seasonal variation in concentrations of pollutants of concern in the YRB is given in Figure 20. Excluding Cd, Ti and Zn, a seasonal variation could not be observed for the concentration of metal pollutants. The concentrations of Ti and Zn were significantly higher in the fall and spring, while Cd concentrations were slightly higher in the winter. Fluoranthene was measured at its peak concentration in the spring season, followed by the fall, summer, and winter seasons. The Hexachlorocyclohexane concentration was higher in fall than in winter. The concentration of Dichlorvos was higher in fall, followed by summer and winter concentrations. The concentrations of PHCs and Ethalfluralin were also highest in the spring. Cypermethrin could only be quantified in the spring season. PHCs and Diflubenzuron followed a distinctive path from other organic micropollutants in seasonal variation. According to these results, the highest total PPP concentrations were observed in the spring (May), which was related to increased run-off from agricultural areas despite higher dilution rates in spring.

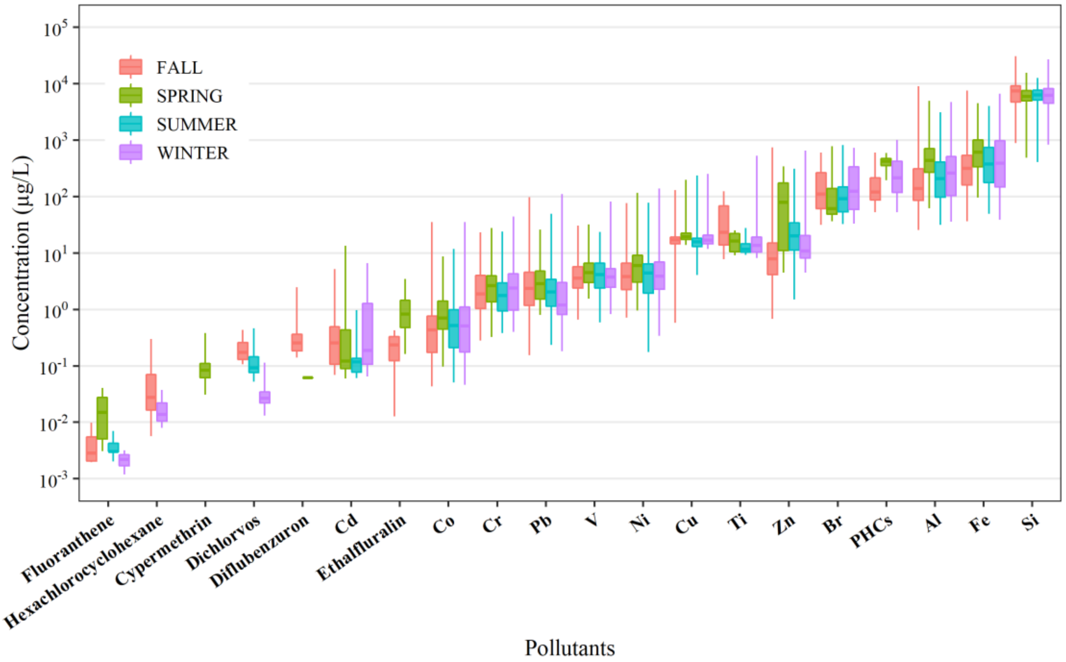
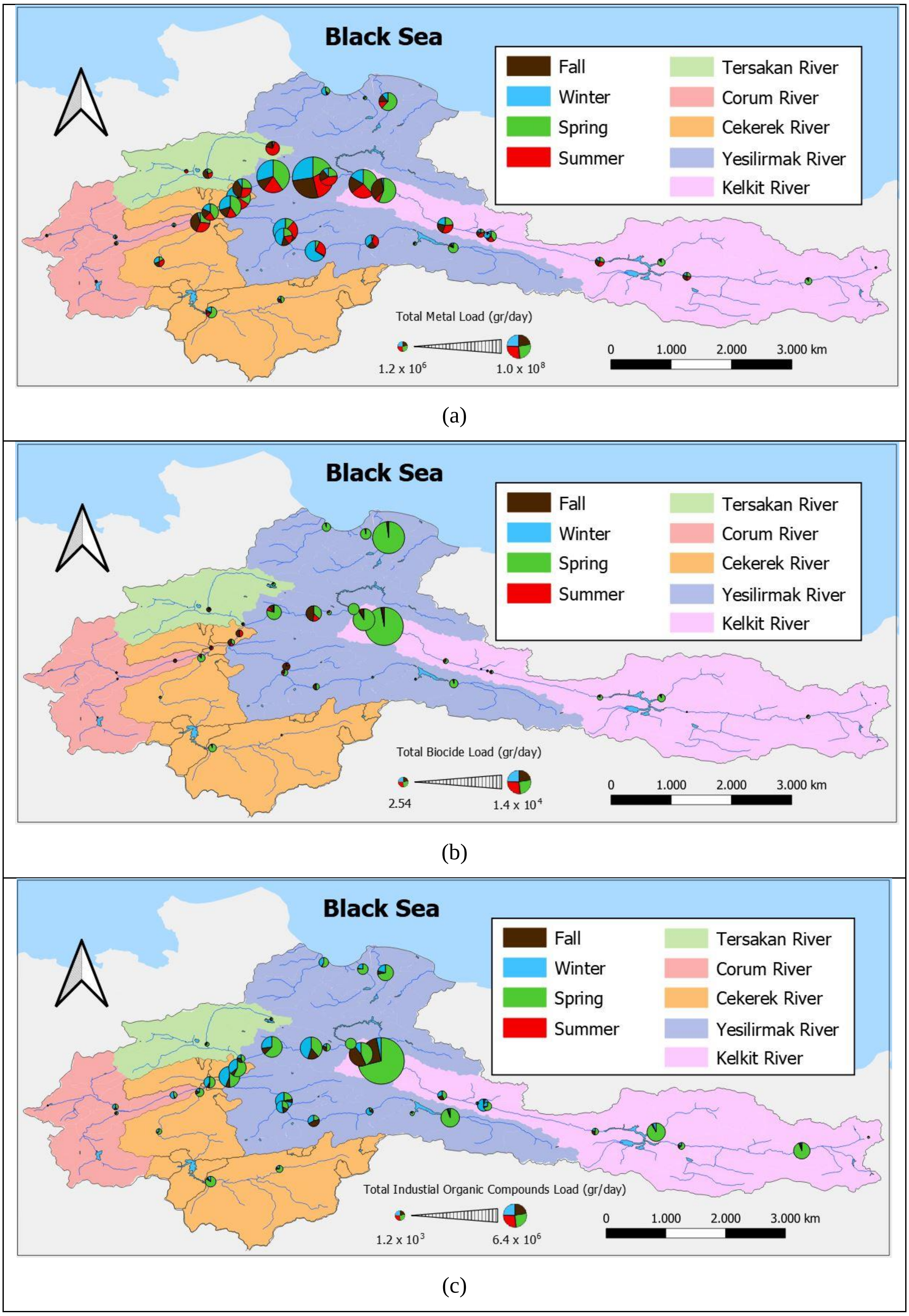


Figure 20. The Seasonal Variation in Concentrations of Pollutants of Concern

The total load of pollutants of concern in the YRB is also an important indicator of micropollutant pollution. The spatio-temporal variation of main pollutant groups (i.e. metals, biocides and PPPs, and industrial organic compounds) are given in Figure 21. The YRB was divided into five sub-basins based on its main tributaries to investigate the total pollution load and generate catchment-specific monitoring strategies. The evaluation of the total pollution load in the YRB showed different characteristics than the individual concentration distribution of pollutants.

The metal and metallic substances pollution (Al, Br, Cd, Co, Cr, Cu, Fe, Ni, Pb, Si, Ti, V, and Zn) in the YRB showed seasonal and spatial variances. The total loads increased at surface water monitoring stations, which are heavily affected by urban, and industrial activities (Appendix H - Figure A 3). The total metal pollution loads in Kelkit and Çekerek sub-basins were higher in the spring, while it was higher in winter and spring at upstream and downstream of the Yeşilırmak river sub-basin, respectively.



(a)

(b)

(c)

Figure 21. Total Seasonal Load of Main Pollutant Groups (a) Metals, (b) Biocides and PPPs, (c) Industrial Organic Compounds

The total pollution load of biocides and PPPs (Cypermethrin, Dichlorvos, Diflubenzuron, Ethalfluralin, and Hexachlorocyclohexane) showed variances, which were attributed to precipitation patterns and crop patterns. The PPP loads were highest in spring in most sub-basins, while total loads at some surface water monitoring stations peaked in the fall season. Downstream of Kelkit and Yeşilırmak sub-basins, the total PPP loads were significantly higher. Downstream of the Çekerek River sub-basin, the total PPP load was calculated to be highest in the fall. For industrial organic compounds (Fluoranthene and PHCs), the highest pollutant load was measured in spring at Kelkit and Yeşilırmak sub-basins, and in winter at Çekerek and Tersakan sub-basins.

3.4 Conclusion

The occurrence of 45 priority substances and 250 river basin specific pollutants were investigated in the YRB to evaluate the surface water chemical status of the basin in accordance with the WFD and the SWQR. The results of a two-year monitoring campaign were used to build up the first comprehensive water quality data in the YRB with the aim of supporting management strategies to control micropollutant pollution.

During the monitoring campaign, 166 micropollutants were detected at least once in the YRB. Among the detected micropollutants, 54 pollutants were frequently detected in the YRB. These micropollutants were identified as selected pollutants and based on their extent of AA-EQS exceedance, 20 among 54 micropollutants were identified as the pollutants of concern in the YRB (Pb, Al, Cu, Zn, V, Si, Fe, Ti, Co, Cr, Ni, Cd, Br, Dichlorvos, Hexachlorocyclohexane Ethalfluralin, Cypermethrin, Diflubenzuron, PHCs, and Fluoranthene).

The metal pollution observed in the YRB was primarily attributed to mining activities, and the metal industry in the basin since background concentrations of the metallic pollutants in the basin are below their EQS values.

The presence of Dichlorvos, Hexachlorocyclohexane Ethalfluralin, Cypermethrin, and Diflubenzuron in surface waters was attributed to their agricultural use since they are not manufactured in the basin. Although the use of Dichlorvos, Hexachlorocyclohexane, and Ethalfluralin has been banned, unexpectedly they had an occurrence frequency of 16.2%, 10.1%, and 7.2%, respectively.

Among industrial organic compounds, the presence of PHCs in the surface water monitoring stations of the YRB was attributed to accidental spills and diffuse emissions since the manufacturing of crude oil is not carried out within the basin boundaries. Similarly, the major source of Fluoranthene pollution in the YRB was identified as urban and domestic WWTPs, since it was detected in effluents of major urban WWTPs, and industrial processes responsible for its discharge are not available in the YRB.

A strong correlation between the occurrence of Al and Fe, and a similar relationship between Co, Ni, and V were identified. A strong negative correlation was found between Si and organic micropollutants Diflubenzuron and Hexachlorocyclohexane, while a weak negative correlation was also present between Si, PHCs, Dichlorvos, and Fluoranthene. This was attributed to the possible adsorption of organic pollutants to the soil.

Developing sound management strategies to control chemical substances requires substantial information on their occurrence and relationship. To this end, the pollutants of concern in the YRB were grouped under three main categories, metals, PPPs, and industrial organic compounds. Their seasonal variations in the basin were assessed based on their total pollution load in surface waters. The results indicated that the highest concentrations for the three categories of pollutants were observed in the spring, and therefore, the preferred monitoring season should be spring for a cost-effective monitoring strategy. It is believed that cost-effective water quality monitoring programs can be established at different river basins using this approach.

CHAPTER 4

ASSESSMENT OF DILUTION FACTOR APPROACH AS A POINT SOURCE CONTROL MECHANISM

The results of the surface water monitoring study were discussed in Chapter 3, and 20 micropollutants were identified as a cause of concern in the YRB. The main source of these micropollutants in the surface waters is regarded as the municipal WWTPs (Gogoi et al., 2018a; Tran et al., 2018). The MoEUCC is planning to implement the revised WPCR (Official Gazette No: 25687, Date: December 31, 2004), and a fixed DF approach was proposed as a point source control strategy. The proposed methodology and its potential impacts on the surface water quality of the YRB will be assessed in this chapter.

In the following sub-sections, first, a short introduction to DF and its practical use in point source management is made, and an overview of the transposition of the water quality-based discharge limits into the national legislation is provided. Second, the challenges that raise the motivation of the present study are presented. Third, a literature review on point source pollution and the main challenges of pollution control is provided and followed by an overview of the point source control strategies. Finally, the methodology, results, and discussion are provided in the final sub-sections.

4.1 Introduction

4.1.1 Background

The untreated micropollutants in urban WWTPs have significant toxicity risks to aquatic organisms (Loos et al., 2013). On the other hand, pharmaceuticals, PCPs, and industrial chemicals are discharged into the environment continuously through

WWTPs and sewage systems. The pharmaceutical and PCP market is growing exponentially and a large array of chemicals with distinct biochemical properties are continuously introduced to the market. The widespread use results in high concentrations in raw wastewater and notable concentrations in the treated effluent.

The WWTP effluents have significant effects on the aquatic ecosystem. The PPPs from WWTP effluent have affected invertebrate communities (Münze et al., 2017) and the effect of PPPs was found to be decreasing with distance from WWTP effluents, and improvements in the treatment process (Ashauer, 2016; Bunzel et al., 2013). The stream flow rate is an important variable in the risks associated with PBT substances in WWTP effluents since the ecotoxicities of these substances are directly related to the dilution downstream (Englert et al., 2013; Munz et al., 2017; Neale et al., 2017).

The DF, the ratio between the volumes of freshwater available and the wastewater discharge, can be used as a surrogate to compare risk levels caused by chemical exposure between and within countries (Keller et al., 2007). The Technical Guidance Document on Risk Assessment (TGD), in support of the Commission Directive 93/67/EEC on risk assessment for new notified substances recommends an average DF of 10 for sewage from municipal wastewater treatment plants. In addition, this fixed DF is regarded as the default dilution value for other types of substances if specific data are not available (EC, 2002). During environmental exposure assessments of pharmaceuticals and PCPs in the WWTP effluents, a standard DF of 10 is recommended (ECHA, 2016; EMA, 2006).

The DFs reported for selected EU countries are provided in Table 17. The lowest DFs were reported as < 1, which means that the river flow rate is less than the WWTP flow rate. On the other hand, very high DF values, such as more than 10,000, were also reported. Except for Germany, the total number of samples was not enough to be representative of respective countries. In Germany, 1225 national WWTPs were evaluated and it was found that the fixed DF approach of 10 overestimates the dilution potential of 60% of receiving waters with a median DF of five (Link et al., 2017).

Table 17. Dilution Factors in European Urban WWTPs

Country	Dilution Factor	Reference
Spain	5-1500	Gros et al., (2007, 2010)
Switzerland	1.1-2.7	Ort & Siegrist, (2009)
Italy	151	Verlicchi et al., (2014)
UK	15.2-15.7	Baker & Kasprzyk-Hordern, (2013)
	13-23	Kasprzyk-Hordern et al., (2009)
Germany	<1 – more than 10,000	Link et al., (2017)

Keller et al. (2014) estimated the annual median DF for Turkey as 56.20, with a range from approximately 5 to 169. It is known that the real DF of receiving environment in Turkey is less than five for most large WWTPs (MoAF, 2017; MoEUCC, 2018; TUBITAK, 2019). A study estimating the dilution of WWTP effluents showed that in low flow conditions 17% of all rivers had a DF of less than 10 on a global scale, without considering untreated wastewater sources (Ehalt MacEdo et al., 2022). The results of the same study indicate a low-flow dilution of 66%, 25%, 21%, and 14% in some Mediterranean countries, Spain, Turkey, Italy, and Greece, respectively. Turkey has an official WWTP coverage of 87.9% (TUIK, 2020); however, it is known that a significant amount of that coverage is due to WWTPs in metropolitan cities. The predicted environmental concentrations used in risk assessments are based on recommended DF of 10 and a significant difference in DF of water bodies could affect the severity of the exposure.

4.1.2 Transposition of the Water Quality-Based Discharge Limits into National Legislation

In the EU, the Industrial Emissions Directive (IED) (2010/75/EU) requires industrial establishments to apply Best Available Techniques (BATs) and target Best Available Technique Associated Emission Levels (BATAELs) at industrial discharges

(European Commission, 2010). With the application of BATAELs, the industrial establishments are expected to comply with the EQS of priority substances and river basin specific pollutants. If the EQS cannot be met, measures beyond BATAEL must be taken, and water quality-based ELVs must be set.

In Turkey, industrial discharges are not legally bound to BATAELs since the IED is not yet implemented as part of the EU harmonization process. This creates a conflict in the implementation strategy of the IED and moreover, since the BATs are not legally bound in Turkey, many industrial establishments have high pollutant concentrations at their discharges. These industries will face difficulties in implementing the SWQR (Official Gazette No: 29797, Date: August 10, 2016).

In the scope of the “Determination of Environmental Quality Standards Based Discharge Limits and Development of Implementation Strategies Project”, draft legislation has been proposed for an approach to determine EQS-based discharge standards/limits applicable in Turkey (MoEUCC, 2018). The technical capabilities of industrial facilities and municipalities to comply with stricter discharge standards have been taken into account. It has been evaluated that there may be inadequacies in the short and medium term while upgrading old WWTPs and establishing new WWTPs. Another important factor, the need to consider the economic conditions of both municipalities and industrial facilities has been considered. In the short term, it has been evaluated that strict discharge restrictions may bring serious investment and operating costs in WWTPs. Another consideration was the laboratory infrastructure required to analyze the priority substances and river basin specific pollutants defined in the SWQR. Undoubtedly, with the change of regulations to include discharge limitations for new pollutants, the necessary laboratory infrastructure will be formed in this direction over time. However, only a limited number of laboratories in Turkey were able to analyze all micropollutants defined in the SWQR during the period that the project was carried out. This created an impression that the laboratory infrastructure and capacity in Turkey could be insufficient to support the implementation of the SWQR. Considering the factors mentioned above, a realistic EQS-based discharge standard/limits determination approach has been proposed to the WPCR (Official Gazette No: 25687, Date: December 31, 2004) (MoEUCC, 2004).

The proposed implementation strategy is a three-stage implementation (Table 18), where the first stage is only updating the current emission standards present in the WPCR (MoEUCC, 2018). The second stage covers only the priority substances, which were identified during monitoring studies, and the addition of the BATAELs from the literature. The third stage introduces the river basin specific pollutants after a brief period, which is estimated as five to ten years. The dilution scenario introduces a fixed DF of ten in all point sources as a provisional approach. The implementation strategies should provide a smooth transition period to cover the cost of treatment investments required at point source discharges.

Table 18. Proposed Implementation Strategy for the Water Pollution Control Regulation

Stage	Approach	Proposed Date	Discharge Limit or Standard	Mixing Zone Concept
1	**Revision of Discharge Standards in Water Pollution Control Regulation**			
	Revision of current discharge standards only			
2	**Revision of Discharge Standards in Water Pollution Control Regulation**			
	Update of sector-specific tables present in the Directive with BATAELs and Priority Pollutants	2025	Discharge Standard	No
3	**Discharge Limit for Priority and Specific Pollutants**			
	Dilution Scenario	+5 years	Discharge Limit	No
	Discharge Test	+10 years	Discharge Limit	Yes
	Total Maximum Daily Load	+ >20 years	Discharge Limit	Yes

Previous studies in the YRB had shown that discharge limit determination in point sources is not possible using Discharge Test software or TMDL since the surface water is already polluted (Kucuk, 2018; MoEUCC, 2018). The mixing zone approaches consider the upstream concentration of pollutants at a point discharge, and since the upstream concentration was higher than the EQS, neither methodology could be adopted. Because, in both of these approaches, a conservative pollutant mass balance was established around the point of discharge, and the allowable pollutant concentration for the industrial discharge was calculated. When the upstream concentration of a pollutant is already above the corresponding EQS value, the discharge limit had to be set as a “negative” value. Therefore, it is required to have improvements in the ecological and chemical status of the surface waters before starting the implementation of the above-mentioned methodologies (Kucuk, 2018). The concept of mixing zone delineation and modeling assisted EQS-based discharge limit determination had been investigated in the Tersakan tributary of the YRB, which is known for its industrial wastewater problem, and the results indicated that point source discharges in the Tersakan River sub-basin are within legislative limits of the SWQR, both in high and low flow rate seasons (Çelebi et al., 2021). By comparison of these two previous studies by Kucuk (2018) and Çelebi et al. (2021), it is indicated that the implementation of the discharge limit is a complicated task. Comprehensive volumetric flow rate data, long-term surface water quality monitoring data, and detailed point source effluent information used by Çelebi et al. (2021) made it possible to use a mixing zone approach. This result proved that the mixing zone approaches require long-term environmental monitoring of both quality and quantity elements in surface waters and point sources, in order to return statistically evident results.

4.2 Objective and Scope of the Dilution Factor Assessment

The motivation behind this chapter is the key differences in implementation strategies of the EU WFD (2000/60/EC) in Turkey and the EU. The MoEUCC is planning to implement the revised WPCR (Official Gazette No: 25687, Date: December 31, 2004) after 2025. The second stage of the implementation strategy proposes a fixed DF approach to control priority substances and river basin specific pollutants at the WWTPs. This chapter aims to investigate the actual DF of point sources in the YRB and identify the risks associated with the overestimation of empirical DF of 10. In this regard, the objectives of this chapter that focus on the above-mentioned motivation are:

- to estimate the low-flow stream flowrate using a statistical approach
- to develop a methodology to estimate the stream flow rates at surface water monitoring stations and point sources in the YRB
- to calculate the DFs for all point sources in the YRB for low flow (MLF) and mean flow (MF) conditions
- to evaluate and quantify the associated risks in the YRB by assessing the fixed DF strategy proposed by the MoEUCC

To achieve these objectives, several probability distribution functions were assessed to calculate the MLF and MF of surface waters using SHW stream gauging stations' data. Then a point source inventory was built, and the DFs of point sources were calculated for two stream flow estimation approaches under two DF calculation scenarios for MF and MLF conditions. The results of the point source monitoring study and DF of point sources were evaluated by conducting a DF assessment for three cases. These cases were selected as "business as usual", "full commitment to the EU WFD", and "the fixed DF approach of the revised WPCR". The results of the DF assessment contributed to the development of a point source control strategy by revealing the potential load reduction in effluents and the identification of additional micropollutants that are the cause of concern at point source discharges. The workflow methodology of the DF assessment study is given in Figure 22.

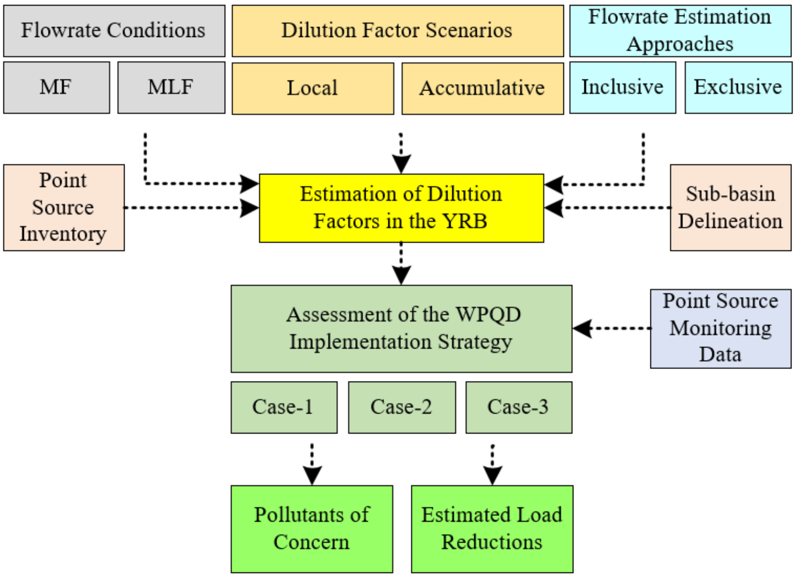


Figure 22. The Workflow Methodology of the Dilution Factor Assessment

4.3 Point Source Pollution and Main Challenges

The WFD (2000/60/EC) has entered its third cycle in 2021; however, despite all the combined efforts carried out in the last two decades, good chemical status in surface and groundwater bodies could not be achieved (Mohaupt et al., 2020). Over eight million water quality parameters from 8213 sampling stations have been analyzed in the EU, and the results indicate an increase in the frequency of organic micropollutants in surface waters (Wolfram et al., 2021). The wastewaters from industries, residential and commercial zones, and sometimes from agricultural activities undergo end-of-pipe treatment without considering their chronic effects on the aqueous ecosystems. These wastewaters contain micropollutants due to the manufacture and use of many chemical substances such as personal care products (PCPs), PPPs, pharmaceuticals, active substances, and surfactants, which eventually end up in the surface waters, groundwater, and sediments after treatment. The treatability of these micropollutants in the conventional WWTPs varies significantly, and the main factors affecting the removal efficiency are sorption capacity and biodegradation kinetics (Luo et al., 2014b; Tran et al., 2018). The removal of these pollutants in conventional WWTPs is generally low (< 40% at the global scale), and even negative removal efficiencies may be encountered. These instances are attributed to the latent dissolution of micropollutants in feces particles, the formation of metabolites, and the inevitable nature of the grab sampling technique (Guillossou et al., 2019; Tran et al., 2018). Even under controlled laboratory conditions, the removal efficiencies of micropollutants vary significantly (Gusmaroli et al., 2020). Since the surface and groundwater sources are valuable resources for agricultural, industrial, and domestic water supply purposes, there is a continuous accumulation of micropollutants in water due to the extraction of water from already polluted sources. As an example, pharmaceuticals and PCPs are detected at the outlet of conventional drinking water treatment plants, and their removal efficiencies are found close to zero in the absence of advanced treatment units such as nanofiltration, reverse osmosis, and activated carbon (Tröger et al., 2018). The effectiveness of advanced treatment options depends on the physico-chemical properties of the target micropollutants and the contact time; however, the overall efficiency of these systems reduces with usage time (McCleaf et al., 2017; Stackelberg et al., 2007). For this particular reason, the main source of micropollutants in the aqueous phase is regarded as the urban and domestic WWTPs (Blum et al., 2017; Cho et al., 2014; Eggen et al., 2014; Fairbairn et al., 2016; Gogoi et al., 2018b; Gusmaroli et al., 2020; Pal et al., 2010; Tran et al., 2018). In addition to wastewater discharges from WWTPs, untreated direct wastewater discharges are important sources of pollutants. Without any additional measures to control pollution loads to the environment, by 2050, it is expected that nutrient inputs will increase by 163% in the Eastern Mediterranean region due to increasing population, sewer connectivity, and per capita protein intake (Powley et al., 2016). Since domestic and urban wastewaters are the highest contributors to micropollutant pollution, it is likely to observe a similar increase in total micropollutant concentrations in aqueous ecosystems. Some researchers believe that the circular economy model, which requires closed-circle recycling and re-using of resources, should be adapted to the water and wastewater treatment systems to avoid micropollutant intrusion into the aquatic ecosystems (Taheran et al., 2018).

A wide variety of advanced chemical and physical treatment techniques such as activated carbon adsorption, O_3, and H_2O_2 oxidation, photocatalysis, and membrane filtration (ultrafiltration, nanofiltration, reverse osmosis) could be applied to remove micropollutants in WWTPs (Ahmed et al., 2017; Kovalova et al., 2013). Since the cost of treatment is an important factor, a cost-benefit analysis should be carried out to identify which treatment techniques are more suitable. Membrane processes and advanced oxidation processes are well known for their high performances and costs, while activated carbon is a popular choice due to its relatively low costs and ease of use (Bui et al., 2016). However, the removal efficiencies of ozonation and adsorption heavily depend on the composition of wastewater. Ozone or hydroxyl radicals oxidize the dissolved organic matter present in the wastewater, and this significantly reduces the oxidation potential of micropollutants if the dissolved organic carbon (DOC) content is high (Mulder et al., 2015). Since DOC also competes with micropollutants during adsorption, the efficiency of activated carbon treatment is also affected by the presence of high DOC. The pilot scale treatability studies indicate that both the activated carbon adsorption and ozonation are feasible solutions to micropollutant removal in urban wastewater treatment, whereas ozonation is better at the removal of targeted compounds and activated carbon performs better at the removal of mixed organic and inorganic micropollutants (Margot et al., 2013). The full-scale applications of ozonation and activated carbon are also in line with these findings, and on average, 80% micropollutant removal efficiency could be achieved with these techniques (Bourgin et al., 2018; Guillossou et al., 2019).

4.4 Point Source Control Strategies

Legislative liabilities are the main driving factors for the point sources to implement advanced treatment techniques to control micropollutant emissions. Although each country uses these techniques to treat micropollutants, their intention of use is different. In the USA and Australia, micropollutants are mostly treated when wastewater is planned to be reused (Bui et al., 2016). In Europe, monitoring and legislation studies are still in development for most countries. In Germany, some wastewater treatment plants are taking proactive measures to treat micropollutants at their discharges (Mulder et al., 2015). Switzerland is the first country that decided to upgrade 100 urban WWTPs over the next two decades for the removal of micropollutants. It was decided to cover WWTPs, which serve at least 80,000 people or have low dilution during low-flow conditions or discharge into sensitive areas (Eggen et al., 2014).

Although each country has its specific strategy to control point source pollution, all these strategies are based on the framework approaches proposed by the EU WFD (2000/60/EC) and the US Clean Water Act (CWA) (USEPA, 1972). These approaches are outlined in the following sections.

4.4.1 EU Water Framework Directive Approach to Controlling Point Sources

The WFD (2000/60/EC) requires that pollution prevention and control in point sources must be based on a combined approach, which incorporates both the ELV and the EQS. The determination of ELV in the EU follows a combined approach in accordance with the EU WFD and the IED (2010/75/EU) (European Commission, 2010). Under the IED, the BREFs cover brief information on a specific industrial or agricultural sector in the EU and give detailed information about sector-specific production techniques and processes, current emission and consumption levels and techniques to be considered when determining BATs. A BAT summarises technology, equipment, and operational practices to prevent or minimize emissions and impacts on the environment in a sector.

Article 14(3) of the IED proposes that "BAT conclusions" that are an important part of the BREFs shall be the reference for setting the permit conditions and will be separately published by the EC. In this context, the ELVs proposed in the BAT conclusions (BATAELs) cannot be exceeded at an industrial discharge unless there is clear local justification for granting a derogation. The flexibility of operating an installation with less than BAT performance is given to the Member States due to technical characteristics, geographical location, and local environmental conditions.

The discharge standards for the urban WWTPs are regulated with respect to the Urban Waste Water Treatment Directive (91/271/EEC) (European Commission, 1991).

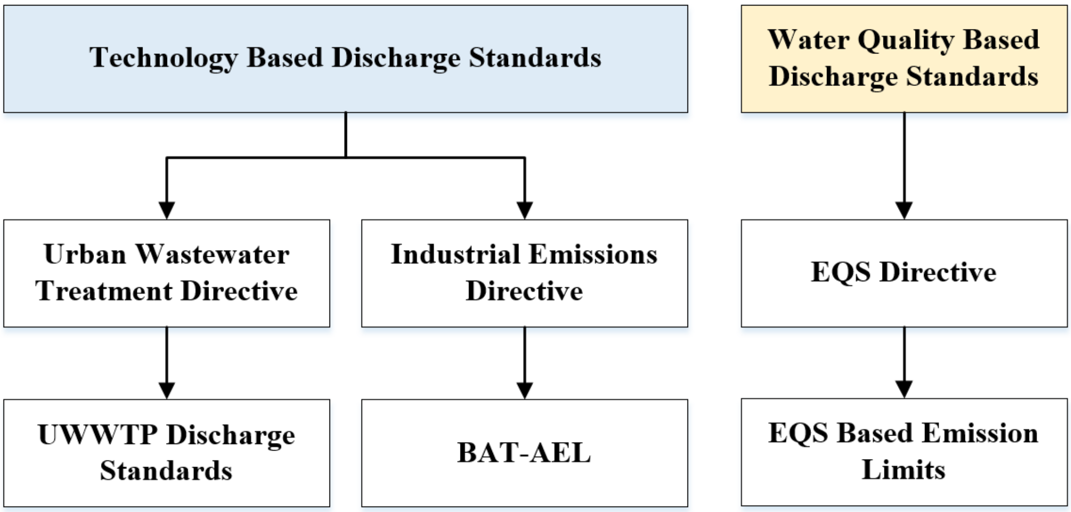


Figure 23. Discharge Standard or Emission Limit Determination Methodology

In conclusion, according to the IED, an industry must comply with the BATAELs without considering the relevant EQSs. If the concentration of a pollutant in the receiving environment after the discharge is above its EQS, Article 18 of the IED proposes that additional measures beyond BAT-based emission limits should be taken (Figure 23). Although the BREF documents and BAT recommendations clearly indicate the need to reduce PBT substances, the BAT conclusions do not describe the priority substances or river basin specific pollutants, which is regarded as an incomplete harmonization between the WFD and the IED (Brack et al., 2017).

4.4.2 The United States Environmental Protection Agency Approach to Controlling Point Sources

According to the US CWA, each activity that discharges pollutants to the receiving environment must obtain a discharge permit stating that it meets the limits for these pollutants in its discharge. The role of the EU IED is given to the USEPA's National Pollutant Discharge Elimination System (NPDES). The NPDES regulates the direct discharges to aquatic systems and gives discharge permits. The permits for point sources given by NPDES include what quality of wastewater can be discharged, monitoring and reporting requirements, and all other measures necessary to ensure that the discharge does not have any negative effects on water quality and human health. In the USA, both technology-based and water quality-based discharge limits are applied within the scope of the US CWA. Each state enforces its own technology-based discharge standards. According to the US CWA, discharge standards must be reviewed every three years and the updated standards should be reviewed by the USEPA. The discharge standards are determined by several effluent guidelines published by the USEPA on a sector-specific basis. These guidelines and the pollutants regulated by them are given in Table 19. BPT, BCT, and BAT regulate the existing direct discharges, while new direct discharges are regulated by the NSPS. The indirect discharges are regulated by PSES and PSNS for existing and new discharges, respectively.

Table 19. Effluent Guidelines and Pollutants Regulated (USEPA, 2022)

Effluent Guidelines	**Priority Pollutants**	**Conventional Pollutants**	**Nonconventional Pollutants**
Best Practicable Control Technology Currently Available (BPT)	X	X	X
Best Conventional Pollutant Control Technology (BCT)		X	
Best Available Technology Economically Achievable (BAT)	X		X
New Source Performance Standards (NSPS)	X	X	X
Pretreatment Standards for New Sources (PSNS)	X		X
Pretreatment Standards for Existing Sources (PSES)	X		X

4.4.3 Approaches Adopted to Set Emission Limits

The commonly used framework approaches to setting emission limits are summarized in the following sub-sections.

4.4.3.1 Mixing Zone Approach

According to the mixing zones approach, the concentration of a micropollutant must meet the water quality-based standards at the end of a mixing zone (Figure 24) rather than the immediate discharge point. In the EU, the EQSD allows the Member States to define mixing zones for their water bodies, and a technical guideline document is available to assist them during this stage (EC, 2010b). Member States have adopted different approaches to determining the size of the mixing zone, although there is not any obligation. For example, Denmark applies a mixing zone of 50 to 100 meters from the discharge point as the initial dilution zone for coastal waters. In the other Member States, the maximum size of the allowable mixing zone is directly proportional to the width of the water body and is limited by a fixed maximum value. In the Netherlands, the fixed value is equal to 10 times the width of the body of water, up to a maximum of 1000 meters (EC, 2010b).

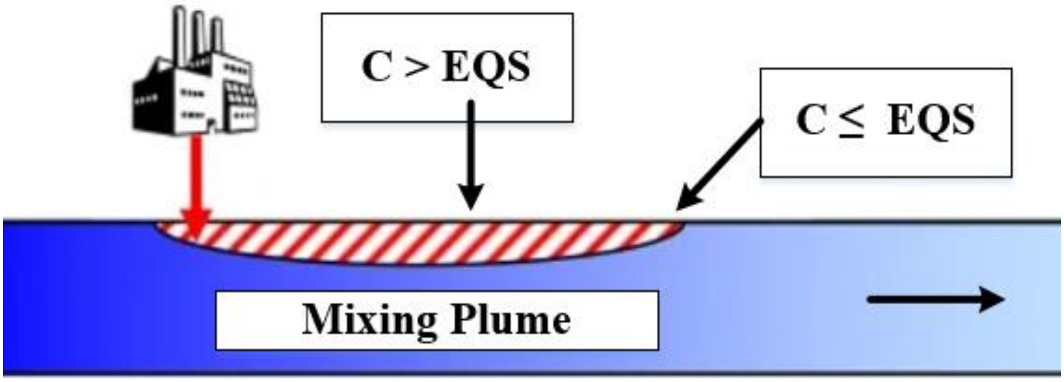


Figure 24. Concept of Mixing Zone (Bijstra et al., 2015)

The Technical Background Document on Identification of Mixing Zones describes the steps for identifying sources with significant impacts on water bodies, which is called the “Tiered Approach” (Figure 25) (EC, 2010a). The basic idea of having such an approach is to eliminate sources that do not have a significant impact on water bodies and to focus available resources on more critical situations. The aim of having such an approach is to analyze the conditions of point sources at the stage of setting emission permits and to offer the most appropriate solution from simple to complex while protecting the receiving environment.

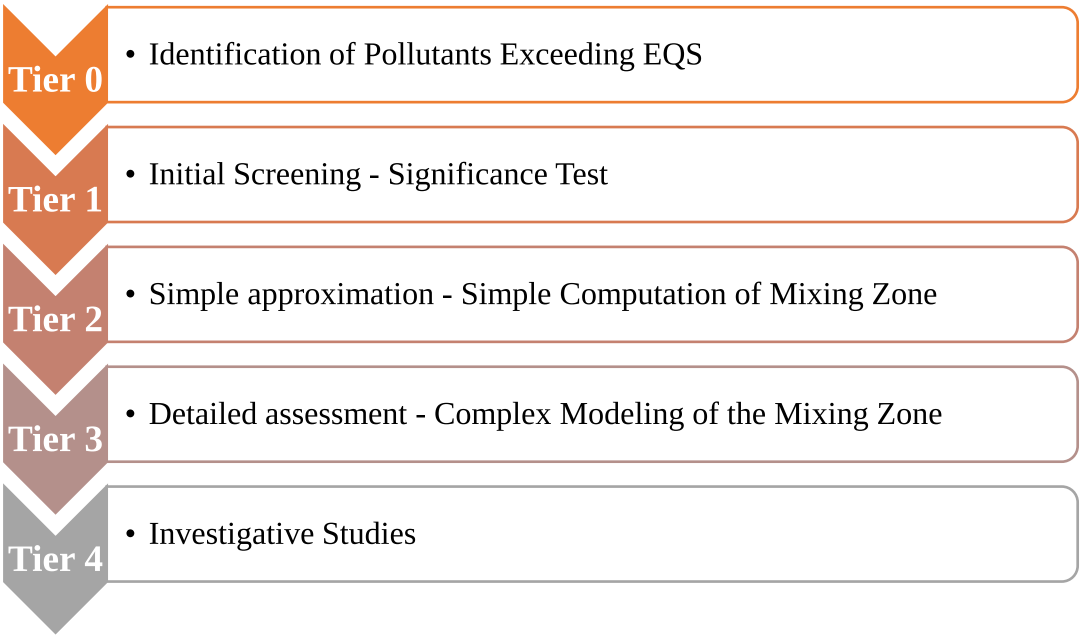


Figure 25. The EU Tiered Approach (EC, 2010b)

Tier 0 is the identification of pollutants that have a concentration greater than EQS at each individual discharge. If the pollutant concentration is below its EQS, then those pollutants are considered insignificant for that source since its concentration will not increase the concentration in receiving environment above the EQS value. Tier 1 is the significance test for pollutants that exceed the EQS at the discharge. Process Contribution (PC) of each facility and pollutant is calculated. The PC is compared with the allowed limits of concentration increase in the receiving environment. The allowable increase of the concentration varies from 0.5% to 7.9%

depending on the type of receiving waters (EC, 2010a). If the concentration increase (PC) is beyond allowable limits, Tier 2 is applied. At Tier 2, the dimensions of the mixing zone are "estimated" by simple computation methods. Likewise, Tier 3 is applied with increasing detail for the estimation of the mixing zone if Tier 2 approach results do not satisfy the EQS limitations. Tier 4 methodology includes a wide range of investigative activities such as chemical concentrations, bathymetry, sediment characteristics, dispersion characteristics, receptor characterization, and new ecotoxicology studies.

Although there are numerous tools and software available to calculate mixing zones with simple approximations, the Discharge Test software is an MS Excel Workbook recommended in "Technical Guidelines for the Identification of Mixing Zones" (EC, 2010b). The Discharge Test software was developed to investigate the concentration of pollutants of concern at the end of a simple mixing zone. The dimensions of the mixing zone are calculated using "Fischer" equations. The working principle of the Discharge Test software is given in Figure 26. In order to calculate if the concentration at the discharge is permissible or not, simple information such as flow rate, concentration, depth, and width of surface water should be entered.

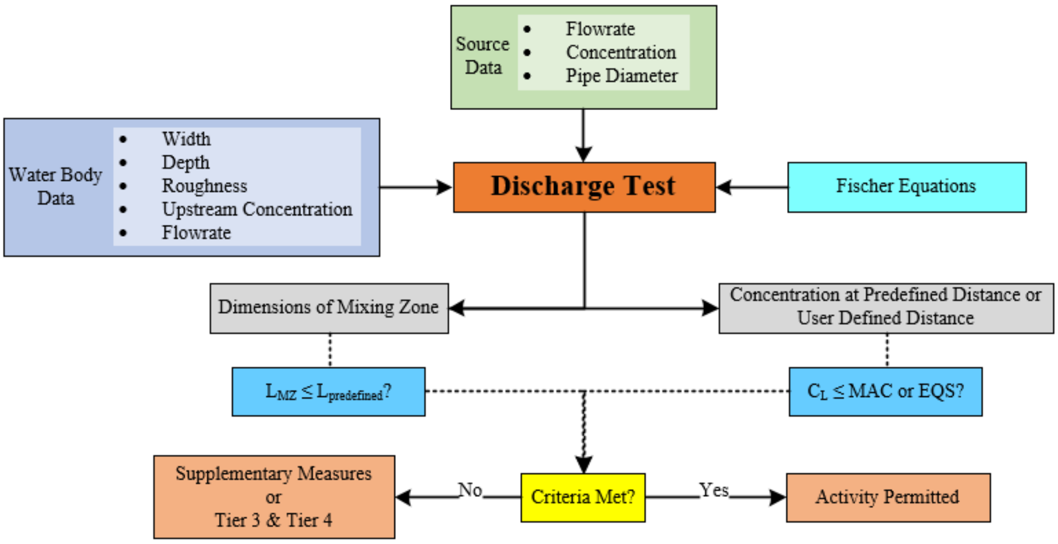


Figure 26. Working principle of the Discharge Test Software (Kucuk, 2018)

Similar to the EU WFD approach, the US CWA also enacts the determination of mixing zones to set emission limits to point sources. The USEPA is the authorized institution for the development of the mixing zones approach and establishing a mixing zone policy. Similar to the EU WFD (2000/60/EC), the acute and chronic toxicity-based mixing zones approach is adopted by the USEPA. The Criteria Maximum Concentration (CMC) is used to define acute environmental standards, while the Criteria Continuous Concentration (CCC) is used to define chronic environmental standards. The CMC can be regarded as the equivalent of MAC-EQS, while the CCC can be regarded as the equivalent of AA-EQS. Once again, another similarity with the EU WFD approach, USEPA defines two mixing zones at an effluent outfall (Figure 27), where the first one surrounds the outfall in a small zone and the CMC must be met in this zone. The boundary of the second zone is the extent of the mixing plume, where CCC must be met after that point. The USEPA requires the use of water quality modeling software such as PLUMES and CORMIX to calculate the extent of mixing zones and to set ELVs (USEPA, 2006).

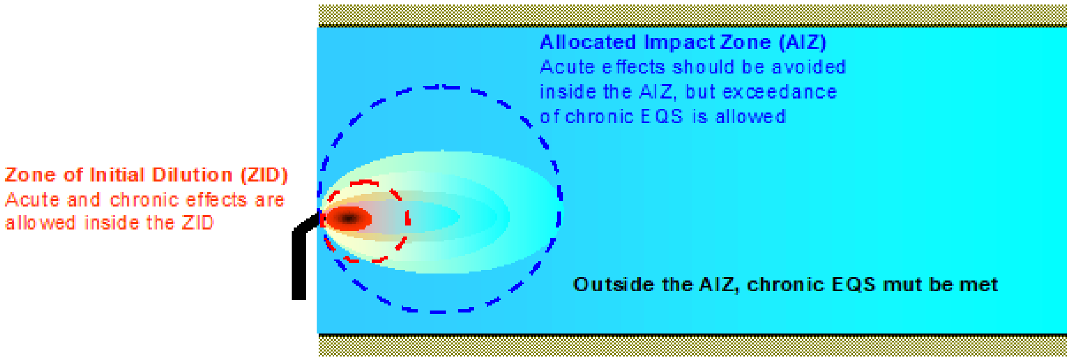


Figure 27. Regulatory Mixing Zones Defined by the USEPA (EC, 2010a)

4.4.3.2 Total Maximum Daily Load Approach

The TMDL is another concept for setting ELVs to the point source discharges, which considers the total mass of a pollutant that can be discharged into surface water. In other words, a TMDL is the calculation of the maximum amount of a pollutant allowed to enter a water body so that the water body will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the sources of the pollutant (USEPA, 2021c). Mathematically, TMDL is expressed as Equation-6:

$$TMDL\left(\frac{Mass}{Day}\right) = \sum WLA + \sum LA + MOS \qquad (Equation - 6)$$

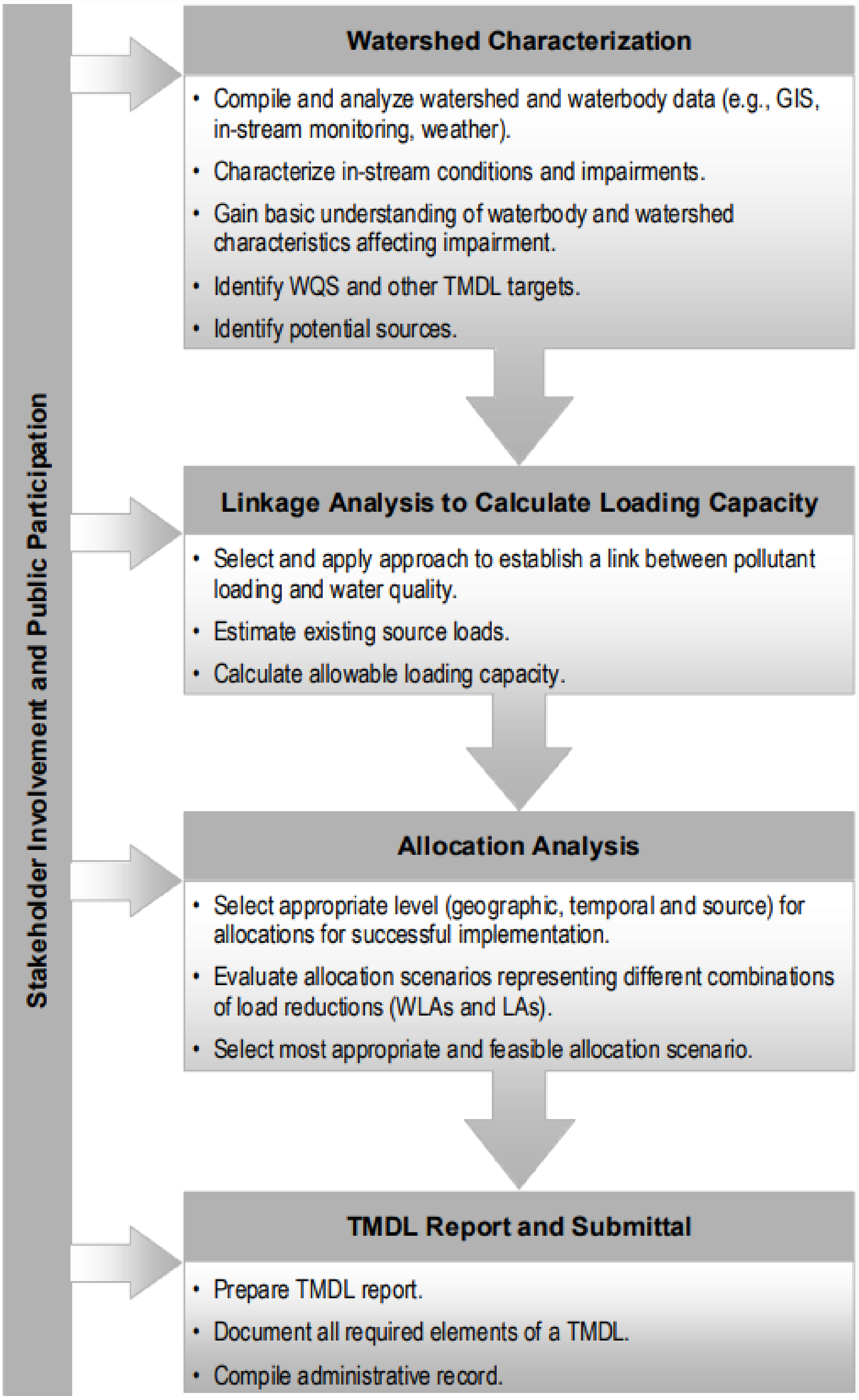
where;

WLA: Waste load allocation of point sources (mass/day)

LA: Sum of non-point source allocations and background (mass/day)

MOS: Margin of safety (mass/day)

As the definitions imply, each implementation step reduces the load of pollutants that can be discharged into a river body. This situation conflicts with the nature of planning treatment plants and abatement techniques since these investments should be planned in the long term. The first development step of a TMDL is identified as basin characterization. Point and diffuse pressures, and background concentrations should be identified. In the second step, linkage analysis is conducted to establish a link between pollutant loads and water quality, and allowable capacity should be calculated. In the third step, pollutant loads are allocated between sources by using water quality models and/or simple mass balance calculations adopting a conservative approach. Stakeholder involvement is an important element of the TMDL development and public participation is targeted in all steps.



- Compile and analyze watershed and waterbody data (e.g., GIS, in-stream monitoring, weather).
- Characterize in-stream conditions and impairments.
- Gain basic understanding of waterbody and watershed characteristics affecting impairment.
- Identify WQS and other TMDL targets.
- Identify potential sources.

- Select and apply approach to establish a link between pollutant loading and water quality.
- Estimate existing source loads.
- Calculate allowable loading capacity.

- Select appropriate level (geographic, temporal and source) for allocations for successful implementation.
- Evaluate allocation scenarios representing different combinations of load reductions (WLAs and LAs).
- Select most appropriate and feasible allocation scenario.

- Prepare TMDL report.
- Document all required elements of a TMDL.
- Compile administrative record.

Figure 28. Workflow of Developing a TMDL (USEPA, 2008)

4.4.3.3 Empirical Dilution Factor Approach

In Japan, the discharge limits are also determined by considering the environmental concentrations of pollutants. The framework approach is similar to the approaches of the EU WFD (2000/60/EC) and the US CWA. During the transitional period of adapting water quality-based discharge limits from technology-based discharge standards, the Environment Management Bureau of Japan decided to apply a provisional fixed DF of 10 for some specific sources that face difficulty in meeting EQS-based effluent limits (Figure 29) (Wako, 2012). In principle, the EQS of a pollutant is multiplied by 10 and set as the discharge limit. This provisional measure is reviewed every three to five years to consider the status of the sector having difficulties and to reflect technological advancement in provisional measures. A wastewater volume threshold of 50 m^3/day was determined to apply the empirical fixed DF assessment. A major weakness of this approach is that the low-flow conditions in surface waters are not considered during the determination of emission limits.

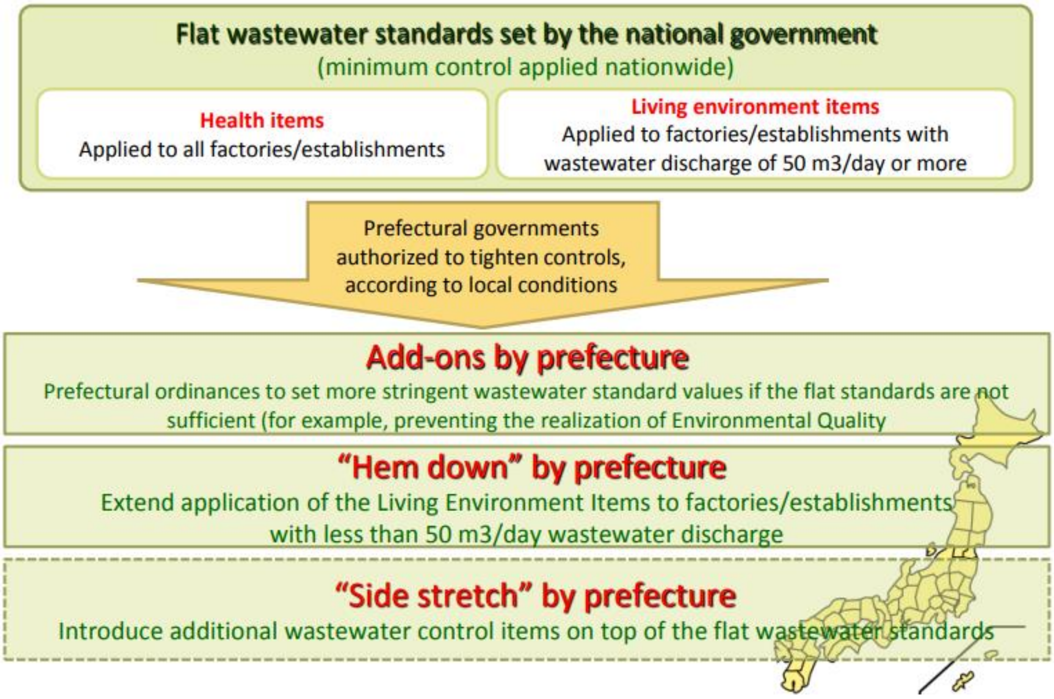


Figure 29. Provisional Effluent Pollution Control Strategy in Japan (Wako, 2012)

4.5 Methodology

4.5.1 Low Flow Estimation

The low-flow conditions should always be considered during the calculation of dilution of a point source at receiving water body. Low flow is the “flow of water in a stream during prolonged dry weather conditions”. Ecosystems are most vulnerable during low-flow periods because of water temperature extremes, dissolved oxygen reduction, and reduced effluent dilution. Low flow statistics provide a valuable estimate of the conditions experienced during the dry seasons. The complexity of calculation and the multidisciplinary variances in low-flow estimations make it difficult to come up with a common approach to calculating low flow (Ouarda et al., 2008). The "Manual on Low-flow Estimation and Prediction", published by the World Meteorological Organization (WMO), gives an idea of how to analyze stream flow data focusing on low-flow issues (WMO, 2008). Many designs or water resources management decisions are based on three main indices:

- Mean Flow
- 95-percentile (Q95)
- Mean annual minima: MAM (n-day)

Mean annual minima can be calculated from the daily flow series by selecting the lowest flow every year. In low flow hydrology, minima of different durations, such as 1, 7, 10, 30, 90, and 120-days moving averages derived from daily data are frequently used. Estimates of the mean annual minimum 7-day flow (MAM(7) - the lowest average flows that occur for a consecutive 7-day period during a year) are frequently used for ecological risk assessments (WMO, 2008). In the USA, the lowest 7-day average flow that occurs once every ten years (7Q10) is recommended for point sources (USEPA, 2021b). In the EU, the 10th percentile is the recommended low-flow to be considered during the environmental exposure assessment of a chemical substance; however, one-third of the average flow can also be used if data is unavailable (ECHA, 2016).

For an accurate calculation of low flow statistics, an observation duration of 30 years is recommended; however, capturing 15-20 years of data is also found adequate (USEPA, 2018). Although the location of surface water monitoring stations in this study represents the YRB well, the total number of samples is not enough to conduct low flow statistics. In addition, the flow of unmonitored tributaries is required to calculate the dilution of untreated point wastewater discharges. The data for stream gauging stations from 1959 to 2015 was published by the MoAF – SHW (MoAF, 2015). Only data from 1997 to 2015 (19 years) could be used since the data regarding earlier years are not formatted properly during publishing and were not suitable for processing. The data from MoAF are provided as a pdf file for each day of a year for 1610 gauging stations in Turkey with varying observation durations. A sample data format was provided in Appendix I - Figure A 4. In the YRB, 381,672 daily observations were available for 110 stations, which were converted to a table format and corrected for multiple records, unique station IDs, and coordinates and then exported to Geographic Information System (GIS) (Figure 30). Among these stations, 49 stations have a historical observation duration of at least 10 years, 30 stations have an observation duration of at least five years, and 31 stations have an observation duration of less than four years (Figure 31).

During low flow analysis, parametric estimation methods (probability distribution functions) are required. Different distribution methods should be evaluated to identify which distribution best represents the observed variables, which are selected among an extensive library of established distribution families (Zaidman et al., 2002).

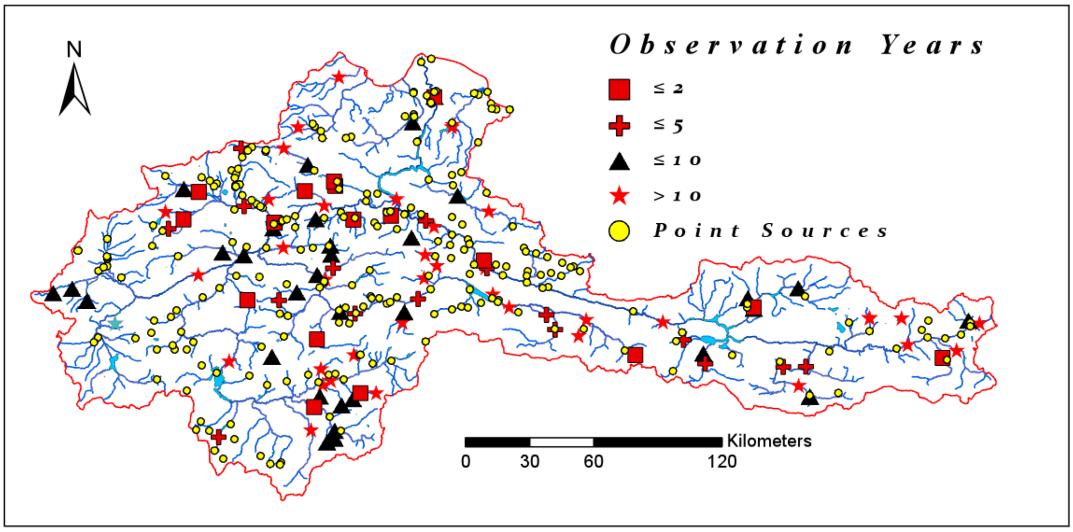


Figure 30. Superposition of SHW Gauging Stations and Point Sources, and Observation Years Available at Each Station

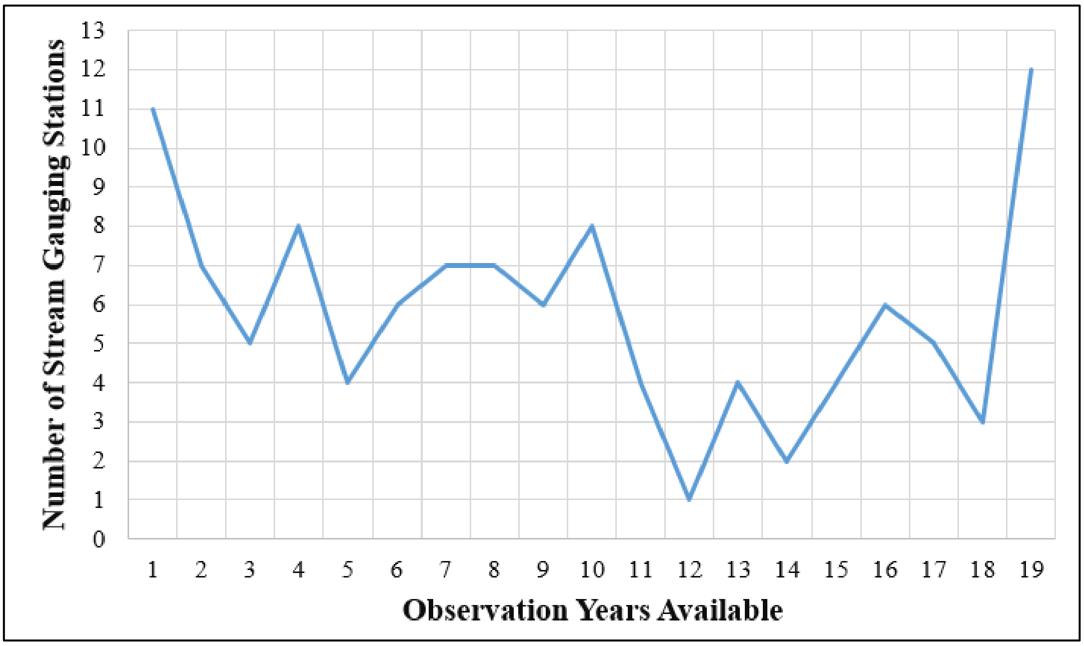


Figure 31. Variance in Observation Durations of SHW Gauging Stations

Previously, seven different distribution functions, i.e., Weibull (W2/W3), Gamma (G2/G3), Generalized Extreme Value (GEV), and log-normal (LN2/LN3), were checked with their suitability in Meriç-Ergene, Gediz, Seyhan and Ceyhan River

Basins; three-parameter log-normal distribution (LN3) was identified as the best fit for most river basins, while Weibull (W3) was found as the best fit to Seyhan River Basin (Eris et al., 2019). In the YRB, normal (N), LN2, LN3, logistic (LOG), GEV, generalized Pareto (GPA), and log-Pearson type three (LP3) were evaluated for three stream gauging stations and LP3 was identified as the best fit in most seasons (Yürekli et al., 2005). In this study, the eleven different probability distribution functions were checked in 110 stream gauging stations in the YRB, and the coefficient of determination (R^2) for each function was given in Figure 32, with median R^2 values inside the boxplots.

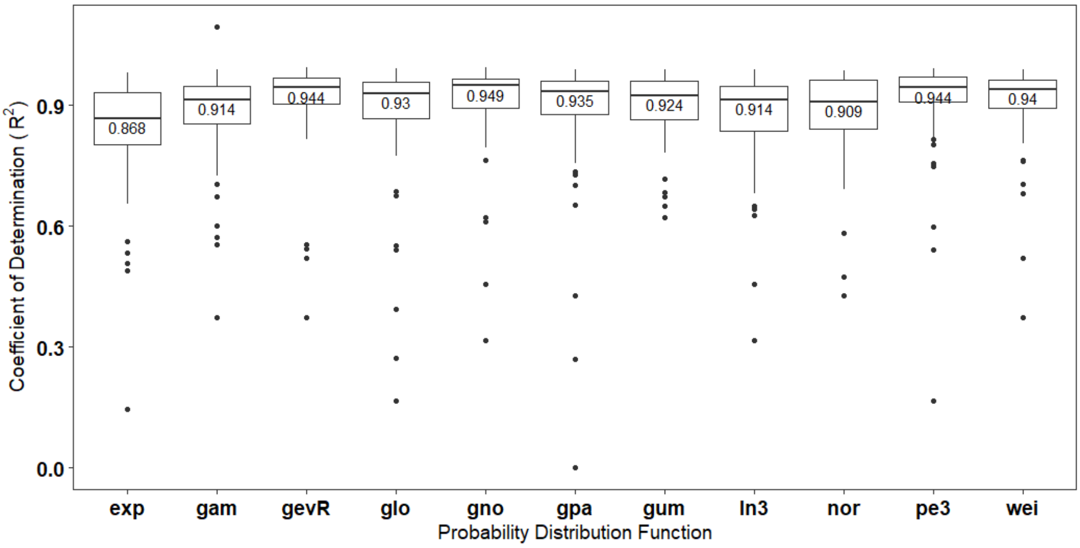


Figure 32. Probability Distribution Functions and Coefficient of Determinations

As can be seen from Figure 32, the R^2s of some stream gauging stations are significantly low. These are the outlier values and their low R^2 was not considered during the identification of the best fitting model. However, all stations could not be modeled using the given distribution functions, and the summary of each model was provided in Table 20. The models validated in the previous studies (LN3 and LP3/pe3) could not be fitted into approximately 35% of the YRB stream gauging stations' historical data due to year gaps in the data or missing values, which means that low flow value could not be evaluated in those stations. Similarly, any of the three-parameter distribution functions could not be fitted for more than 25% of stations for 7Q10 and 18% of stations for 7Q2. The spatial distribution of these stations in the YRB and the total number of valid low-flow calculations were evaluated together to identify a methodology. It was decided that the three-parameter Pearson type III distribution (pe3) using the 7Q2 method of low-flow estimation was the best fit for flow calculations in the YRB.

Table 20. Low-flow Distribution Functions and Total Number of Modeled Stream Gauging Stations

Distribution Function		**# of Stations**	
		7Q10	**7Q2**
Two-parameter exponential distribution	exp	93	103
Three-parameter reverse generalized extreme-value distribution	gevR	74	80
Three-parameter generalized logistic distribution	glo	81	87
Three-parameter generalized normal distribution	gno	80	86
Three-parameter generalized Pareto distribution	gpa	81	91
Two parameter Gumbel (extreme-value type I) distribution	gum	84	101
Normal distribution	nor	79	103
Three-parameter Pearson type III distribution	pe3	79	87
Three-parameter Weibull distribution	wei	83	83
Two-parameter gamma distribution	gam	102	102
Three-parameter lognormal distribution	ln3	71	71

* Two-parameter: combinations of shape, location, and scale distribution; three-parameter: location, scale, shape distributions

The Pearson type III distribution contains three-parameter gamma distribution with a finite lower bound and positive skewness, which prevents negative flow value estimations. The distribution's three parameters are μ (the mean, a location parameter), σ (the standard deviation, a scale parameter), and γ (the skewness, a shape parameter), and calculated according to Equation -7 (Hosking, 2022).

$$f(x) = \frac{|x-\varepsilon|^{\alpha-1}\exp(-|x-\varepsilon|/\beta}{\beta^{\alpha}\,\Gamma(\propto)} \qquad (Equation - 7)$$

$where\ If\ \gamma \neq 0, let\ \ \propto = 4/\gamma^2\,, \beta = 1/2\ \sigma\ |\gamma|\,, \varepsilon = \mu - 2\sigma/\gamma$

4.5.2 Estimation of Stream Flow Rates at Point Source Discharges

As mentioned in Chapter 4.5.1, the SHW stream gauging stations' spatial distribution in the YRB is adequate to estimate the stream flow rates at point source discharges. However, these stations are usually at least a few kilometers away from discharge locations (Figure 33). In addition, some point sources are located on the tributaries of main rivers, where stream gauging stations are not available.

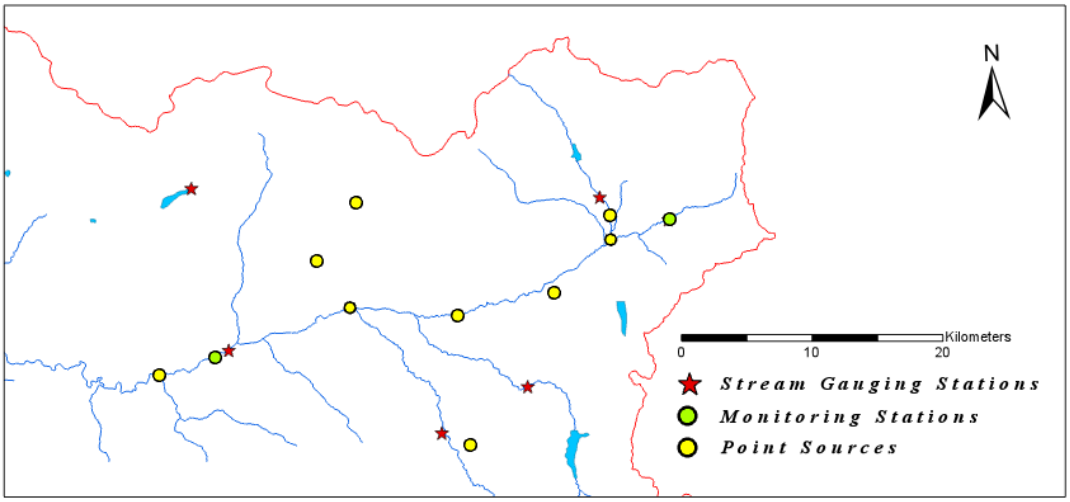


Figure 33. Position of SHW Stream Gauging Stations, Point Sources and Surface Water Monitoring Stations

The MF and the MLF (MLF / 7Q2) of streams were estimated for each point source and monitoring station in the YRB. The flow accumulation map of the YRB was used to estimate any stream flow rate between two SHW stream gauging stations, following the catchment area ratio method (Hirsch, 1979). Flow accumulation maps calculate the accumulated flow as the accumulated weight of the area flowing into a point. The catchment area and flow rate of the upstream gauging station (CA_{US} and Q_{US}, respectively), the catchment area and flow rate of the downstream gauging station (CA_{DS} and Q_{DS}, respectively), and the catchment area of the point source (CA_{PS}) were used to estimate the unknown stream flow rates at point source discharges (Q_{PS}), by using Equation-8. If either of the upstream or downstream stations was not available (Figure 34), the stream flow rate at a point source was calculated by using Equation-9. The stream flow rates of monitoring stations were also estimated using the same methodology.

$$Q_{PS}\left(\frac{m^3}{day}\right) = Q_{US} + \left(\frac{CA_{PS} - CA_{DS}}{CA_{US} - CA_{DS}}\right) * (Q_{US} - Q_{DS}) \qquad (Equation - 8)$$

$$Q_{PS}\left(\frac{m^3}{day}\right) = \left(\frac{CA_{PS}}{CA_{US}}\right) * Q_{US} \quad or \quad Q_{PS} = \left(\frac{CA_{PS}}{CA_{DS}}\right) * Q_{DS} \quad (Equation - 9)$$

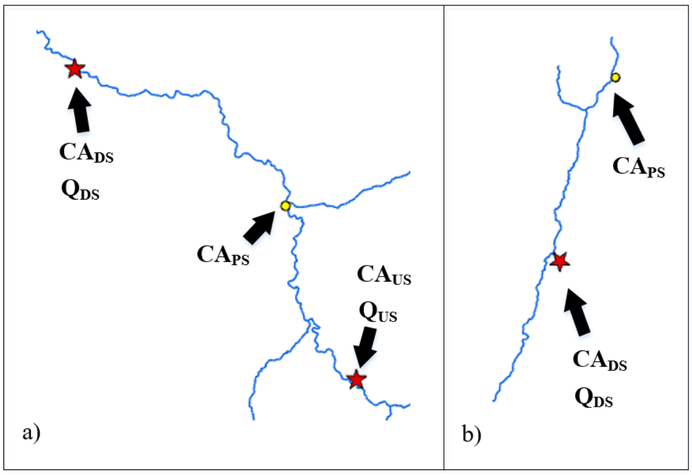


Figure 34. Example Positioning of Stream Gauging Stations and Point Sources: (a) both Upstream and Downstream Gauging Stations Available, (b) only Downstream Gauging Station Available

As the distance between stream gauging stations and the estimated location increases, the uncertainty of the estimation also increases due to external factors along the river path such as direct wastewater discharges, withdrawal and discharge from agricultural activities, and surface-groundwater interaction. An example is given in Figure 35, where the stream flow rate of the point source is estimated as 105 m^3/day since it is located at the center of two reference catchment areas (CA). The error of estimation increases with the extent of water withdrawal downstream of the point source. Water withdrawals between two reference points cause underestimation, while water discharges cause overestimation. A conservative mass balance approach was adopted during steam flow rate estimation, assuming that all withdrawals and discharges are negligible.

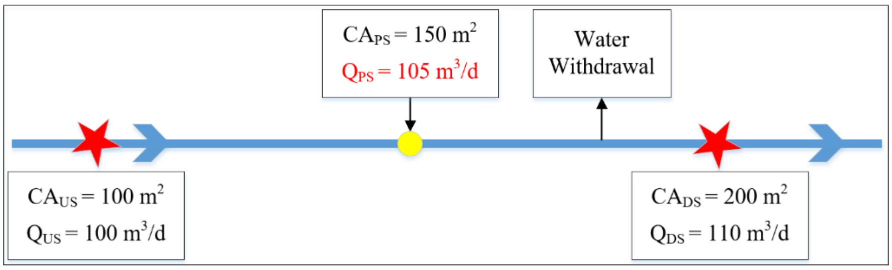


Figure 35. Example of Uncertainty in Stream Flow Rate Estimation

4.5.3 Calculation of Dilution Factor

The calculation of DF is a straightforward methodology, which requires the flow rate of a wastewater discharge to a water body and the stream flow rate at the discharge location (Figure 36). The point source inventory of the YRB was built by merging information from various sources (Chapter 2.2 – Appendix A Table A 1 & Table A 2). The stream flow rates were estimated according to methodologies provided in Chapter 4.5.1 and Chapter 4.5.2.

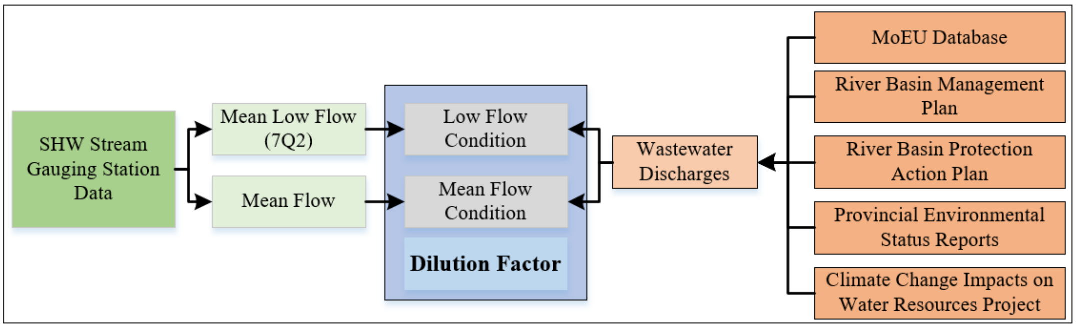


Figure 36. Dilution Factor Assessment Methodology

There are two approaches available for the calculation of the DF. The DF for a given point discharge depends on the corresponding stream flow rate (Q_{stream}). If the Q_{stream} excludes the effluent volume ($Q_{effluent}$), the total flow rate at the point of discharge should be considered. In this case, the DF is calculated according to Equation-10. If the stream flow rate includes the $Q_{effluent}$, which is only available if the flow rate is measured downstream from the effluent discharge point then the DF is calculated according to Equation-11 (EC, 2010b).

$$DF_{ex} = (Q_{effluent} + Q_{stream})/Q_{effluent} \qquad Equation - 10$$

$$DF_{in} = Q_{stream}/Q_{effluent} \qquad Equation - 11$$

An inclusive approach is a conservative approach that should be adapted during risk and impact assessments. In addition to the uncertainty in stream flow rate estimation in the catchment area ratio method, since the stream flow rates were estimated from SHW stream gauging stations' historical data, it is unknown if the stream flow rate measurements include the point source discharges and other external factors mentioned in Chapter 4.5.2. Assuming all inputs and outputs are reflected in the stream flow rate measurements, inclusive or exclusive approaches should not affect the DF. However, due to external factors, the results of the inclusive and exclusive approaches are always different and add another uncertainty to flow rate estimations. As a result, the upstream flow rate can be calculated as a negative value when using the inclusive approach, which decreases the reliability of the DF calculations. An example showing the negative upstream flow rate calculation is provided in Figure 37.

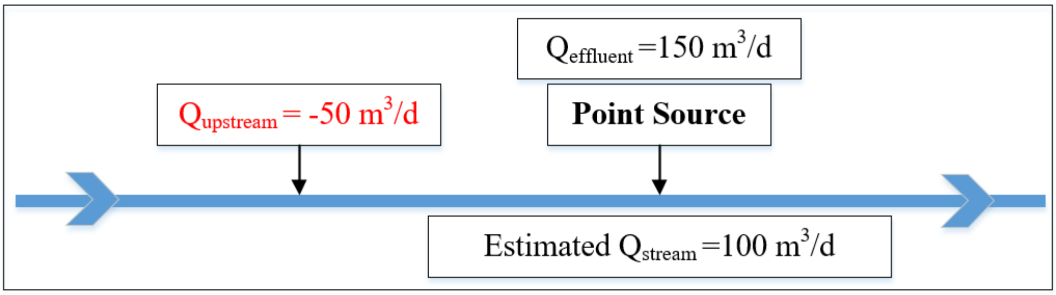


Figure 37. Example Negative Upstream Flow Rate Calculation

In this study, the inclusive approach will be preferred if it is possible to calculate the DF of the YRB sources. In case the inclusive approach was not found viable for the DF calculations, where the upstream flow rates are calculated as negative, the exclusive approach will be preferred for that sources. For this reason, the DFs for the inclusive and exclusive approaches were calculated separately and checked for any significant differences.

In addition to the inclusive and exclusive approaches of stream flow rate estimation, a conservative approach may be adapted to consider the discharges of other WWTPs and other known sources. In this case, the DF is calculated according to Equation-12 and Equation-13 for exclusive and inclusive approaches, respectively (Link et al., 2017).

$$DF_{ex,j} = (\sum_{j=1}^{n+1} Q_{effluent,j} \quad + Q_{stream_j}) \Big/ \sum_{j=1}^{n+1} Q_{effluent,j} \qquad Equation-12$$

$$DF_{in,j} = Q_{stream_j} \Big/ \sum_{j=1}^{n+1} Q_{effluent,j} \qquad Equation-13$$

where:

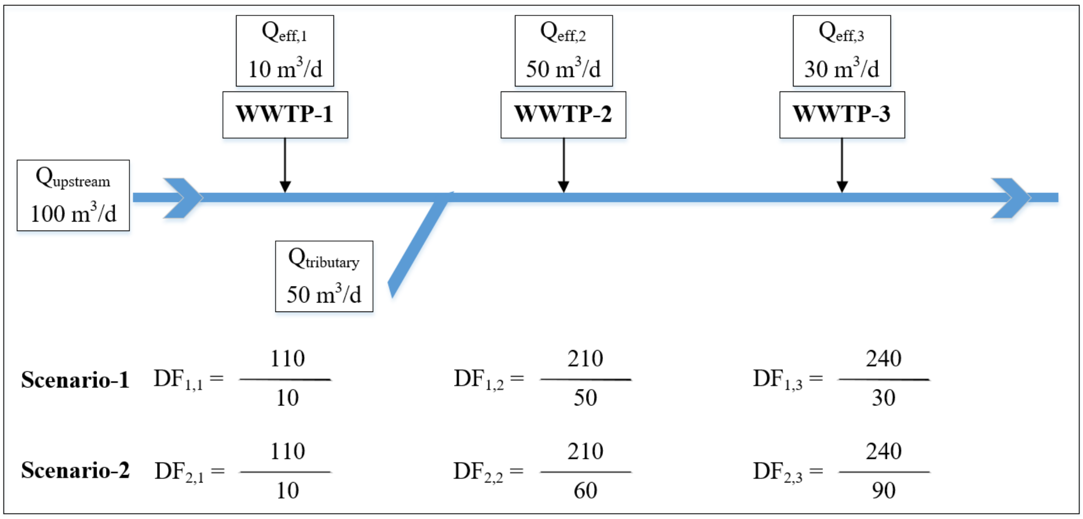
j = (n+1)th point source in the stream flow order

n = Number of point sources upstream of *j*

The DF was calculated for both exclusive and inclusive stream flow rate estimation approaches under two different scenarios:

- **Scenario 1 (DF_1):** The first scenario is the local DF, which neglects the accumulated pollution load in the catchment. This type of DF calculation is used for environmental exposure assessments in the EU (ECHA, 2016). This is also the suggested method for simple approximation of the extent of the EQS exceedance in the EU Tiered Approach (EC, 2010a).
- **Scenario 2 (DF_2):** The second scenario is the river basin DF, which accounts for the total wastewater discharges along the YRB. This scenario assumes that micropollutants have high environmental persistence, undergo negligible degradation, and accumulate downstream of the YRB.

For inclusive and exclusive approaches, the calculation of DF under both scenarios is demonstrated in Figure 38. Both DF calculation scenarios have their advantages and limitations. The DF_1 can be applied to any source without considering other sources in a basin; however, if the distance between two sources is short and their effluent mixing zones overlap, this might cause an underestimation in both the DF and environmental exposure. On the other hand, the DF_2 scenario assumes a conservative approach, which rarely occurs in environmental conditions unless the mixing zones of two or more sources overlap. In addition, all sources and their flow rates must be identified to calculate DF_2. Under ideal conditions, the extent of the mixing zone for each source, and the environmental fate of each micropollutant should be identified prior to the calculation of the DF, and the resulting DF would be a value between DF_1 and DF_2. In this study, an evaluation was made using both extreme ends of the DF calculation, without going into details about mixing zones and environmental fates.



Scenario-1 $DF_{1,1} = \frac{110}{10}$ $DF_{1,2} = \frac{210}{50}$ $DF_{1,3} = \frac{240}{30}$

Scenario-2 $DF_{2,1} = \frac{110}{10}$ $DF_{2,2} = \frac{210}{60}$ $DF_{2,3} = \frac{240}{90}$

Figure 38. Example Calculation of Dilution Factor under Two Scenarios

4.5.4 The Skeletal Structure of the Streamflow Network

Based on the locations of the 52 surface water monitoring stations, 21 monitoring stations were identified to divide the YRB into representative sub-basins. The selection of surface water monitoring stations was based on their location in the YRB, where stations downstream of major urban and industrial WWTPs, and junctions of main tributaries were prioritized. The average distance between monitoring stations was also considered and 31 monitoring stations were screened since they were too close to each other to form representative sub-basins. For example, there are five surface water monitoring stations on the Tersakan River, and only one station downstream of all point sources was designated to create a sub-basin. The placement of these 21 sub-basins and point sources in the YRB was given in Figure 39. The sub-basin 21 is not a tributary of the Yeşilırmak River and discharges into the Black Sea from Samsun. The point sources, which do not belong in any of these sub-basins were categorized separately and named "Other". Among 249 point sources in the YRB, 12 point sources are located on small streams that are too close to the Black Sea. These streams do not have a connection to any SHW stream gauging station and hence the stream flow rate was not estimated for these sources. These 12 point sources were not evaluated during the calculation of the DFs.

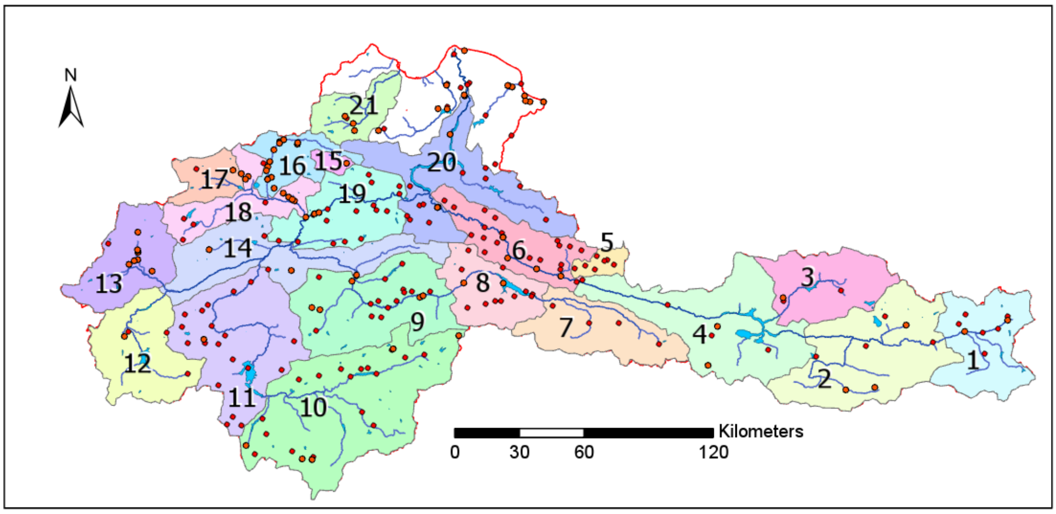


Figure 39. The 21 Sub-basins Identified and Point Sources in the YRB

After delineating the sub-basins, the skeletal river network of the YRB was identified (Figure 40) in order to sort the point sources by streamflow order starting from the first point source to the upstream. First, the point sources in each main tributary of the YRB (Kelkit River, Çorum River, Çekerek River, and Tersakan River) were sorted in their respective sub-basins and eventually merged into subsequent sub-basins numbered 14, 19, and 20, respectively.

Although there is not any upstream-downstream relationship among the four tributaries, the spatial sorting of point sources was started upstream of Kelkit River. Six sub-basins were identified as part of the Kelkit River before joining Yeşilırmak River in sub-basin 20. The point sources in the Upper Yeşilırmak River, which includes sub-basins 7, 8, and 9, were sorted after the Kelkit River. The second upstream tributary was identified as the Çekerek River (Sub-basins 10 and 11) in the Southern Region of the YRB. The third upstream tributary, Çorum River (Sub-basins 12 and 13), merges with Çekerek River and flows into Yeşilırmak in Amasya. Finally, the fourth tributary, the Tersakan River (Sub-basins 15, 16, 17, and 18) flows into Yeşilırmak in Amasya. The Yeşilırmak River flows into the Black Sea in the Çarşamba District of Samsun.

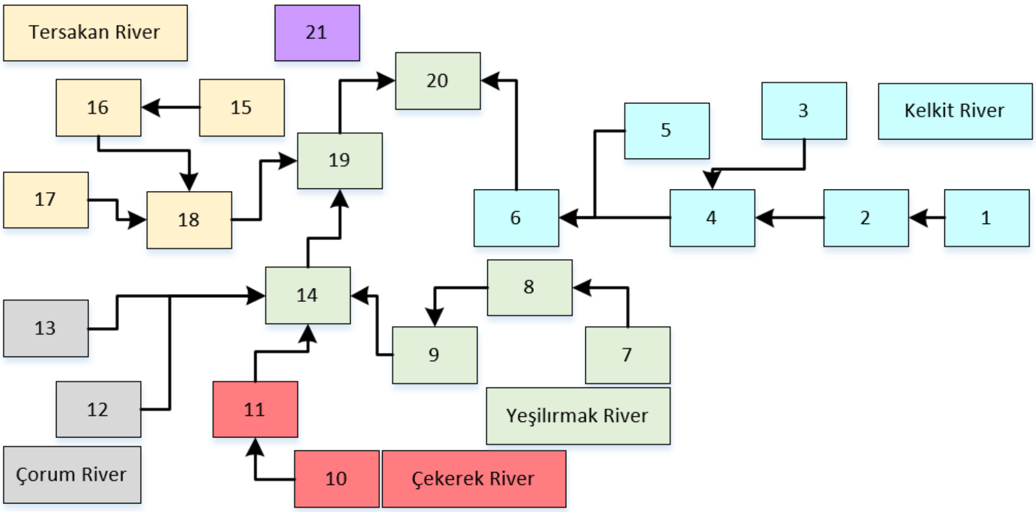


Figure 40. The Skeletal River Network of the YRB

4.5.5 Fixed Dilution Factor Assessment Methodology

The assessment of using fixed DF as a point source control strategy was conducted by the methodology proposed in Figure 41. In the first step, a relevance check was conducted similar to the Tier-0 approach of the EU WFD (2000/60/EC). Any micropollutant quantified in the surface water samples or the WWTP effluents were assessed for their significance. In the second step, the annual average concentration of micropollutants in surface waters and the WWTP effluents were compared with their respective AA-EQS values. In the third step, the annual average concentrations of micropollutants were compared with their LoQ values to screen out any false positive measurements. As mentioned in Chapter 2.3, 13 micropollutants were excluded from evaluation due to various reasons. In addition to these micropollutants, an additional eight micropollutants (Chlorfenvinphos, DEHP, 1-chloronaphthalene, 1-Methylnaphthalene, 2-chloronaphthalene, Acetachlor, Br, Fosetyl-Al) were flagged for concentration control since their LoQ value changed during the monitoring campaign and this may cause a false positive result.

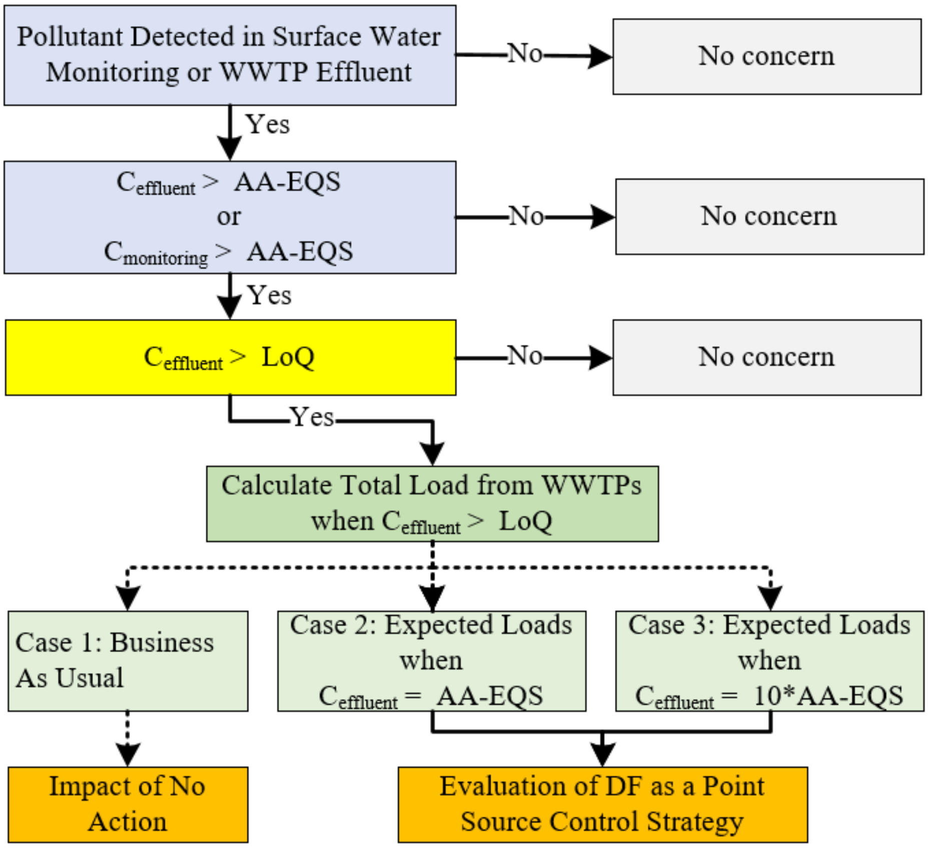


Figure 41. Proposed DF Assessment Methodology

The business-as-usual case (Case-1) and the expected loads (Case-2 and Case-3) were calculated according to the results of the monitoring study, following these two assumptions:

- All untreated direct wastewater discharges will be connected to a WWTP in their sub-basin
- Any significant improvements will not be made in the WWTPs

The pollutant loads from unmonitored point sources were calculated using the sectoral average of similar monitored sources. For example, the monitoring results of Türkiye Şeker Fabrikaları A.Ş. (Turhal) were used for Çorum and Çarşamba sugar factories, and the results of the municipal WWTP monitoring were used to estimate unmonitored urban pollution in the YRB.

After identifying the pollutants that exceed their AA-EQS value, their loads in each sub-basin were calculated using two different methodologies for Case-1. In the first methodology, the results of the surface water monitoring study were used to calculate pollutant loads (L_1), while in the second methodology, the results of the point source monitoring study were used to estimate the pollutant loads (L_2). These results were compared to each other to evaluate if the accumulated pollutant load from point sources is adequate to explain the pollutant loads in surface waters. L_1 was calculated according to Equation-14, while L_2 was estimated according to Equation-15. A conservative approach was adopted during point source load calculations, which assumes that micropollutants have high environmental persistence, and undergoes negligible degradation. For Case-2 and Case-3, the load of pollutants in each sub-basin was estimated using L_2 only. While calculating the L_2, the effluent concentrations ($C_{j,i,Case}$) of micropollutants were adjusted according to three cases defined in the DF assessment methodology. For Case-1, the effluent concentration of a micropollutant was taken as it is, and for Case-2 and Case-3, the effluent concentrations were adjusted according to the proposed effluent limitations. For Case-2, if the concentration of a pollutant after dilution was higher than its AA-EQS, the effluent concentration limit was set as AA-EQS, and if it was lower than its AA-

EQS, the effluent concentration was taken as it is. Similarly, for Case-3, the effluent concentration limit was set as 10 times AA-EQS if the effluent concentration was higher than its AA-EQS after considering dilution. In both Case-2 and Case-3, the DF was not considered during setting effluent concentration limits, since it requires setting different effluent limits for each point source and contradicts the regulatory approach of the MoEUCC. The local DF scenario (DF_1) under the MLF condition was used to evaluate the concentration of a pollutant after dilution to follow a regulatory context. However, in all three cases, the accumulative DF scenario (DF_2) under the MLF condition was used to estimate loads of pollutants at each sub-basin (L_2) to reflect the conservative approach, and their estimated surface water concentrations ($C_{est,i}$) were calculated by using the MLF surface water flow rates at the sub-basin outfalls (Equation-16). Finally, the estimated load reductions of Case-2 and Case-3 were calculated according to Equation-17.

Estimated surface water concentrations ($C_{est,i}$) will be used to evaluate if the proposed implementation strategy of the draft WPCR (Official Gazette No: 25687, Date: December 31, 2004) is adequate to reduce the surface water concentration of micropollutants from point sources to a value below AA-EQS.

$$L_{1,i}\left(\frac{mg}{day}\right) = C_{s,i}\ \left(\frac{\mu g}{L}\right) x\ Q_s\left(\frac{m^3}{day}\right) \qquad (Equation-14)$$

$$L_{2,i}\left(\frac{mg}{day}\right) = \sum_{j=1}^{n} L_{j,i} = \sum_{j=1}^{n} C_{j,i,Case}\ \left(\frac{\mu g}{L}\right) xQ_j\ \left(\frac{m^3}{day}\right) \qquad (Equation-15)$$

$$C_{j,i,Case}\ \left(\frac{\mu g}{L}\right) = \begin{cases} Case-1; & C_{j,i} \\ Case-2; \begin{cases} \dfrac{C_{j,i}}{DF_{1,j}} > AA-EQS_i; & AA-EQS \\ \dfrac{C_{j,i}}{DF_{1,j}} \leq AA-EQS_i; & C_{j,i} \end{cases} \\ Case-3; \begin{cases} \dfrac{C_{j,i}}{DF_{1,j}} > 10xAA-EQS_i; & 10xAA-EQS \\ \dfrac{C_{j,i}}{DF_{1,j}} \leq 10xAA-EQS_i; & C_{j,i} \end{cases} \end{cases}$$

$$C_{est,i}\left(\frac{\mu g}{L}\right)=\frac{L_{2,i}\ \left(\frac{mg}{day}\right)}{MLF\ \ \left(\frac{m^3}{day}\right)} \qquad (Equation-16)$$

$$\begin{matrix}Load\\ Reduction\end{matrix}\ (\Delta L)(\%)=\begin{cases}Case-2;\ \dfrac{L_{2,i_{Case1}}-L_{2,i_{Case2}}}{L_{2,i_{Case1}}}x100\\ Case-3;\ \dfrac{L_{2,i_{Case1}}-L_{2,i_{Case3}}}{L_{2,i_{Case1}}}x100\end{cases} \qquad (Equation-17)$$

where:

i: Micropollutant

j: Point source

n: total number of point sources upstream from the outfall of a sub-basin

$L_{1,i}$: Load of pollutant i at the outfall of a sub-basin, calculated from surface water monitoring results (mg/day)

$L_{2,i}$: Load of pollutant i at the outfall of a sub-basin, estimated from point source monitoring results (mg/day)

$L_{j,i}$: Load of pollutant i from point source j (mg/day)

$C_{s,i}$: Concentration of pollutant i at the outfall of a sub-basin (µg/L)

$C_{j,i,Case}$: Dilution adjusted effluent concentration of pollutant i

$C_{j,i}$: Concentration of pollutant i at the effluent of point source j (µg/L)

$C_{est,s,i}$: Estimated concentration of pollutant i at the outfall of a sub-basin

Q_j: Effluent flow rate of point source j (m^3/day)

Q_s: MLF stream flow rate at the outfall of a sub-basin (m^3/day)

MLF_s: Estimated low flow at the outfall of a sub-basin (m^3/day)

4.5.6 Statistical Methods and Tests

Predictive and descriptive statistical methods and tests were used to generate and evaluate the results of the DF and pollutant load calculations in the sub-basins. All statistical computing was done using R version 4.1.2 (R-Core-Team, 2017). R is an integrated environment for data processing, calculation, and visualization. These methods and tests were described briefly in the following sections.

4.5.6.1 Statistical Packages Used

The following libraries were used to process, interpret, and visualize data.

Table 21. R Libraries Used in This Study

Library	**Explanation**
readxl / xlsx	Import and export from excel files
tidyverse	Data cleaning, grouping, categorization
pdftools	Extracting information from SHW stream gauging station data
lfstat	Low flow and mean flow calculation
Hmisc / factoextra / FactoMineR/ dunn.test / wilcox.test	Statistical package for describing data.
ggplot2 / ggpubr / scales / RColorBrewer / heatmaply / corrplot / ggcorrplot / psych	Data visualization

4.5.6.2 Shapiro-Wilks Normality Test

The distribution of data is the most important parameter in descriptive statistics as most statistical tests are based on the assumption that the data is normally distributed. The Shapiro-Wilks normality test was applied to verify if the distribution of DFs in the sub-basins is normally distributed. The null hypothesis (H_0) was set as the population is normally distributed, and the significance level was adjusted to 0.05. The p-values equal to or above 0.05 shows that the data is normally distributed.

4.5.6.3 Kruskal-Wallis Test

Kruskal-Wallis test is a test used to identify if there are any similarities among the distribution of DFs in the sub-basins. The Shapiro-Wilks normality test revealed that the distribution of DFs in the sub-basins is not normally distributed. Although the most popular similarity test is the one-way ANOVA, the Kruskal-Wallis can be applied to small population sizes that are not normally distributed, since it is a ranking-based test. In addition, more than two samples could be evaluated at the same time. The null hypothesis (H_0) was set as the population is similar to each other, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the sub-basins are significantly different.

4.5.6.4 Wilcoxon Test

The Kruskal-Wallis test indicates if the population is similar or different. However, it does not show which populations are similar or different from each other and must be followed by a post-hoc test to identify the populations that are related to each other. The Wilcoxon test uses the rankings from Kruskal-Wallis Test. Bonferroni-adjusted Wilcoxon Test was applied to sub-basins to identify which sub-basins are significantly different from others in terms of DF distribution. The Bonferroni adjustment could be applied to populations that do not have an equal sample size.

4.5.6.5 Principle Component Analysis

The Principle Component Analysis (PCA) is a data interpretation analysis, which is essentially used to summarize the information in data described by multiple inter-correlated variables. In a multivariate environment, the PCA can be used to describe which variables contribute most to the variation in the whole data. One of its main uses is to reduce the number of variables in a data set without losing too much information by presenting important information from the data with fewer new variables called the principles components. The variables in the data must be correlated for the PCA to provide useful information, and the PCA also reveals the high correlation among variables. In this study, the relationship between effluent flow rates and incidences of AA-EQS exceedance was investigated using PCA. The outlier values must be removed from the data prior to any PCA. The outliers were removed from the data by using the methodology described in Chapter 3.2.2.

The first principle (PC1 or Dim 1) shows the largest variation in a dataset and is placed on the x-axis. The second principle (PC2 or Dim2) is orthogonal to PC1 and shows the second largest variation in a dataset on the y-axis. An example principal components plot is given in Figure 42. The circle is called the "correlation circle" and the variables that are closer to this circle are more significant to interpret the components.

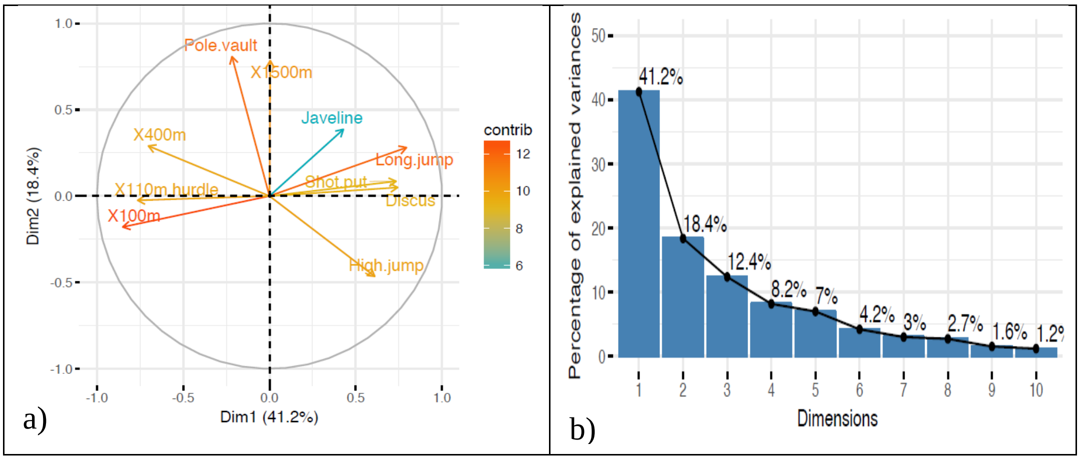


Figure 42. Example (a) Principle Components Plot and (b) Scree Plot (Kassambara, 2017)

The position on the plot shows if the correlation is positive or negative. The positive correlations are presented on the right and top regions for PC1 and PC2, respectively. The angle between the variables is an approximation of their correlation. The eigenvalues explain the amount of variation retained by each principal component. A scree plot visualizes the eigenvalues from largest variation to smallest (Figure 42).

Generally, the cumulative variance of the first two components is enough to explain total variation.

4.5.6.6 Correlation Analysis

The correlation analysis describes the relationship between two variables by analyzing if the rate of change and direction are similar. If two variables move in the same direction, this means that they are described as positively correlated, and if they move in the opposite direction, they are negatively correlated. The rate and shape of the correlation also describe the significance of the relationship. The Pearson correlation (R) was used to describe if there is any linear relationship between effluent-to-stream flow rate ratios and EQS exceedance incidences. The null hypothesis (H_0) was set as the correlation occurred by chance, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the correlation was not by chance.

4.6 Results and Discussion

4.6.1 Point Source Discharges in the Yeşilırmak River Basin

In the YRB, there are 249 point sources that discharge into the surface waters. In Appendix A - Table A 1 and Table A 2, a list of these discharges is provided. In Table 22, the total number of discharges in each sub-basin and the total wastewater flow rates are provided. As shown, the untreated wastewater discharges in nine sub-basins (Sub-basins 3, 6, 8, 10, 11, 12, 14, 17, and 21) are significantly higher than urban and industrial WWTP discharges. In sub-basins 5 and 7, the only wastewater sources are untreated urban discharges, and the amount of untreated wastewater in sub-basin 20 is more than the treated wastewater amount. The total wastewater discharges in sub-basin 13 are significantly greater than most of the other sub-basins, which is approximately 22% of the total. It is followed by sub-basins 9 and 20, which have a wastewater flow rate of 13% and 12% of the total, respectively. The urban WWTPs of Çorum and Tokat are discharging into sub-basins 13 and 9, respectively. The sub-basin 20 receives urban WWTP discharges from Tokat Erbaa and Samsun Çarşamba districts.

Among 163 untreated point sources and 86 urban and industrial WWTPs, the DFs were calculated for 237 discharges (95%). The total wastewater at sub-basin 20 was calculated as 288,485 m^3/day, which is approximately 96% of the total wastewater discharges in the YRB. The total wastewater at sub-basin 21 and other small river basins was calculated as 12,094 m^3/day, which increases the percentage of total wastewater discharges evaluated to 99%.

Table 22. Total Number of Discharges and Wastewater Flow Rates in Each Sub-basin

Sub Basin	**Wastewater from WWTPs**		**Untreated Direct Discharges**		**Total**		
	# of Sources	**Flow Rate (m^3/day)[1]**	**# of Sources**	**Flow Rate (m^3/day)[1]**	**# of Sources**	**Flow Rate (m^3/day)**	**%**
1	2	10,900	6	2,836	8	13,736	4.6
2	3	3,259	4	1,305	7	4,564	1.5
3	1	7	2	3,107	3	3,114	1.0
4	2	10,008	3	1,480	5	11,488	3.8
5	-	-	7	2,562	7	2,562	0.9
6	7	279	20	15,053	27	15,332	5.1
7	-	-	4	1,410	4	1,410	0.5
8	2	1,030	11	4,084	13	5,114	1.7
9	5	34,901	13	5,555	18	40,456	13.5
10	5	1,012	16	11,224	21	12,236	4.1
11	1	450	19	7,570	20	8,020	2.7
12	1	9	3	4,450	4	4,458	1.5
13	8	66,570	1	163	9	66,733	22.2
14	3	1,589	4	13,400	7	14,989	5.0
15	1	36	-	-	1	36	0.0
16	12	9,350	2	7,215	14	16,565	5.5
17	1	240	1	2,729	2	2,969	1.0
18	8	9,775	5	1,167	13	10,941	3.6
19	3	12,604	16	5,254	19	17,858	5.9
20	5	16,280	15	19,624	20	35,905	11.9
21	3	355	1	1,963	4	2,318	0.8
Other[2]	5	698	6	9,078	11	9,776	3.3
Total	**78**	**179,351**	**159**	**121,228**	**237**	**300,580**	100.0

[1] The flow rates of individual sources are provided in Appendix A - Table A 1 and Table A 2.

[2] 12 point sources were excluded since their stream flow rates and hence the DFs could not be evaluated. The contribution of these 12 sources is less than 1% in the YRB.

4.6.2 Dilution Factors Calculated for Point Sources in the Yeşilırmak River Basin

At this point, it is crucial to note that the DF approach was solely developed to assess the environmental significance of pollutants from WWTPs in water bodies and it is not applied to untreated point wastewater sources under normal conditions (EC, 2010a). The DF is not only about the wastewater flow rates, but also it is closely related to the total pollution load from these sources. Since the total pollution load in an untreated wastewater source is multiple times higher than the treated sources, it is not reasonable to assess their significance by the DF test. However, when the ratio of untreated wastewater to treated wastewater in the YRB was considered, it was seen that the untreated sources could not be neglected. The untreated point sources were treated as potential WWTP discharges and evaluated accordingly.

The DF at the YRB point sources were calculated for eight different cases using two stream flow rate estimation methodologies (Exclusive & Inclusive), two river flow conditions (MLF & MF), and two DF calculation scenarios (Local – DF_1 & Accumulative – DF_2). The detailed results showing the DF of each case are given in Appendix J - Table A 13.

4.6.2.1 Evaluation of Stream Flow Rate Estimation Approaches

The DF statistics for exclusive and inclusive stream flow rate estimation approaches are given in Figure 43 for each sub-basin. Any statistically significant difference was not observed between flow rate estimation methodologies, excluding sub-basins 17 and 21. The DFs of 33 cases, which had a DF of greater than 10,000, are not shown in Figure 43.

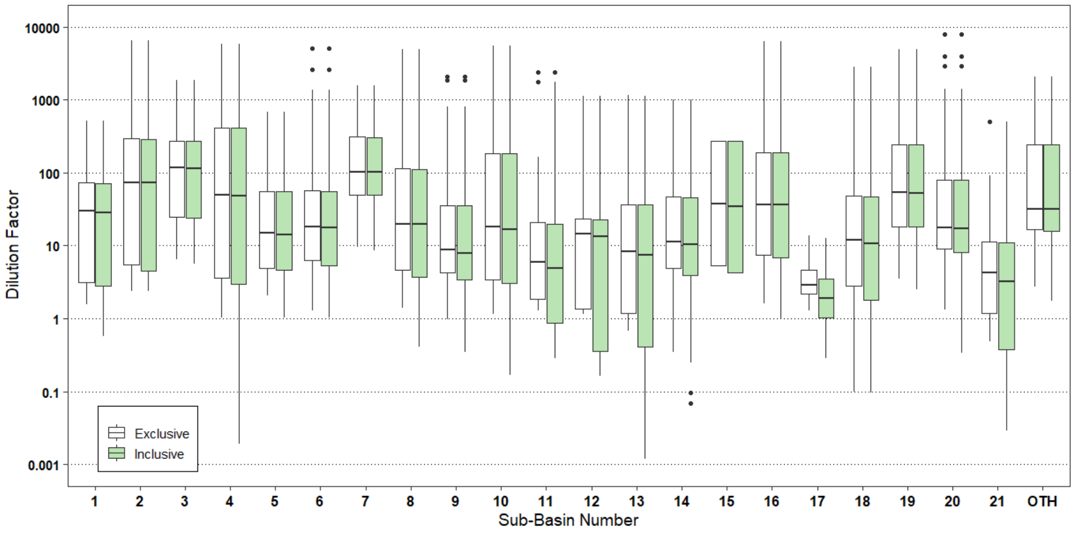


Figure 43. Dilution Factor Statistics of Each Sub-basin under Different Stream Flow Rate Estimation Approaches

For the inclusive approach under the MLF condition, 43 point sources (18%) had greater wastewater flow rates than their respective stream flow rates, which can be explained by the low flow estimation methodology. The flow rates of the wastewater discharges are based on annual average values and most of the WWTPs report their treatment capacity as the average treated flow rate. On the other hand, the MLFs in this study were estimated based on the lowest period of two consecutive years, which might not be related to the fluctuations in the wastewater discharged. Under MF conditions, only four cases were identified, where the stream flow rates were lower than the wastewater flow rates. These are Sivas Suşehri Urban WWTP in sub-basin 4, Çorum Central WWTP in sub-basin 13, Merzifon Municipality WWTP in sub-basin 18, and Samsun Kavak point discharge in sub-basin 21.

Based on the results obtained from the stream flow rate estimation approach analysis, the inclusive approach was adapted for further evaluations of the DF-based point source control strategy. However, the DFs of the above-mentioned 43 sources were calculated using an exclusive approach, since the upstream flow rate is calculated as a negative value when using the inclusive approach, and decreases the reliability of the DF calculations. The effect of this choice was negligible in data interpretation since the wastewater flow rates under the MLF scenario were always greater than their respective stream flow rates, and the DFs were less than two in all cases.

4.6.2.2 Distribution of Dilution Factors in the Yeşilırmak Sub-basins

The distributions of DFs in each sub-basin for DF_1 and DF_2 scenarios are given in Figure 44. For both MLF and MF conditions, the median values of local dilution at discharge points ($DF_{1,i}$) (Figure 44-a) were higher than the empirical dilution factor limit of ten (DF_{10}) in seven sub-basins. Among these sub-basins, sub-basin 2 and 3 are upstream of the Kelkit River and sub-basin 7 is upstream of the Yeşilırmak River. Two of these sub-basins (19 and 20) are located towards the end of the YRB and have the highest amount of accumulated flow rate. Surprisingly, the sub-basin 16 (Tersakan) also had a median $DF_{1,i}$ of greater than DF_{10} for both flow conditions. The Tersakan River has the highest number of point source discharges per river length, where four domestic WWTPs, seven food industry WWTPs, and one mining industry WWTP discharge into the river in less than 10 km. In addition to these seven sub-basins, the point sources, which do not belong in any sub-basins ("Others – OTH") had a median of greater than ten for MLF and MF conditions. The sub-basin 17, which is located upstream of Amasya had a median $DF_{1,i}$ of less than DF_{10} for both MLF and MF. The remaining sub-basins (1, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 18 and 21) had a median $DF_{1,i}$ of greater than DF_{10} for under MF conditions, however their median $DF_{1,i}$ was lower than DF_{10} during MLF conditions.

On the other hand, the effect of accumulative wastewater load had affected the $DF_{2,i}$ in sub-basins, where the point sources are lined up along the stream (Figure 44-b). Sub-basins 3, 7, 12, 15, and 17 were not affected by accumulative wastewater loads since either the point sources in these sub-basins are positioned in separate upstream locations or the wastewater flow rates of upstream sources are negligible with respect to the downstream sources. All other sub-basins had significantly lower median $DF_{2,i}$ during both MF and MLF conditions. Sub-basins 8, 19, 20, and the "Other" category did not have any significant changes in their median $DF_{2,i}$ but had reduced $DF_{2,i}$ with respect to $DF_{1,i}$ as expected. Sub-basin 9 had a median $DF_{2,i}$ similar to its $DF_{1,i}$ during MLF conditions but its $DF_{2,i}$ was calculated less than DF_{10} during MF conditions. Sub-basin 21 had a significantly lower $DF_{2,i}$ for both MF and MLF conditions, and both of them were below DF_{10}.

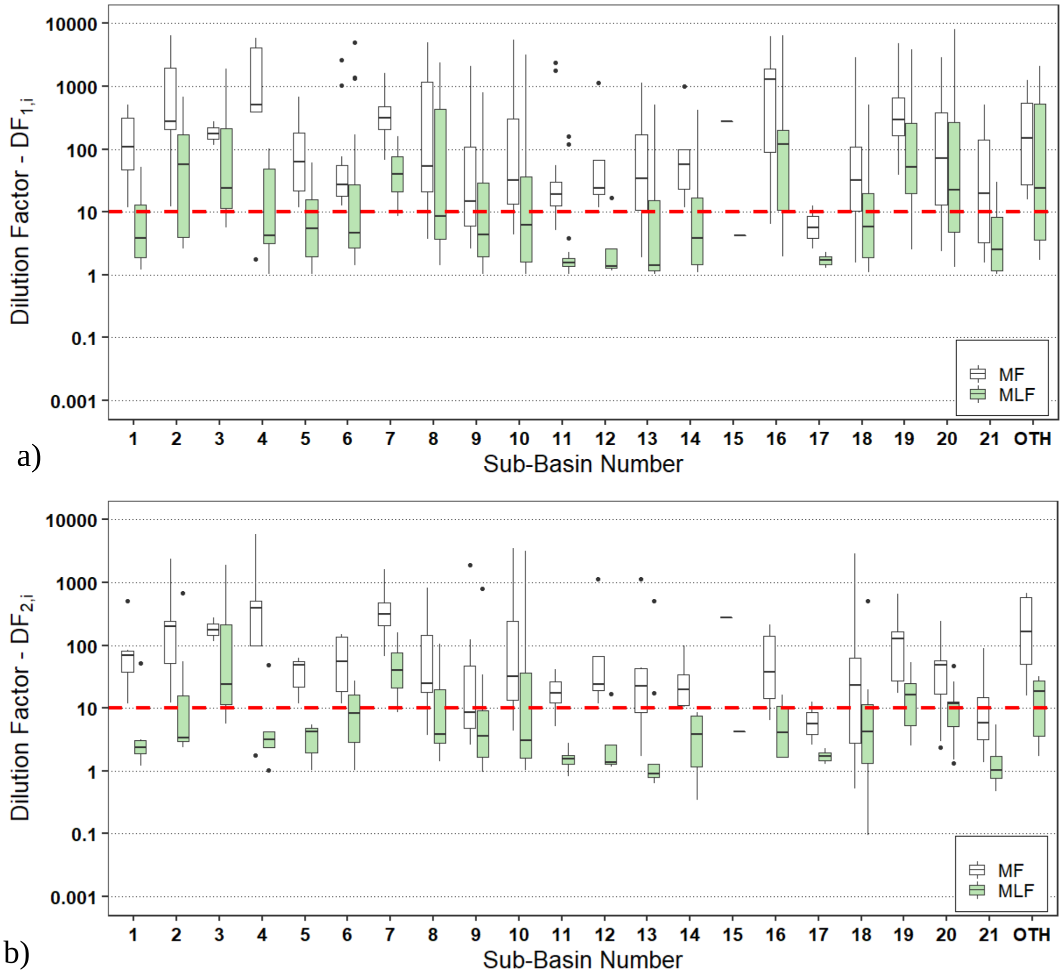


Figure 44. The Distribution of Dilution Factors in Each Sub-basin for MF and MLF (a) Local Dilution at Source$_i$ $DF_{1,i}$ and (b) Accumulative Dilution at Source$_i$ $DF_{2,i}$

The sub-basins 2 and 16 still had a median $DF_{2,i}$ greater than DF_{10} for MF condition; however, during MLF, their median $DF_{2,i}$ was calculated below as DF_{10}. The remaining sub-basins (1, 4, 5, 6, 10, 11, 13, 14, and 18) did not have a change in their status and had a $DF_{2,i}$ greater than DF_{10} for MLF conditions and had a $DF_{2,i}$ lower than DF_{10} for MF conditions. The DFs of all point sources with respect to the stream flow conditions are given in Figure 45. The critical threshold, DF_{10} is given in the dashed red line. The WWTP point sources (PS) and untreated point sources (UT) were given separately to identify any similarities or differences between these two categories. In the case of receiving water bodies receiving a high volume of point source discharges, the accumulative DF scenario (DF_2) should be the choice for the evaluation of DFs. If the accumulative point source discharges in a water body are negligible as compared to stream flow rate, both DF scenarios are applicable.

Any significant similarities between sub-basins were tested statistically. Sub-basins 3, 4, 7, 12, 15, 17, and 21 were removed from statistical testing since their sample sizes were too small. First, the distribution of DFs in the sub-basins was evaluated by the Shapiro-Wilks normality test. The Shapiro-Wilks normality test returned a maximum p-value of 0.04, which showed that DFs were not normally distributed. Then, the non-parametric Kruskal-Wallis test, which can be used on small sample sizes with non-normal distribution, was used to test for any similarities between sub-basins. The Kruskal-Wallis test returned a p-value of 1.24×10^{-4}, showing significant differences between sub-basins. From the output of the Kruskal-Wallis test, we know that there is a significant difference between sub-basins. However, it does not show which pairs are significantly different from each other. Bonferroni-adjusted Wilcoxon test was used as a pairwise post-hoc test to identify which sub-basins are significantly different from others. The results showed that sub-basin 11 was significantly different from sub-basin 16 ($p = 4.4 \times 10^{-5}$, $n = 27$) and sub-basin 19 ($p = 0.02$, $n = 14$). Additionally, sub-basin 19 was found significantly different from sub-basin 9 ($p = 0.01$, $n = 18$) and sub-basin 18 ($p = 0.02$, $n = 13$).

4.6.2.3 Dilution Factors for Point Sources for Local and Accumulative Scenarios

The local ($DF_{1,i}$) and accumulative ($DF_{2,i}$) DFs of WWTP point sources and untreated point sources are given in Figure 45-a and Figure 45-b, respectively, for MF conditions. The median values of $DF_{1,i}$ and $DF_{2,i}$ were calculated as 89.5 and

38.2, respectively. The median DF values for the WWTP point sources were calculated as 94.5 and 69.3 for DF_1 and DF_2 scenarios, respectively. On the other hand, the median DF values for the untreated point sources were calculated as 46.7 and 26.3 for DF_1 and DF_2 scenarios, respectively. Although the median DF values of both the WWTP point sources and the untreated point sources were above DF_{10} for dilution scenarios, the median DF value of the WWTP sources dropped more than the untreated sources under the DF_2 scenario. This shows that the WWTP point sources are generally located on connected streams, where wastewaters from many sources merge into a single stream or main tributary. On the other hand, untreated point sources are generally located on streams that are not affected by any upstream sources.

The local ($DF_{1,i}$) and accumulative ($DF_{2,i}$) DFs of WWTP point sources and untreated point sources are given in Figure 45-c and Figure 45-d, respectively, for MLF conditions. The median values of $DF_{1,i}$ and $DF_{2,i}$ were calculated as 8.8 and 4.1, respectively. The median DF values for the WWTP point sources were calculated as 52.7 and 4.5 for DF_1 and DF_2 scenarios, respectively. On the other hand, the median DF values for the untreated point sources were calculated as 8.2 and 3.2 for DF_1 and DF_2 scenarios, respectively. Different from the MF conditions, the median DF values of both the WWTP point sources and the untreated point sources were below DF_{10} for both dilution scenarios. Additionally, the untreated point sources had a median $DF_{1,i}$ below DF_{10}. The sharp decreasing trend in the median $DF_{1,i}$ value was also valid for the WWTP point sources in the MLF condition.

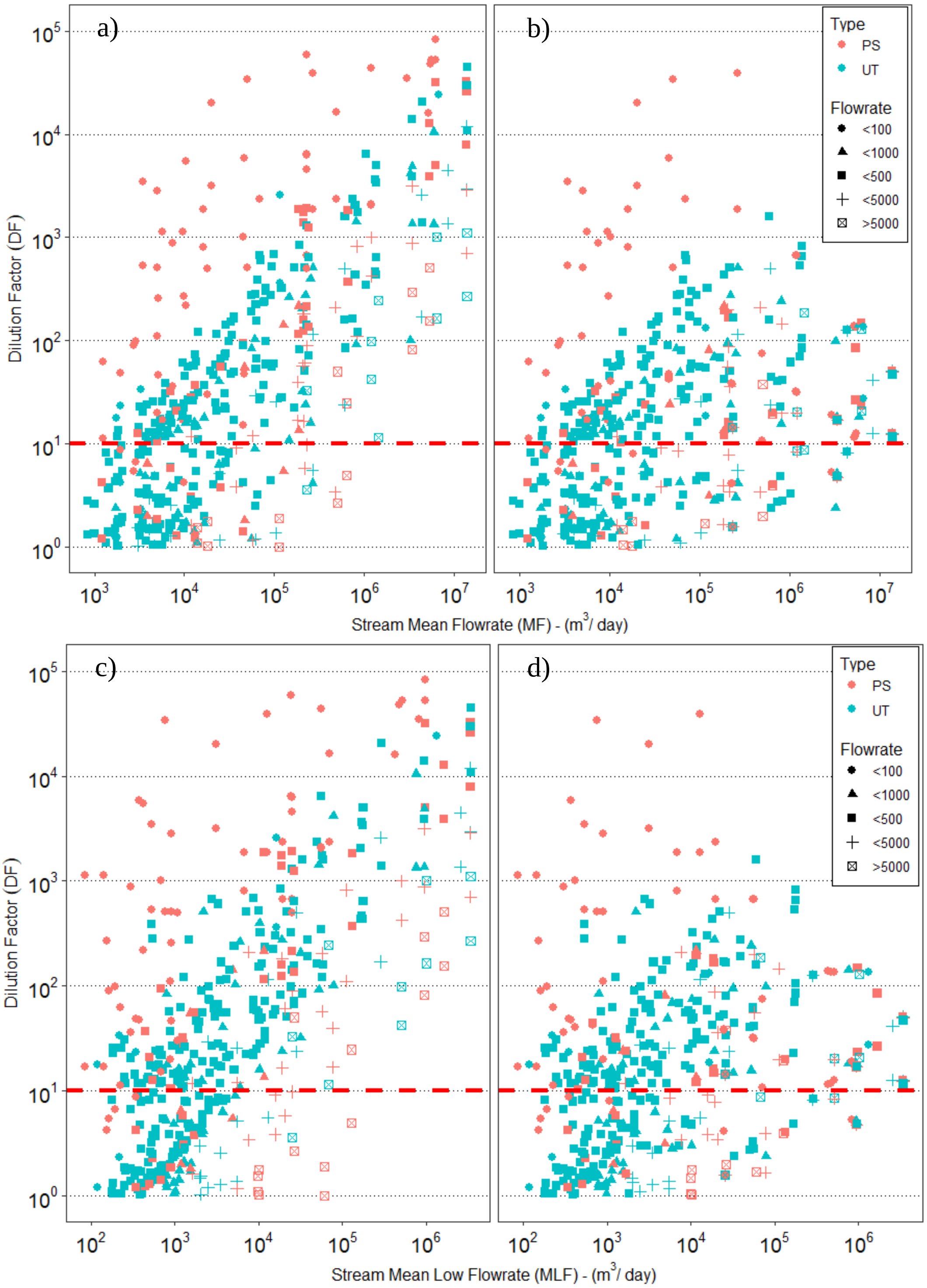


Figure 45. The Dilution Factors of WWTP Point Sources (PS) and Untreated Point Sources (UT) for MF and MLF Conditions and Dilution Scenarios (a) MF - $DF_{1,i}$ (b) MF - $DF_{2,i}$ (c) MLF - $DF_{1,i}$ (d) MLF – $DF_{2,i}$

When the DF calculation conditions were changed from the MF condition to the MLF condition, a drastic decrease was observed in the median DF of point sources in the YRB, which decreased from 89.5 to 8.8 under the DF_1 scenario, and from 38.2 to 4.1 under the DF_2 scenario. This decrease revealed the significance of using MLF conditions during the evaluation of the DF. This situation is closely linked to the occurrence of the highest pollutant concentrations for the MLF conditions. Therefore, the choice of MLF for the evaluation of DFs in a river basin can be regarded as the conservative approach during the estimation of DFs of point sources in a river basin.

The flow rates of point sources were also categorized in Figure 45 to analyze the effect of wastewater flow rate on the DFs in the YRB. For the MF condition, very small-sized sources (<100 m^3/day) had a median DF value above DF_{10} under both scenarios, and all individual DFs were above DF_{10}. For the MLF condition, very small-sized untreated point sources had a median DF value below the DF_{10} under both scenarios, and the DFs of some individual WWTP discharges were also below the DF_{10}. The small-sized sources (<500 m^3/day) followed the same trend as very small-sized sources and had a median DF value above the DF_{10} under both scenarios for the MF condition. For the MLF condition, the median DF values of all sources were below the DF_{10} under the DF_2 scenario, but the WWTP point sources had a median DF value above the DF_{10} under the DF_1 scenario. All medium-sized sources (<1,000 m^3/day) had a median DF value above the DF_{10} for the MF condition and a median DF value below DF_{10} for the MLF condition under both scenarios. The highest DF value for WWTPs was calculated as 13.6 for the MLF condition. The large-sized sources (<5,000 m^3/day) had a median DF value above DF_{10} for MF condition for all sources. For the MLF condition, the median DF values were below DF_{10}, but a median DF_1 value of 16.6 was calculated for the WWTP sources. Following the same trend with other sized sources, the very large-sized sources (>5,000 m^3/day) had a median DF value above DF_{10} for the MF condition. Except for the untreated sources under DF_1 scenarios, all sources had a median DF value below DF_{10} for the MLF condition. These results showed that even for very small-sized sources, the DFs of some sources were below DF_{10} under both dilution factor scenarios. Under the MLF condition, the DFs were below DF_{10} at most sources, without any significant difference between the WWTP sources and the untreated sources. The statistical approach was applied to test for any significant relationship between stream flow rates and the DFs. First, the distribution of DFs and stream flow rates were evaluated under four categories by the Shapiro-Wilks normality test: MF-DF_1, MF-DF_2, MLF-DF_1, and MLF-DF_2. The null hypothesis was the DFs and stream flow rate did not follow a normal distribution ($p < 0.05$) and the Shapiro-Wilks normality test revealed that both stream flow rates and DFs do not follow a normal distribution and they are heavily right-skewed. The correlation between flow rates and DFs was evaluated using Spearman's rho. All correlations except MLF-DF_2 returned a p-value of 1.24×10^{-16}. MLF-DF_2 had a p-value of 3.24×10^{-7}. The highest Spearman's rho was obtained for MF-DF_1 (0.73), followed by MF-DF_2 (0.61), MLF-DF_1 (0.58) and MLF-DF_2 (0.38), respectively. These results show that high DFs under the DF_1 scenario and MF condition could be explained to some extent, but there is not a strong relationship between stream flow rates and DFs.

The percentage of point sources corresponding to fixed DF threshold values for MF and MLF conditions under DF_1 and DF_2 scenarios are given in Figure 46. According to Figure 46-a, for the MF condition, 87.3% and 85.2% of all point sources in the YRB had a DF of greater than DF_{10} under DF_1 and DF_2 scenarios, respectively. A significant reduction was observed under MLF conditions, where 48.5% and 34.2% of all point sources in the YRB had a DF of greater than DF_{10} under DF_1 and DF_2 scenarios, respectively. For MLF conditions, the percentage of sources, which had an equal or greater flow rate than the stream flow rate ($DF < 2$) was identified as 27.1% and 32.1% under DF_1 and DF_2 scenarios, respectively.

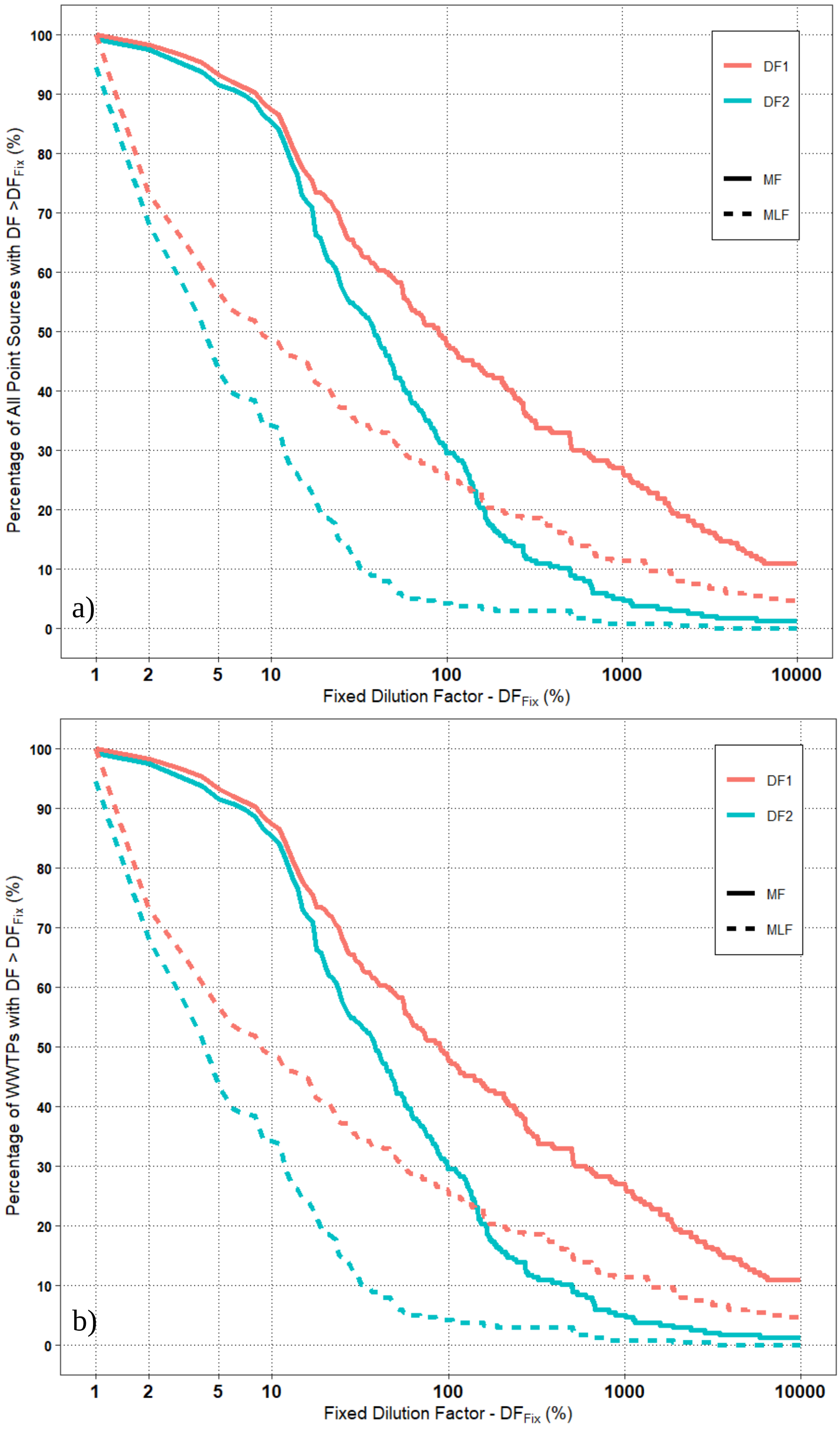


Figure 46. The Percentage of Point Sources Corresponding to Fixed DF Threshold Values for Different Stream Flow Conditions and DF Scenarios (a) All Point Sources in the YRB (b) WWTP Discharges in the YRB

For the WWTP discharges (Figure 46-b), 92.3% and 85.8% of sources in the YRB had a DF of greater than DF_{10} under DF_1 and DF_2 scenarios, respectively. A significant reduction was also observed for the WWTP discharges under MLF conditions, where 65.4% and 47.4% of all WWTP sources in the YRB had a DF of greater than DF_{10} under DF_1 and DF_2 scenarios, respectively. For MLF conditions, the percentage of sources, which had an equal or greater flow rate than the stream flow rate ($DF < 2$) was identified as 15.4% and 25.7% under DF_1 and DF_2 scenarios, respectively. According to these results, the WWTP sources and the untreated wastewater sources followed the same trend under both DF scenarios and a significant difference was not observed. The ratio of point sources, which have a DF of more than ten decreases significantly for the MLF condition both for local and accumulative DF scenarios. This shows that DF assessments should be based on low flow conditions to reflect the possible outcomes of the worst-case scenario.

4.6.3 Assessment of Fixed Dilution Factor as a Point Source Control Strategy

As mentioned in Chapter 4.1.2, the MoEUCC is planning to implement the revised WPCR (Official Gazette No: 25687, Date: December 31, 2004) after 2025. The second stage of the implementation strategy proposes a DF approach to control priority substances and river basin specific pollutants. The DF approach increases the EQS at the discharge location by 10 times without considering the mixing zones. This approach is based on the assumption that all WWTP effluents will undergo a dilution of 10, even if their real dilution is less. According to the implementation strategy, the DF approach will be applied to the MLF condition, without considering the upstream concentration (DF_1 scenario).

The DF analysis showed that 50% of all point sources in the YRB have a DF less than ten for the MLF condition under the DF_1 scenario (Figure 46-a). The distribution of these point sources according to their effluent flow rates and the percentage of sources with a DF greater than the dilution thresholds are given in Table 23. Among the point sources with a DF of less than ten, the untreated point sources do not show any distinct spatial pattern in the YRB, while the WWTPs are located upstream of the Çorum River, and on the Tersakan River.

Table 23. Percentage of Point Sources with a Dilution Factor Greater Than Predefined Dilution Thresholds and Distribution of Sources by Effluent Flow Rate

Effluent Flow Rate (m^3/day)	**% of Sources with DF > DF Thresholds**			**Number of Sources**	
	DF_2	**DF_5**	**DF_{10}**	**WWTPs**	**Untreated Discharges**
< 100	97.5	90.0	82.5	35	5
< 500	69.4	49.2	41.8	19	115
< 1000	59.3	44.4	33.3	4	23
< 5000	66.6	58.3	45.8	13	11
≥ 5000	75.0	50.0	50.0	7	5

Approximately 85% of the very small-sized sources (<100 m^3/day) were WWTPs in the YRB, while the remaining 15% were untreated point sources. In this category, 82.5% of all sources had a DF_1 greater than DF_{10}, while only one source had a greater effluent flow rate than the receiving water body flow rate (DF_2). Approximately 15% of the small-sized sources (<500 m^3/day) were WWTPs in the YRB, while the remaining 85% were untreated point sources. In this category, 41.8% of all sources had a DF_1 of greater than DF_{10}, while the effluent flow rates of 41 sources were higher than the stream flow rate. Approximately 15% of the small-sized sources (<500 m^3/day) and the medium-sized sources (<1,000 m^3/day) were WWTPs in the YRB, while the remaining 85% were untreated point sources. 41.8% and 33.3% of all sources had a DF_1 of greater than DF_{10}, while 41 and 16 had more effluent flow rates than the stream flow rate for small and medium-sized sources, respectively. Approximately 55% of the large-sized sources (<5,000 m^3/day) were WWTPs in the YRB, while the remaining 45% were untreated point sources. In this category, 45.8% of all sources had a DF_1 of greater than DF_{10}, while the effluent flow rates of 10 sources were higher than the stream flow rate. Approximately 60% of the very large-sized sources (≥5,000 m^3/day) were WWTPs in the YRB, while the remaining 40% were untreated point sources. In this category, 50% of all sources had a DF_1 of greater than DF_{10}, while three sources had more effluent flow rates than the receiving water body.

The proposed duration of the stage 2 implementation is regarded as five years; however, the purpose of this stage is to prepare both the WWTP management and the receiving water bodies for the implementation of stage three. Stage three introduces the concept of mixing zones, where the discharge limit of each WWTP will be calculated by the Discharge Test software or TMDL. This concept requires the receiving surface waters to have a concentration less than the EQS. The evaluation of DF as a point source control strategy was conducted according to the methodology presented in Figure 41 to evaluate if the proposed implementation strategy will help reduce the background concentration of pollutants below the EQS.

The concentration of 43 micropollutants exceeded the AA-EQS value in either point source effluents or surface water monitoring stations. Seven of them were priority substances and the remaining 36 were river basins specific pollutants. Among the 20 micropollutants identified as the cause of concern in the YRB (Chapter 3.3.2), 18 pollutants except Cypermethrin and Hexachlorocyclohexane were included in this list. Cypermethrin was excluded since ½ of its LoQ is higher than the EQS, while the concentration of Hexachlorocyclohexane did not exceed the EQS in any samples. Ten pollutants were in the short-listed 54 selected micropollutants in the YRB (Chapter 3.3.1). These pollutants were identified as Ag, As, B, Ba, Be, Diphenyl ether, Imidacloprid, Nonylphenols, Sb, and Trichloromethane. The remaining 19 pollutants were below the predefined 5.5% detection frequency in the YRB. However, since their measured concentrations exceeded the AA-EQS in the point source discharges, they were included in the DF assessment.

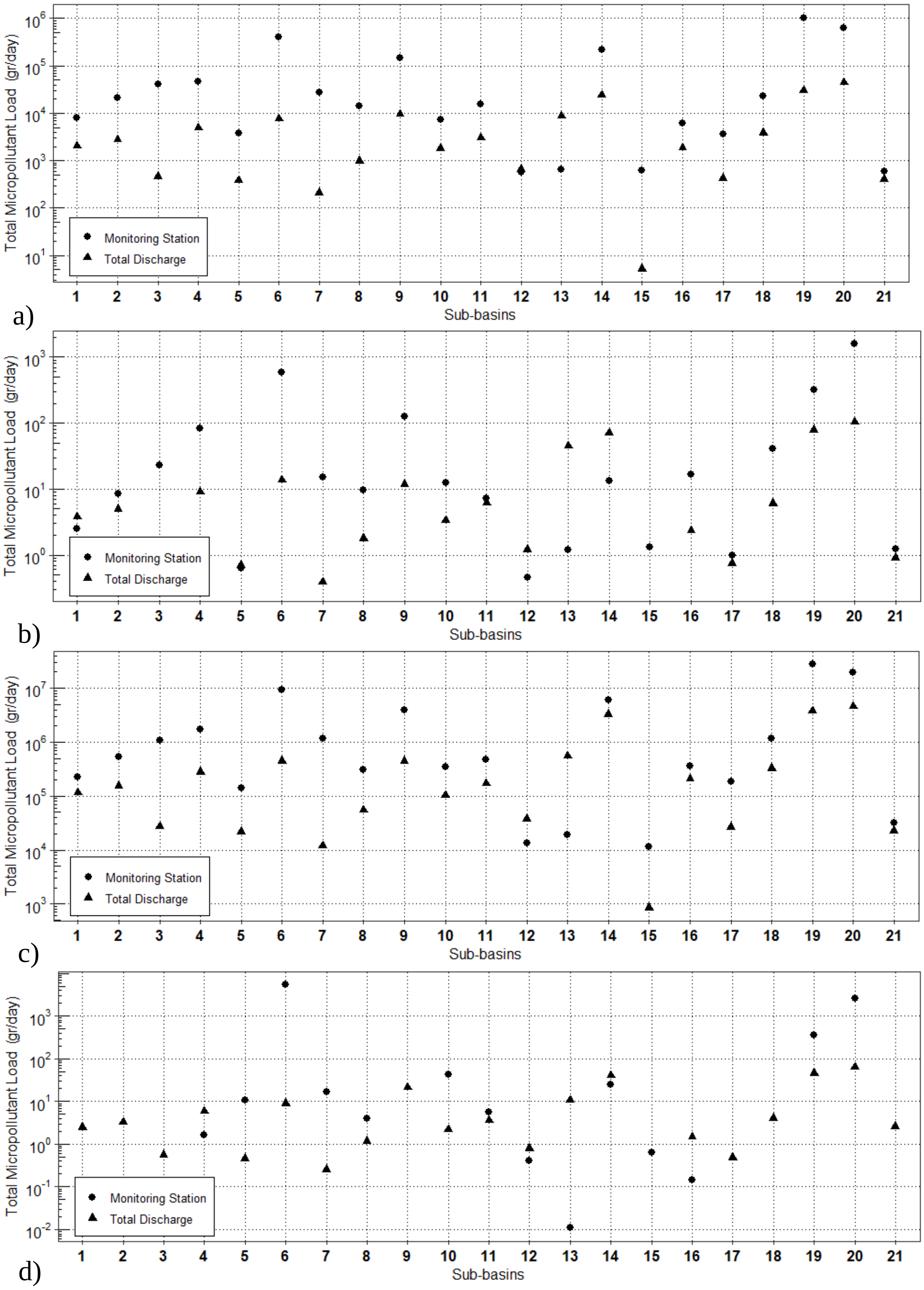


Figure 47. Total Micropollutant Loads in Surface Water Monitoring Stations and Point Source Discharges (a) Industrial Organic Compounds, (b) PPPs, (c) Metals and Metalloids, (d) Pharmaceuticals and PCPs

Bifenox, Aclonifen, Fenpropathrin, Prothiofos, Fenthion, and Diflubenzuron were not quantified in any point sources, although their concentrations exceeded the AA-EQS at the surface water monitoring samples. Similarly, Nicosulfuron, Azinphos-methyl, and Endrin were not quantified in any surface water monitoring samples, but their concentrations exceeded the AA-EQS at the point source discharges. It is interesting to note that all of these micropollutants are of PPP origin, and they are not produced in the YRB, which explains why they should not be quantified in point source effluents. Surprisingly, three of them exceeded the AA-EQS values at point sources, while they were not quantified in any surface water samples. They should be detected in at least one surface water sample if their accumulation in the surface water is high enough to be detected by indirect water usage. This can be regarded as a sign of possible error during analysis or unreliability of the grab sampling method. The total pollutant loads of point sources at sub-basin outfalls were calculated cumulatively in the flow direction by using the results of the point source monitoring study according to using Equation-15, and the cumulative loads were divided by the surface water flow rates to estimate their concentration in surface waters according to Equation-16. The surface water loads were also calculated by using the results of the surface water monitoring study according to Equation-14.

The total load of four pollutant groups, industrial organic compounds, PPPs, metals and metalloids, and pharmaceuticals and PCPs were provided in Figure 47. The detailed load calculations for each micropollutant were provided in Appendix K - Figure A 5. According to these results, except for Pharmaceuticals and PCPs, the total loads of pollutants in the surface water samples were always higher than the total loads from point sources in the YRB, despite the conservative approach adopted during the calculation of loads. The mean absolute error (MAE) between loads from surface water samples and the point source discharges was calculated as 87% according to Equation-18.

$$MAE(\%) = \frac{1}{S}\sum_{s=1}^{S}\left|L_{2,s} - L_{1,s}\right| \qquad (Equation - 18)$$

where:

s: Sub-basins

$L_{1,s}$: Total load of micropollutants at the outfall of sub-basin s, calculated from surface water monitoring results (mg/day)

$L_{2,s}$: Total load of micropollutants at the outfall of sub-basin s, estimated from point source monitoring results (mg/day)

In sub-basins 12 and 13, the total pollutant loads from the point source discharges were always significantly greater than the total loads from surface water samples, where the MAEs were calculated as 115% and 1950% for sub-basins 12 and 13, respectively. These results indicate that the total pollutant loads in surface waters are higher than the point source discharges in 19 sub-basins of the YRB, which could be due to underestimation of the point source pollution or due to diffuse source emissions. Although the diffuse sources could be the main reason for the underestimation of total PPP, metal, metalloid, and pharmaceutical loads in the YRB, approximately 85% error across sub-basins for industrial organic compounds could not be explained by the diffuse sources. On the other hand, in sub-basins 12 and 13, the total pollutant loads were overestimated by at least 19%, which is a clear indication of the overestimation of pollution loads. A total of 24 point sources including both WWTPs and untreated point sources (Chapter 2.3 - Table 8) had been selected as the representatives of the 78 WWTPs and 159 untreated point sources (Chapter 4.6.1 - Table 22). The results of the monitoring study for these 24 point sources were used to estimate the total point source pollution load in the YRB. The monitored 24 point sources had been selected based on their significance in the YRB, in terms of both capacities and expected pollution profiles, and their suitability to represent the pollution profile of other point sources. In estimating the pollutant loads from unmonitored point sources, a sectoral average of similar monitored sources in the YRB were used.

When the MAE between loads from the surface water samples and the point source discharges were calculated, it appeared that even for the conservative mass balance approach, the total pollutant loads from WWTPS and untreated point sources are underestimated or overestimated with respect to the actual loads in surface waters. As the flow rate of both the point sources and the surface waters plays an important role in the determination of pollutant loads, it is essential to have long-term monitoring results for both point sources and surface waters to set up accurate mass balance approaches.

Nevertheless, the concentrations of these pollutants were estimated in surface waters by their total pollution loads from the point source discharges in Case-2 and Case-3, using statistical stream flow rate estimations. Bifenox, Aclonifen, Fenpropathrin, Prothiofos, Fenthion, and Diflubenzuron were excluded from calculations since these micropollutants were never quantified in any point source monitoring study. The results of the DF assessment showing the estimated reductions in total pollution load in the YRB for each micropollutant are given in Table 24. According to these results, any reduction was not foreseen for 10 pollutants for both Case-2 and Case-3 (Fluoranthene, PCB 153, Pyrene, Ag, Ba, Be, Sn, Imidacloprid, and Nicosulfuron). Although the effluent concentrations in some point sources were greater than the AA-EQS, the dilution for the MLF condition was enough to dilute these pollutants downstream. The effluent concentrations of 12 micropollutants required additional measures at the point sources (Benzo(a)pyrene, Tridecane, Al, Cd, Co, Cr, Fe, Ni, Sb, V, Zn, and Dichlorvos). The estimated reductions between Case-2 and Case-3 were significant for Benzo(a)pyrene, Cd, Co, Cr, Ni, V, Zn, and Dichlorvos, where the reductions for Case-2 were much higher than Case-3. The estimated reductions for Tridecane, Al, Fe, and Sb were similar for both cases. For 20 micropollutants, any reduction was not foreseen for Case-3, while an average reduction of 35% was estimated for Case-2 (DTOP, Free CN, Nonylphenols, Octylphenol, PHCs, Trichloromethane, As, B, Br, Cu, Pb, Si, Ti, 4-chloroaniline, Diphenyl ether, Azinphos-methyl, Chlorfenapyr, Endrin, Ethalfluralin, and Fenpropimorph). The total difference between reductions of Case-2 and Case-3 was found as 1.05 tons/day.

Table 24. Results of the DF Assessment

Pollutants & Pollutant Groups	**DF Assessment Cases Total Pollutant Loads (g/day)**			**% Reduction of Loads**	
	Case-1	**Case-2**	**Case-3**	**Case-2**	**Case-3**
Industrial Organic Compounds					
Benzo(a)pyrene	0.10	0.04	0.10	59.0	4.7
DTOP	10.48	7.74	10.48	26.2	-
Fluoranthene	0.48	0.48	0.48	-	-
Free CN	139.19	119.84	139.19	13.9	-
Nonylphenols	49.66	40.64	49.66	18.2	-
Octylphenol	12.96	10.16	12.96	21.6	-
PCB 153	0.013	0.013	0.013	-	-
PHCs	44,082.07	39,590.33	44,082.07	10.2	-
Pyrene	0.80	0.80	0.80	-	-
Trichloromethane	396.14	395.45	396.14	0.2	-
Tridecane	21.56	21.09	21.27	2.2	1.3
Metals and Metalloids					
Ag	23.49	23.49	23.49	-	-
Al	558,527.37	25,773.10	39,523.74	95.4	92.9
As	97,289.64	794.77	97,289.64	99.2	-
B	91,519.18	91,192.49	91,519.18	0.4	-
Ba	24,247.71	24,247.71	24,247.71	-	-
Be	15.63	15.63	15.63	-	-
Br	21,665.43	2,526.03	21,665.43	88.3	-
Cd	109.00	32.65	86.31	70.0	20.8
Co	1,154.03	184.47	1,076.67	84.0	6.7
Cr	2,133.70	588.18	2,124.06	72.4	0.5
Cu	7,104.26	6,085.58	7,104.26	14.3	-
Fe	1,334,807.96	66,123.38	107,052.35	95.0	92.0
Ni	4,274.47	1,259.87	4,249.13	70.5	0.6
Pb	6,203.78	546.00	6,203.78	91.2	-
Sb	123.299.33	566.20	650.44	99.5	99.5
Si	2,289,610.40	1,438,115.72	2,289,610.40	37.2	-
Sn	24.94	24.94	24.94	-	-
Ti	718.40	708.45	718.40	1.4	-
V	1,969.40	666.43	1,938.35	66.2	1.6
Zn	25,436.47	9,633.02	20,961.96	62.1	17.6
Pharmaceuticals and PCPs					
4-chloroaniline	0.05	0.03	0.05	30.4	-
Diphenyl ether	66.68	66.15	66.68	0.8	-
PPPs					
Azinphos-methyl	0.07	0.02	0.07	63.8	-
Chlorfenapyr	0.03	0.01	0.03	47.7	-
Dichlorvos	0.85	0.23	0.64	73.2	24.5
Endrin	0.03	0.00	0.03	84.2	-
Ethalfluralin	74.38	51.24	74.38	31.1	-
Fenpropimorph	0.31	0.23	0.31	26.9	-
Imidacloprid	22.25	22.25	22.25	-	-
Nicosulfuron	6.46	6.46	6.46	-	-
Grand Total	4,635,019.18	1,709,441.35	2,760,969.98	63.1	40.4

A significant portion of this amount is due to metals and metalloids in the YRB, where the total difference between Case-2 and Case-3 was found as 1.04 tons/day. A significant amount of this reduction is due to Si (81%), As (9%), and Fe (4%). The reductions of pharmaceuticals and PCPs were estimated as 0.53 g/day for Case-2, whereas any reduction was not foreseen for Case-3. For the industrial organic compounds, a reduction of 4.53 kg/day and 0.29 g/day was estimated for Case-2 and Case-3, respectively. The contribution of PHCs to this difference was estimated as more than 99%. Finally, for PPPs, the estimated reductions were 23.92 g/day and 0.21 g/day for Case-2 and Case-3, respectively. The contribution of Ethalfluralin to this difference was estimated as 97%, followed by Dichlorvos (2%).

The significance of the pollutant load reductions was also evaluated by calculating the concentration of these pollutants in surface waters. The MLF was used for the estimation of concentrations at each sub-basin. The summary DF assessment results showing the AA-EQS exceedance in sub-basins of the YRB are given in Table 25.

Table 25. Micropollutants Exceeding the AA-EQS Limit in the YRB Sub-Basins According to Case-2 and Case-3 of the DF Assessment

Sub-basin	1		2		4		5		8		9		10		11		12		13		14		16		17		18		19		20		21	
Pollutants	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3	Case-2	Case-3
Al																		+		+				+				+						+
As																						+												
Benzo(a)pyrene																				+														
Br																				+				+				+						
Cd																		+		+														+
Co																		+		+		+	+	+										+
Cr																				+		+												
Cu																				+														
Dichlorvos																		+		+														
Ethalfluralin																				+														
Fe																		+		+				+				+						+
Free CN																				+														
Ni																				+														
Nonylphenols																				+														
Octylphenol																				+														
Pb																		+		+		+								+		+		
PHCs																		+		+														
Si		+												+		+		+		+				+				+						+
V																				+		+												
Zn		+		+		+		+		+		+		+		+		+		+		+	+	+		+		+						+
Exceedance	0	2	0	1	0	1	0	1	0	1	0	1	0	2	0	2	0	9	0	19	0	6	2	6	0	1	0	5	0	1	0	1	0	6

Since the concentrations of the micropollutants are overestimated in 19 sub-basins, any concentration estimation above the AA-EQS is a clear sign of EQS exceedance in the surface waters. In sub-basins 12 and 13, the estimations that are above the AA-

EQS must be treated with caution and should be regarded as an indicator of a potential AA-EQS exceedance in the surface waters. The surface water concentration of 10 micropollutants, which did not need any load reduction, was estimated below the AA-EQS in all sub-basins. Among 12 micropollutants, which required additional measures both in Case-2 and in Case-3, the surface water concentration of Tridecane did not exceed the AA-EQS. Two micropollutants (Co and Zn) exceeded the AA-EQS both in Case-2 and in Case-2, while the remaining nine micropollutants exceeded the AA-EQS in only Case-3. Among 20 micropollutants, where any reduction was not foreseen for Case-3, the surface water concentrations of 11 micropollutants (Free CN, Nonylphenols, Trichloromethane, B, Ti, 4-chloroaniline, Diphenyl ether, Azinphos-methyl, Chlorfenapyr, Endrin, and Fenpropimorph) did not exceed the AA-EQS. For Case-3, the surface water concentrations of the remaining nine micropollutants (DTOP, Octylphenol, PHCs, As, Br, Cu, Pb, Si, and Ethalfluralin) were above the AA-EQS.

According to Figure 48, the surface water concentration of Zn exceeded the AA-EQS in the majority of the sub-basins, except the downstream sub-basins 19 and 20, where the stream flow rate reached its peak values. On the other hand, except As, the surface water concentrations of micropollutants exceeded the AA-EQS in sub-basin 13, where the effluent/stream flow rate ratio is highest. The effluent/stream flow rate ratio was calculated for each sub-basin according to Equation-19. This ratio can be regarded as a pollution indicator of a sub-basin (Keller et al., 2014), and corresponds to 1/DF, with an inclusive stream flowrate calculation approach.

$$Effluent\ Ratio\ (\%) = \frac{Effluent\ Flowrate}{Stream\ Flowrate} x100 \qquad (Equation-19)$$

The PCA was used to visualize the inter-correlations among effluent ratio, exceedances of industrial organic compounds, PPPs, and metals (Figure 48-a). The pharmaceuticals and PCPs were excluded from the PCA analysis since their concentration did not exceed the AA-EQS in any sub-basins. The PCA allows us to visualize the most important information from multivariate data and summarizes this information in a simple form, highlighting which variables contribute to the total variation most. According to Figure 48-a, exceedance incidences of metals, PPPs, and industrial organic compounds contributed positively to the variation of Dim1 (PC1), where there was a strong relationship between effluent ratio and exceedances.

This relationship is given in Figure 48-b as a correlation plot. The Pearson correlation coefficient (R) was calculated as 0.81 ($p < 7.81 \times 10^{-6}$), 0.86 ($p < 6.81 \times 15^{-7}$) and 0.87 ($p < 3.12 \times 10^{-7}$) between effluent ratio and exceedance events of industrial organic compounds, metals, and PPPs, respectively. According to Figure 48-a, six clusters were identified for effluent ratio among sub-basins. Sub-basin 13 (97%) was an outlier among other sub-basins.

The sub-basins 12, 21, and 16 formed the second cluster with effluent ratios between 38% and 64%. Sub-basins 14 and 18 varied from the remaining sub-basins and formed the third cluster with low effluent ratios and a high amount of exceedances. The fourth cluster included sub-basins 1, 5, 10, 11, and 17, while the last cluster was formed among the remaining sub-basins. These results indicate that the high effluent ratio is the primary cause of AA-EQS exceedance in the sub-basins since the dilution capacity of the surface waters decreases with increasing amounts of effluents. A DF of ten in a sub-basin almost eliminates entire exceedance incidences. A DF of less than 15 is a guaranteed exceedance in at least one pollutant in the YRB case.

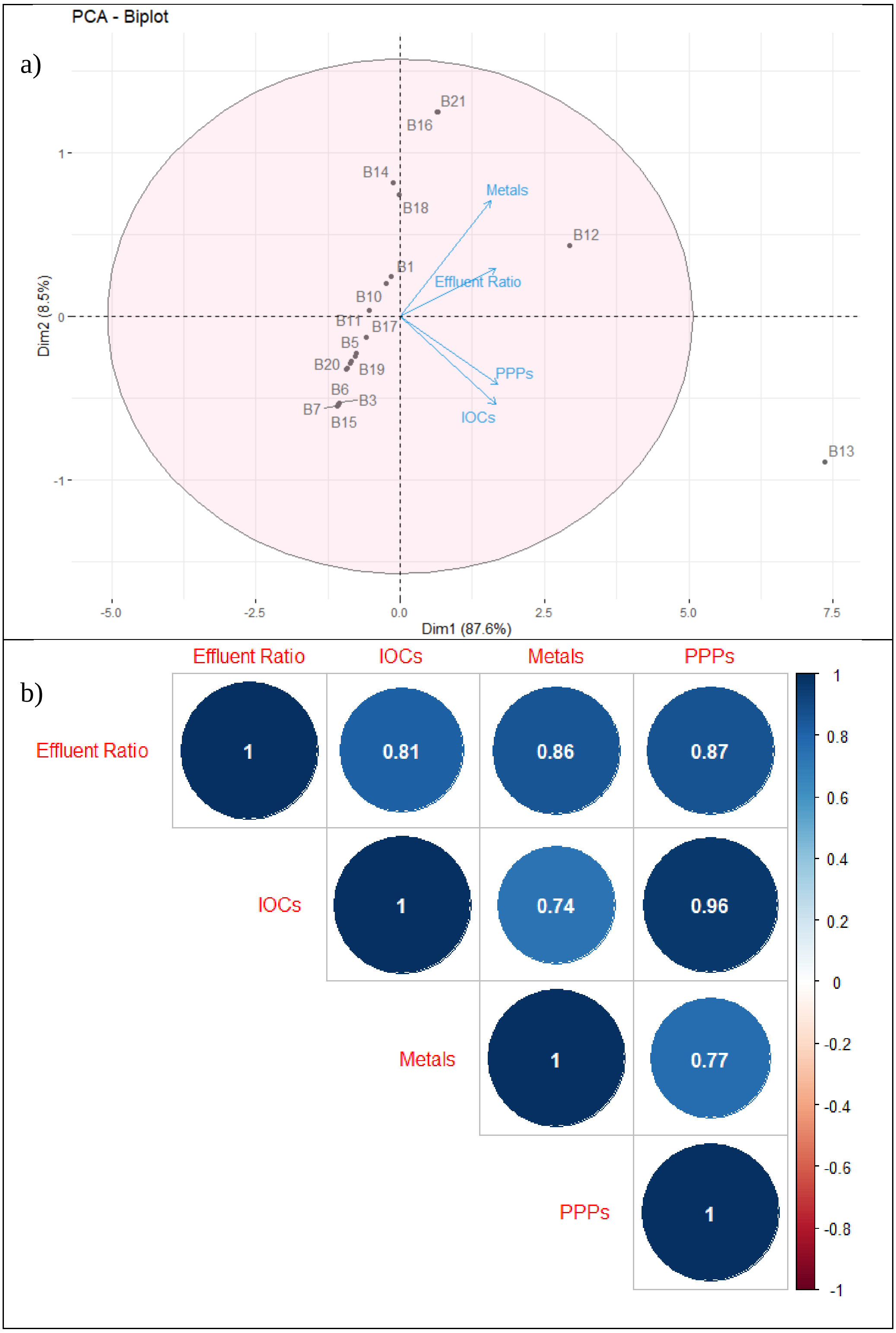


Figure 48. (a) PCA-Biplot of Effluent Ratio and Micropollutant Exceedances in Sub-basins, (b) Correlation Plot of Exceedance with Effluent Ratio (IOCs: Industrial Organic Compounds)

The results of the total micropollutant exceedance evaluations (Table 25) were compared to Case-1, and the improvements in each sub-basin are given in Figure 49 as a percent difference from Case-1. According to the results of Case-2, the only exceedance was observed in sub-basin 16 (Tersakan), which is heavily affected by industrial and municipal wastewater discharges. The average improvement in the YRB was calculated as 98% in total exceedances. Case-3, which represents the proposed implementation strategy of the draft WPCR (Official Gazette No: 25687, Date: December 31, 2004) had an average improvement of 29% in the YRB. The sub-basins 3, 6, 7, and 15 had reached a good chemical status, while slight improvements were observed in sub-basins 14, 18, 19, 20, and 21. The status of the remaining sub-basins did not change. According to these results, the proposed implementation strategy does not look adequate for reducing the background concentrations of micropollutants in the majority of the sub-basins in the YRB. In this regard, as an alternative to Case-3 (DF_{10}), two additional cases were evaluated, which were selected as DF_5 and DF_2. According to the results of these cases, the overall improvements in the YRB were evaluated as 37% and 57%, for DF_5 and DF_2, respectively. Any other scenario other than using the EQS as discharge limitations was not adequate in the YRB to reach good chemical status. However, it is important to remind that these results were evaluated under the MLF condition with limited monitoring in municipal and industrial WWTPs. The assessment of DF or any other point source control strategy such as TMDL and Discharge Test requires a substantial amount of data regarding both the point sources and the receiving water body. The pollutants, their concentration, and environmental fate should be monitored for extended periods, while the stream flow rate at the discharge point must be known. Additional monitoring studies and detailed flow rate measurements from the effluent locations are necessary to evaluate these results more accurately. These results indicate that to control micropollutant emissions in the YRB and to achieve “good surface water chemical status”, measures beyond the proposed implementation strategy of the draft WPCR should be taken.

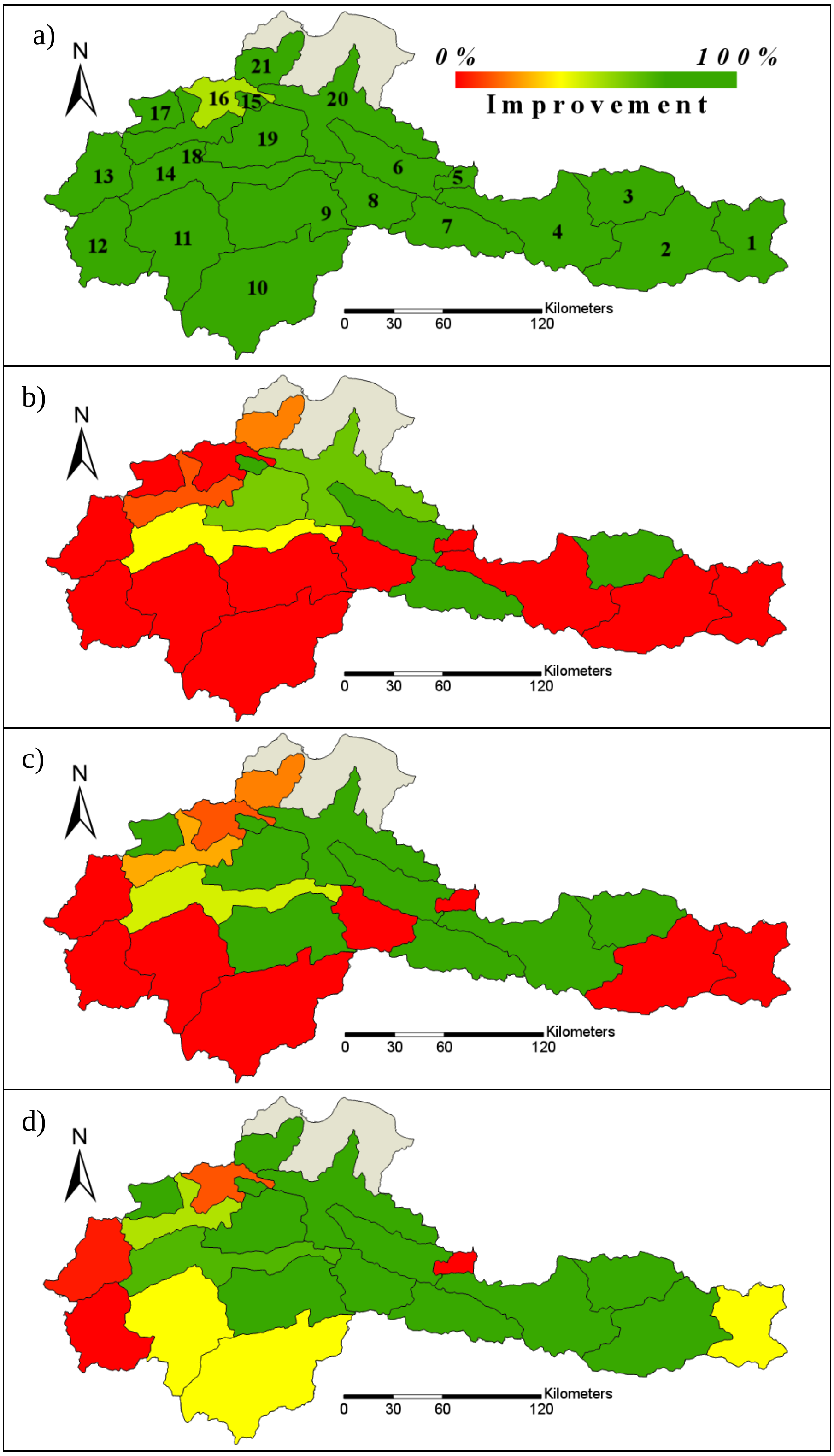


Figure 49. The DF Assessment Results (a) Case-2 (b) Case-3 (c) Alternative Case with DF$_5$ (d) Alternative Case with DF$_2$

4.7 Conclusion

The DFs of point sources were assessed for the first time to test if the use of a fixed DF is a proper management strategy to control micropollutants from point sources in the YRB. For the calculation of DF for point sources, MLF values were calculated using eleven different probability distribution functions. The results indicated that the three-parameter Pearson type III distribution (pe3) using the 7Q2 method of low-flow estimation is the best fit for MLF calculations. The DFs of all point source discharges in the YRB were calculated under two dilution scenarios, which are the local dilution factor (DF_1) and the accumulative dilution factor (DF_2). Based on the results obtained, the following conclusions were drawn.

For the MF condition, the median values of $DF_{1,i}$ and $DF_{2,i}$ were calculated as 89.5 and 38.2, respectively. For the MLF condition, the median values of $DF_{1,i}$ and $DF_{2,i}$ were calculated as 8.8 and 4.1, respectively. For the MLF condition, the dilution of point source effluents in the YRB is reduced by approximately 90%, which shows the importance of using the MLF conditions for attaining the EQS. The choice of MLF for the evaluation of DFs in a river basin appears to be the most conservative approach during the estimation of DFs of point sources in a river basin.

The proposed strategy of implementing a fixed DF of ten was not found to be adequate to reduce the surface water concentrations of target micropollutants below EQS. These results indicate that to control micropollutant emissions in the YRB and to achieve “good surface water chemical status”, measures beyond the proposed implementation strategy of the draft WPCR should be taken.

CHAPTER 5

RISK ASSESSMENT AND SOURCE APPORTIONMENT IN THE YEŞİLIRMAK RIVER BASIN

In this chapter, the ecotoxicological risks associated with the micropollutants that are the cause of concern are evaluated to identify high-risk sub-basins in the YRB. In addition, the source of these micropollutants are be evaluated using a statistical approach. For this purpose, the basin characteristics are evaluated together with the surface water monitoring study results to identify the possible sources of these micropollutants in the YRB. The results of the risk assessment and source apportionment are then interpreted together to suggest a micropollutant management strategy in the YRB.

5.1 Introduction

5.1.1 Background

Chemical substances are part of our life that play a vital role in the manufacturing practices of many products used daily. Some of these chemical substances have hazardous properties that can harm humans and/or the environment. In Europe, 84% of people are worried about the presence of chemical products in everyday products, and even more, people are worried about their environmental impacts (EC, 2020). The EU chemical strategy is evolving to maximize its contribution to society while promoting safe and sustainable use in line with the European Green Deal. In order to track these chemical substances, the American Chemical Society (ACS) – Chemical Abstract Service (CAS) registers chemical substances with a unique, globally accepted identifier number, known as the CAS registry number (CAS, 2022a). Over 197 million organic and inorganic substances are available in the CAS registry, and the regulated chemicals listing (CHEMLIST) contains more than 400,000 chemical substances (CAS, 2022b). Across the EU, the protection of human health and the environment from the manufacture and use of hazardous substances is ensured by the regulation Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) (European Commission, 2006). REACH provides the base for collecting and assessing information regarding hazardous substances and introduces risk management measures such as substitution with less dangerous substances and restriction of use.

Despite all the efforts, the aquatic environments polluted by the point and/or diffuse sources contain complex mixtures of micropollutants, but it is not viable to detect all pollutants by targeted chemical analysis. The micropollutants in these mixtures can create synergism or antagonism during interaction with each other; however, in environmental samples, the synergism is rare due to low concentrations (Neale et al., 2015). A lethal effect on the embryo might be induced by various toxicity pathways such as mutagenicity, hepatotoxicity, cytotoxicity, estrogenicity, androgenicity, genotoxicity, and oxidative stress. Although the toxic actions of many micropollutants are known and synergism is rare, single chemical exposure risk assessments might not reflect the overall implications of micropollutant mixtures (Shao et al., 2019). Even some of the effects occurring in the aquatic phase could seem normal, although there are significant changes in the population of species. For example, continuous exposure to hazardous substances may cause changes in macro-invertebrate communities, which favors tolerant species to prevail (Bunzel et al., 2013). The two fundamental concepts of the toxicity assessment are concentration addition (CA) and independent action (IA), which are considered the boundaries of the prediction window (Backhaus & Faust, 2012). The CA is used to estimate toxicity when more than one chemical substance that induces the same toxicity pathway is present at the same time, while the IA concept assumes that substances in a mixture affect different subsystems. Both the CA and the IA neglect any interaction between chemical substances in environmental mixtures.

The water quality standards are derived from the ecotoxicological data using an ecosystem risk quotient (RQ). A conservative approach to the calculation of the RQ is provided in Equation-20 (Backhaus & Faust, 2012). The assessment factor (AF) used in calculating RQ depends on the available effect assessments from toxicity tests on three trophic levels (Algae, *Daphnid sp*., and fish) (Knacker, 2009). If at least three short-term toxicity tests are available, the AF is taken as 1,000; when only one long-term toxicity test on *Daphnia* or fish is available, the AF is taken as 100; when two long-term toxicity tests are available, the AF is taken as 50; and when at least three long term toxicity tests are available on three trophic levels, the AF is taken as 10.

$$RQ = \sum_{i=1}^{n} \frac{PEC_i}{PNEC_i}$$
$$= \sum_{i=1}^{n} \frac{PEC_i}{\min\left(EC50_{algae}, EC50_{daphnids}, EC50_{fish}\right)_i x(1/_{AF_i})} \quad (Equation - 20)$$

where:

i: Pollutants that induce the same toxicity pathway

n: Total number of pollutants that induce the same toxicity pathway

PEC_i: Predicted environmental concentration of pollutant i (µg/L)

$EC50_i$: The concentration of the pollutant i in water causing a 50% reduction in growth (µg/L)

$PNEC_i$: Predicted no-effect concentration for pollutant i (µg/L)

AF_i: Assessment factor for pollutant i

The summation of the PEC/PNEC ratio of different trophic levels is regarded as a conservative approach since it does not follow the fundamental concept of the CA, where toxicity estimates are based on toxicity pathways of single species. The toxic unit risk quotient (TU) incorporates the CA concept into the RQ and the ecotoxicity of the most sensitive trophic level is adopted as the water quality standard (Equation-21) (Backhaus & Faust, 2012). Due to methodological differences in the calculation, the RQ is always higher than the TU, which is the main reason why the RQ is regarded as the conservative approach between the two risk quotients.

$$TU = \max\left(TU_{algae}, TU_{daphnids}, TU_{fish}\right) xAF \qquad (Equation - 21)$$

$$= max\left(\sum_{i=1}^{n} \frac{PEC_i}{EC50_{i,algae}}, \sum_{i=1}^{n} \frac{PEC_i}{EC50_{i,daphnids}}, \sum_{i=1}^{n} \frac{PEC_i}{EC50_{i,fish}}\right) x\ AF$$

where:

i: Pollutants that induce the same toxicity pathway

n: Total number of pollutants that induce the same toxicity pathway

PEC_i: Predicted environmental concentration of pollutant i (µg/L)

$EC50_i$: The concentration of the pollutant i in water causing a 50% reduction in growth (µg/L)

AF_i: Assessment factor for pollutant i

The IA concept is a data-demanding methodology that requires the concentration-response curves of each chemical substance in a mixture. The environmental mixtures are often composed of chemical substances with very low concentrations and these mixtures should be concentrated at least ten times to observe any direct effects (B. I. Escher et al., 2014). The joint CA/IA mixture model studies showed that it is assumed safe to use the CA concept and the TU approach for estimating ecotoxicological risks of surface water mixtures at true environmental levels (B. Escher et al., 2020).

The European Technical Guidance Document on Risk Assessment suggests calculating acute and chronic RQs on aquatic life according to Equation-22 and Equation-23, respectively (EC, 2002). During the estimation of acute and chronic toxicities, the EC50 and no observed effect concentration (NOEC) are used for risk assessment, respectively. The evaluation criteria of the chronic RQ for interpreting the risk level have been applied as low risk (between 0.01 and 0.1), medium risk (between 0.1 and 1), and high risk (> 1) for two decades (Ben et al., 2018; Hernando et al., 2006; Ofrydopoulou et al., 2022).

A new evaluation criterion has been proposed to interpret the risk levels at WWTP effluents, which classifies the risks as no risk (< 0.1), negligible risk (between 0.1 and 1), low risk (between 1 and 10), medium risk (between 10 and 100), and very high risk (> 100) (Gosset et al., 2021). However, this new evaluation criterion does not reflect the DF of surface waters to the concentration of chemical substances.

$$RQ_{i,acute} = \frac{\mathrm{MEC}_i}{\mathrm{PNEC}_{a,i}} = \frac{MEC_i}{\min\left(EC50_{algae}, EC50_{daphnids}, EC50_{fish}\right)_i \, x \left({}^{1}/_{AF_i}\right)} \quad (Equation - 22)$$

$$RQ_{i,chronic} = \frac{\mathrm{MEC}_i}{\mathrm{PNEC}_{c,i}} = \frac{MEC_i}{\min\left(NOEC_{algae}, NOEC_{daphnids}, NOEC_{fish}\right)_i \, x \left({}^{1}/_{AF_i}\right)} \quad (Equation - 23)$$

where:

i: Pollutants

MEC_i: Measured environmental concentration of pollutant i (µg/L)

$EC50_i$: The concentration of pollutant i in water causing a 50% reduction in growth (µg/L)

$NOEC_i$: The highest concentration of pollutant i for which there is no statistically significant difference of effect ($p<0.05$) when compared to the control group (µg/L)

$PNEC_{a,i}$: Predicted no-effect concentration of pollutant i for acute effects (µg/L)

$PNEC_{c,i}$: Predicted no-effect concentration of pollutant i for chronic effects (µg/L)

AF_i: Assessment factor for pollutant i

As different than the above-mentioned RQ calculation approaches, the frequency of detection (f) was suggested to be taken into account as a critical parameter of risk estimation (Equation-24) (Figuière et al., 2022; Kandie et al., 2020; Ofrydopoulou et al., 2022). The f is regarded as the ratio of the number of samples that exceed the PNEC value at a sampling site, to the total number of samples taken.

$$RQ_{i,f} = \mathrm{RQ}_i \text{ x } \mathrm{f}_i$$

$$= \mathrm{RQ}_i \text{ x } \frac{Total \ \# \ of \ Samples \ where \ MEC_i > PNEC_i}{Total \ \# \ of \ Samples} \qquad (Equation - 24)$$

where:

RQ_i: Risk quotient of pollutant i (acute or chronic)

i: Pollutants

f: Frequency of detection

MEC_i: Measured environmental concentration of pollutant i (µg/L)

$PNEC_i$: Predicted no-effect concentration of pollutant i (µg/L)

Adopting a similar approach, the RQs in the point source effluents have been evaluated by either using an f (Ofrydopoulou et al., 2022). As an alternative approach, the DF was used to predict concentrations in the surface waters to calculate the RQ of pollutants (Thomaidi et al., 2015) as the DF plays a critical role in the ecotoxicity since concentrations and hence the risk at the effluent discharge point increase during low flow conditions (Munz et al., 2017).

5.1.2 Objective and Scope

The primary objective of the present study is to develop a new methodology for calculating the RQ for micropollutants in surface water. This methodology aims to consider and compare the risks imposed by the micropollutants both in the point source discharges and in receiving surface waters.

The surface water and point source concentrations of micropollutants that are the cause of concern in the YRB were used to calculate the RQs at sub-basin outfalls in the YRB following the EU WFD methodology (2000/60/EC). In sub-basins, the RQ of each micropollutant calculated based on maximum surface water concentration was compared to the RQ value calculated based on maximum point sources concentration. The higher RQ was designated as the RQ of the sub-basin for that micropollutant.

The secondary objective is to develop a point source management strategy based on the risks calculated for each micropollutant in sub-basins of the YRB. For each sub-basin, the RQ of micropollutants that are the cause of concern in the YRB is calculated based on the surface water concentrations and compared to the RQ value calculated based on predicted point source concentration. Source apportionment was carried out to estimate the potential sources of the cause of concern micropollutants. The findings were used to develop a point source management strategy by evaluating the results of the risk assessment and source apportionment together.

5.2 Methodology

5.2.1 Risk Assessment Methodology

The risk assessments of surface waters and point sources were based on the results of the monitoring study. The RQs of micropollutants in surface waters were calculated according to Equation-25 by using the results of the monitoring study (Figuière et al., 2022; Kandie et al., 2020; Ofrydopoulou et al., 2022). The RQs from point source pollution were calculated by using the same approach adopted in Chapter 4.5.5, where the total load of each micropollutant downstream of a sub-basin was calculated with a conservative approach, and divided by the stream flow rate to estimate the surface water concentration (Equation-26). The f was incorporated in the estimation of risks with a minor difference. At surface water samples, the RQ was multiplied by f to evaluate the RQ of a pollutant. At point sources, since the total load was estimated downstream of each sub-basin, the f was applied to the effluent concentration of micropollutants at the source. The $MEC_{surface\ water,i}$ and the $C_{point\ source,j,i}$ of a micropollutant was taken as the maximum measured concentration at surface water and point source sampling, respectively. The PNEC values were accepted to be equal to the EQS values derived for each micropollutant since the evaluation methodology of the EQS and PNEC values are the same (Knacker, 2009). The EQS is also used to follow a regulatory context while calculating the RQs (Munz et al., 2017).

$$RQ_{s,i-Surface\ Water} = \frac{MEC_{surface\ water,i}}{PNEC_i} x f_i \qquad (Equation - 25)$$

$$RQ_{s,i-Point\ Source} = \sum_{j=1}^{k} \frac{C_{point\ source,j,i}\ x\ Q_j\ x\ f_i}{PNEC_i\ x\ MF_s} \qquad (Equation - 26)$$

$$PNEC_i = \frac{\min\left(NOEC_{i,algae}, NOEC_{i,daphnids}, NOEC_{i,fish}\right)}{AF} = EQS_i$$

$$f_i = \begin{cases} Surface\ Water; \dfrac{Total\ \#\ of\ Samples\ where\ MEC_{surface\ water,i} > PNEC_i}{Total\ \#\ of\ Samples} \\ Point\ Source; \quad \dfrac{Total\ \#\ of\ Samples\ where\ C_{point\ source,j,i} > PNEC_i}{Total\ \#\ of\ Samples} \end{cases}$$

where:

i: Micropollutant

j: Point source

k: Total number of point sources upstream of sub-basin s

s: Sub-basin

$RQ_{s,i\text{-Surface Water}}$: The RQ of micropollutant i at the outfall of sub-basin s, calculated from surface water monitoring results

$RQ_{s,i\text{-Point Source}}$: The RQ of micropollutant i at the outfall of sub-basin s, estimated from point source monitoring results

$MEC_{surface\ water,i}$: The maximum measured concentration of micropollutant i at the outfall of sub-basin s (µg/L)

$C_{point\ source,j,i}$: The maximum measured concentration of micropollutant i at point source j (µg/L)

$PNEC_i$: Predicted no-effect concentration of pollutant i (µg/L)

$NOEC_i$: The highest concentration for which there is no statistically significant difference of effect ($p<0.05$) when compared to the control group (µg/L)

EQS_i: Environmental quality standards of micropollutant i (µg/L)

AF: Assessment factor for pollutant i

f_i: Frequency of detection of micropollutant i

Q_j: Effluent flow rate of point source j (m^3/day)

MF_s: Estimated mean flow at the outfall of sub-basin s (m^3/day)

The total chronic ecosystem RQs of the YRB sub-basins were calculated with a conservative approach according to Equation-27. The RQs of each micropollutant calculated from surface water monitoring samples were compared to the estimated RQs from point source monitoring samples, where the higher RQ was designated as the RQ of the sub-basin for that micropollutant. By comparison of RQs from surface water and point source monitoring studies, the highest ecotoxicological risks associated with the 25 cause of concern micropollutants in the YRB will be evaluated to identify high-risk sub-basins. After evaluating the RQ of each micropollutant in the sub-basins, the total RQs of sub-basins were calculated by the addition of RQs of individual micropollutants that have the same ecotoxicity pathway. Finally, the highest RQ among different ecotoxicity pathways was calculated. The known ecotoxicity pathways of the cause of concern micropollutants in the YRB are provided in Appendix L - Table A 14, and the common ecotoxicity pathways of these micropollutants are given in Table 26.

$$RQ_s = \max\left(RQ_{s,p-total}\right) \qquad (Equation - 27)$$

$$RQ_{s,p-total} = \sum_{i=1}^{n} \max\begin{pmatrix} RQ_{s,i-Surface\ Water} \\ RQ_{s,i-Point\ Source} \end{pmatrix}$$

where:

i: Micropollutant

n: Total number of micropollutants that have the ecotoxicity pathway p

s: Sub-basin

p: Common aquatic ecotoxicity pathways

RQ_s: The highest total RQ of sub-basin s

$RQ_{s,p\text{-}total}$: The total RQ of sub-basin s under ecotoxicity pathway p

The endocrine disruptor and estrogenic pathways were agglomerated under mutagenic pathways. Since information regarding aquatic ecotoxicity pathways of Ethalfluralin, Si, and Br is unavailable, their ecotoxicity pathways were estimated. The ecotoxicity pathway of Ethalfluralin was based on Dichlorvos, Cypermethrin, and Diflubenzuron, while the ecotoxicity pathways of Si and Br were based on other metals and metalloids. The majority of the cause of concern micropollutants had oxidative stress pathways including herbicides, insecticides, industrial organic compounds, and metals. Genotoxicity was common among metals and metalloids, while some of them inhibited growth inhibition. Mutagenicity was identified as a common pathway of industrial organic compounds and PPPs.

Table 26. Known Common Aquatic Ecotoxicity Pathways of Cause of Concern Micropollutants

	Aquatic Ecotoxicity Pathways				
Pollutants	**Oxidative Stress**	**Genotoxicity**	**Mutagenicity**	**Neurotoxicity**	**Growth Inhibition**
Fluoranthene	+				
Hexachloro-cyclohexane			+	+	
Nonylphenols			+		
Octylphenol			+		
Benzo(a)pyrene	+				
Cypermethrin	+		+		
Dichlorvos			+		
Cd	+	+	+	+	
Ni	+			+	
Pb	+				+
Al	+	+			
As	+	+			
Co		+			
Cr	+	+			+
Cu	+	+			+
Fe	+	+			
V	+	+			
Zn	+				+
Si*					
Ti	+	+			
Free CN	+				
Br*	+	+			
PHCs	+	+	+	+	
Diflubenzuron	+				
Ethalfluralin*	+		+		

* The ecotoxicity pathways were estimated from similar pollutants.

5.2.2 Source Apportionment in the Yeşilırmak River Basin

The potential sources of the 25 cause of concern micropollutants in the YRB were evaluated using a statistical approach. The land use types, PPP usage information, groundwater operation areas, wastewater discharges, and population of the sub-basins were evaluated together with the results of the monitoring study at surface water monitoring stations. Two monitoring results groups and two basin characteristics groups were created for the statistical analysis (Figure 50). The first monitoring results group was the total concentrations of main pollutant groups among 45 priority substances and 250 river basin specific pollutants. The main pollutant groups are provided in Appendix F - Table A 11. The second monitoring results group was the individual concentrations of 25 pollutants that are the cause of concern in the YRB. The first basin characteristics group consisted of the area of land uses, PPP usage, wastewater discharges, and population. The second group of basin characteristics was created by calculating the ratio of land uses and wastewater discharges in each sub-basin, and by estimating PPP usage per area. The details regarding the calculation of each basin's characteristics are provided in the following sections. The total concentration groups in the sub-basins were calculated to evaluate if there is any relationship between the total concentration of micropollutant groups and basin characteristics in the YRB. In the same manner, the individual concentrations of the cause of concern pollutants were also evaluated for any correlation with basin characteristics. The combination of these four groups provided four matrices for bivariate (pair-wise) correlation analysis. Each matrix had quantitative elements for the 21 sub-basins. The four matrices are as follows:

- Matrix 1: 21 x 21 (8 Total Concentrations + 13 Basin Characteristics)
- Matrix 2: 21 x 21 (8 Total Concentrations + 12 Basin Characteristics)
- Matrix 3: 21 x 38 (25 Cause of Concern Micropollutant Concentrations + 13 Basin Characteristics)
- Matrix 4: 21 x 38 (25 Cause of Concern Micropollutant Concentrations + 12 Basin Characteristics)

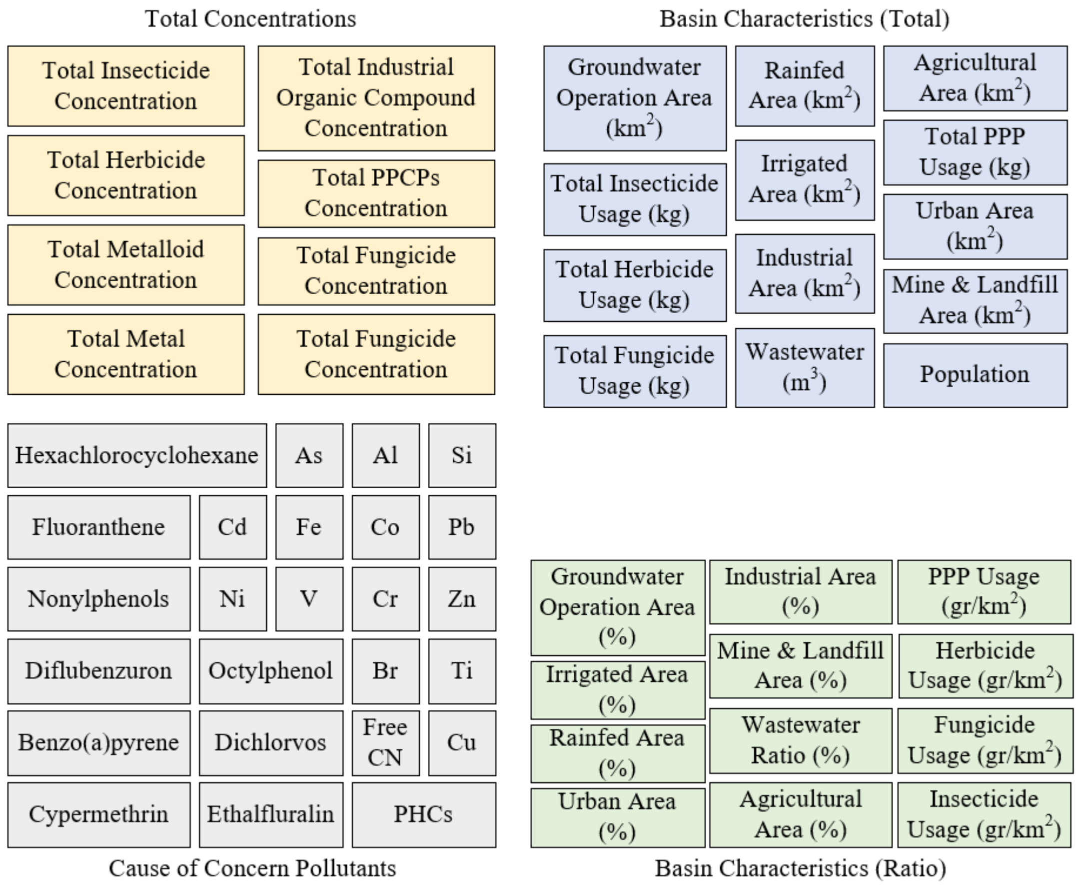


Figure 50. Monitoring Study Results and Basin Characteristics Used in the Source Apportionment

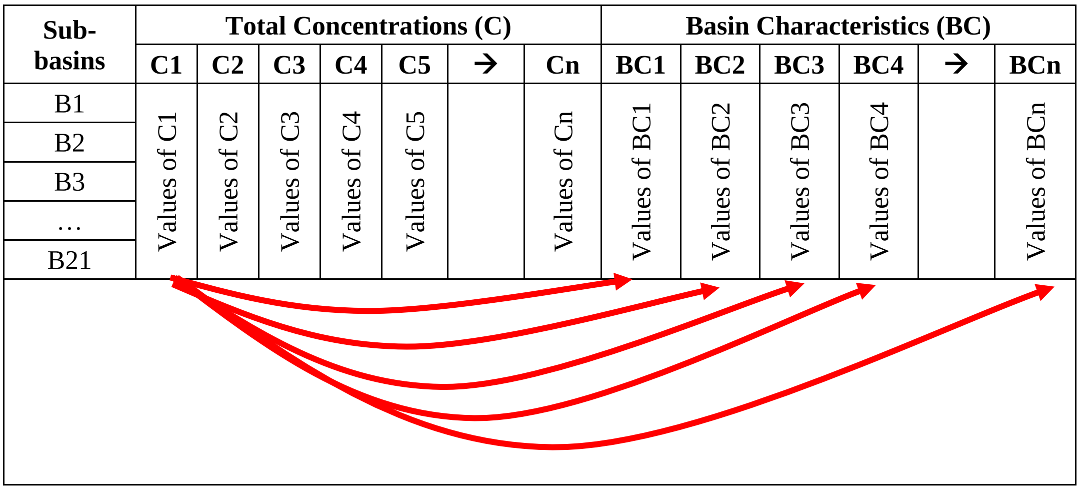


Figure 51. Example Application of Bivariate Analysis Between the First Concentration Element and Basin Characteristics

An example application of bivariate analysis is provided in Figure 51. Each element from the first group (concentrations) was paired with all elements of the second group (basin characteristics). The total number of pairs used in the bivariate analysis was 825. In addition to the concentration of the micropollutants and micropollutant groups, four additional groups were created by using the same principles but using the frequency of detection of these pollutants rather than their concentration. This increased the total number of bivariate analyses to 1,650.

5.2.2.1 Plant Protection Product Usage in the Yeşilırmak River Sub-basins

The annual amounts of PPPs used in the YRB were estimated based on the average use of these products and the distribution of agricultural areas in 21 sub-basins. The use amounts of PPPs at the provincial level are published by the MoAF on an annual basis (MoAF, 2022b). The superposition of provincial zones, agricultural areas, and the YRB boundary are provided in Figure 52. The agricultural areas in each province were retrieved from the Corine Land Cover 2018 data (CLC-2018) (EEA, 2018).

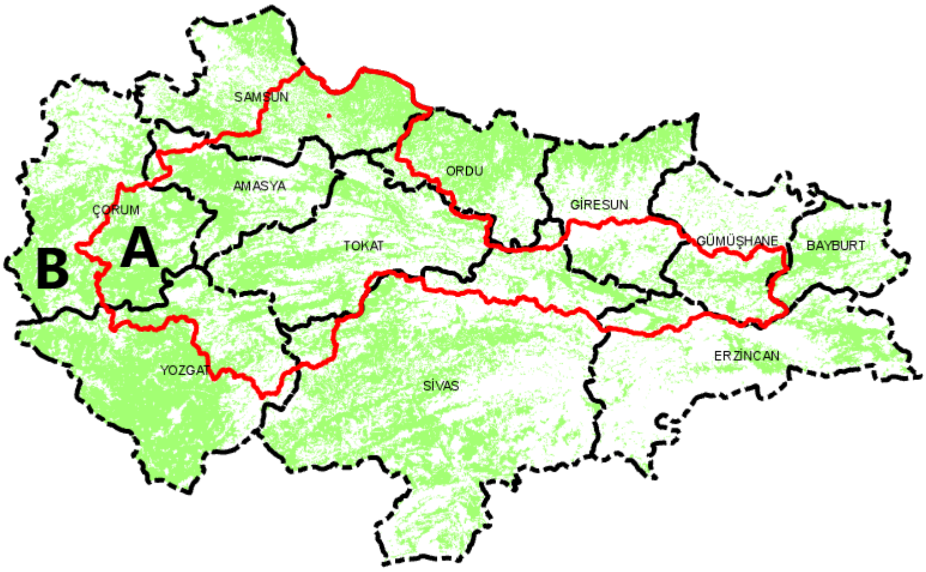


Figure 52. Superposition of Provincial Zones, Agricultural Areas, and the Yeşilırmak River Basin

As it can be interpreted from Figure 52, substantial amounts of agricultural area in each province remain outside of the YRB boundary, which should be considered during the estimation of PPPs use in the sub-basins. The annual PPP usage in the YRB sub-basins was estimated according to Equation-28, assuming that the PPP use is uniformly distributed with the total agricultural area in each province. The A and B in Equation-28 are illustrated in Figure 52. The annual PPP usage in each province was interpreted from total usage in 2016, 2017, and 2018, and the average of three years was used in Equation-28. The annual PPP usage at provincial and sub-basin scales in the YRB was provided in Appendix M- Table A 15.

$$PPP_s\left(\frac{kg}{year}\right) = \frac{Agri.Area_{s,m}}{Agri.Area_m}\ x\ PPP.Use_m \qquad (Equation - 28)$$

where:

s: Sub-basin

m: Province

PPP_s: Plant protection product usage in sub-basin s (kg/year)

$PPP.Use_m$: Plant protection product usage in province m (kg/year)

$Agri.Area_{s,m}$: Agricultural area of sub-basin s in province m (km^2) (A)

$Agri.Area_m$: Agricultural area of province m (km^2) (A+B)

The relationship between micropollutant concentrations in sub-basins and PPP usage was investigated. Total usage of insecticides, herbicides, fungicides, and a total of all PPPs were used in the correlation analysis (Figure 50). In addition, per area usage of the above-mentioned groups was also calculated and used in the correlation. The null hypothesis (H_0) was set as the correlation between the concentration of micropollutants and PPP usage occurred by chance, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the correlation was not by chance.

5.2.2.2 Land Use Types in the Yeşilırmak River Sub-basins

CLC-2018 was used to identify the main land use types in the YRB sub-basins (Figure 53). The original 31 categories in the CLC-2018 data were agglomerated into eight smaller groups to reduce the variable numbers that will be used in the statistical analysis. According to the CLC-2018 data (EEA, 2018), the largest land use type was natural vegetation, which included natural grasslands, moors and woodland shrubs, bare rocks, and sparsely vegetated areas (Table 27). The rainfed agricultural area was the second largest land use type, followed by forests. The irrigated agricultural areas covered approximately 10% of the land use type in the YRB. The urban areas covered only 1% of the total land use. The rainfed and irrigated agricultural, urban, and industrial areas were decided to be used in the statistical analysis to control if the land use type has any relationship with the occurrence and concentration of pollutants.

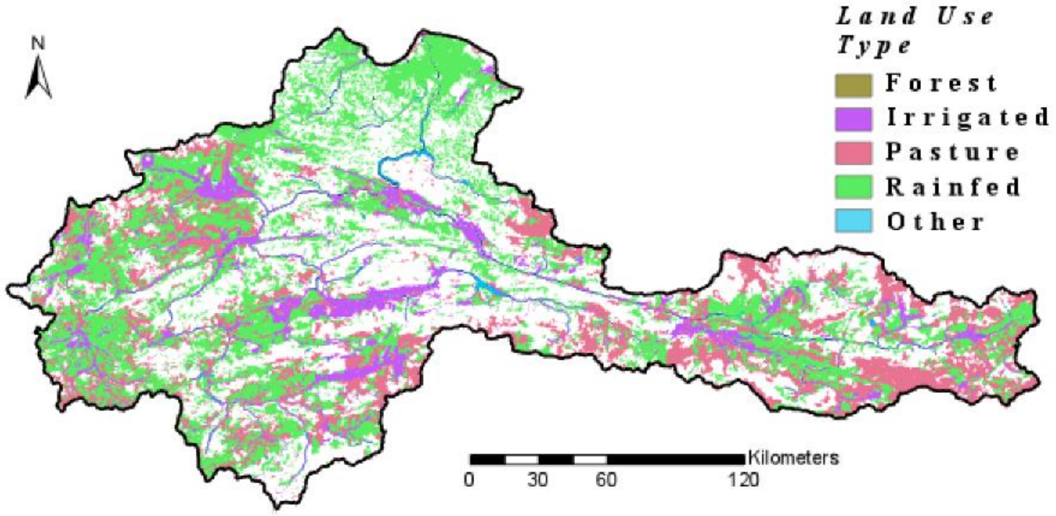


Figure 53. Main Land Use Types in the Yeşilırmak River Basin

Table 27. Areas of Main Land Use Types in The YRB

Land Use Type	**Area (km^2)**	**Area (%)**
Natural Vegetation	12432.9	34.0
Rainfed	12003.3	32.8
Forest	7806.1	21.4
Irrigated	3577.2	9.8
Urban	337.0	0.9
Water Bodies & Wetlands	270.7	0.7
Industrial	65.0	0.2
Mines & Landfills	49.2	0.1
Total	**36541.3**	**100.0**

The Yeşilırmak River Basin Master Plan (MoAF, 2016) was used to compare the sizes of agricultural areas with the CLC-2018 data, and the differences between the two sources are provided in Table 28. The irrigated and rainfed agricultural areas were 18.1% and 7.1% larger in the CLC-2018 data, respectively. Since these differences were significant, the information in the Yeşilırmak River Basin Master Plan was used in this study since it is expected to be more accurate.

Table 28. Differences in Agricultural Land Use Types Between the Yeşilırmak River Basin Master Plan and the CLC-2018

Land Use	**Area (km^2)**		**Difference (%)**
	Master Plan	**CLC-2018**	
Irrigated	3029.1	3577.2	18.1
Rainfed	11209.9	12003.3	7.1

The relationship between micropollutant concentrations in sub-basins and land use characteristics was investigated. Total agricultural area, rainfed and irrigated agricultural areas urban area, industrial area, and mine and landfill area were used in the correlation analysis. In addition, the percent distribution of the above-mentioned groups in each sub-basin was also calculated and used in the correlation (Figure 50). The null hypothesis (H_0) was set as the correlation between the concentration of micropollutants and land use characteristics occurred by chance, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the correlation was not by chance.

5.2.2.3 Population in the Yeşilırmak River Sub-basins

The population of each sub-basin was calculated using TUIK address-based population registration system (ADNKS) (TUIK, 2022). The densely populated areas in the YRB are shown in Figure 54 and the populations are given in Table 29. The sub-basins 9, 13, 20, and 19 have the highest population among the YRB sub-basins, and Tokat, Çorum, Samsun-Çarşamba, and Amasya provinces are located in these sub-basins, respectively. The relationship between micropollutant concentrations in sub-basins and the population was investigated with a correlation analysis (Figure 50). The null hypothesis (H_0) was set as the correlation between the concentration of micropollutants and population occurred by chance, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the correlation was not by chance.

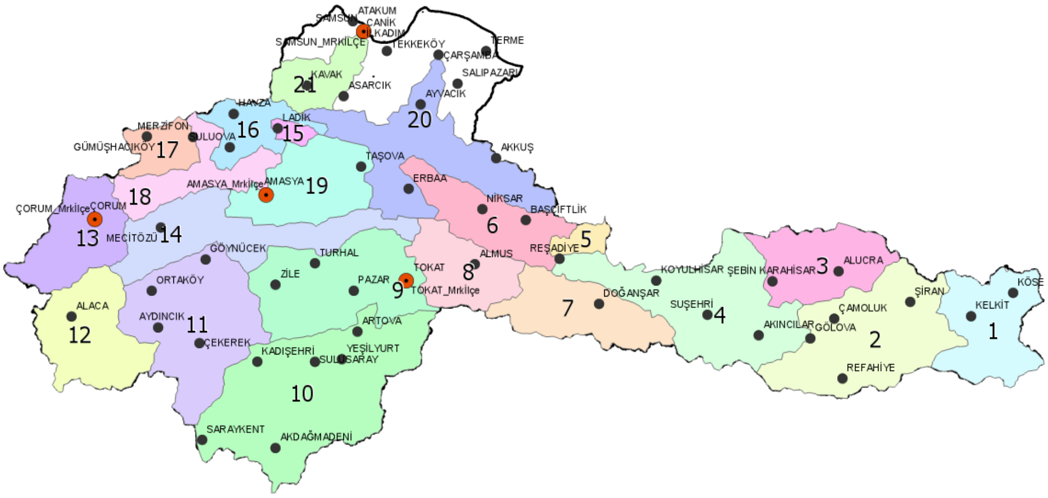


Figure 54. Densely Populated Areas in the YRB Sub-basins

Table 29. The population of the YRB Sub-basins

Sub-basins	Population
1	61,775
2	46,359
3	31,207
4	41,201
5	13,556
6	111,018
7	2,678
8	27,370
9	344,931
10	92,743
11	46,960
12	31,594
13	294,050
14	14,937
15	16,126
16	86,542
17	94,665
18	6,173
19	174,150
20	250,763
21	20,079
Grand Total	**1,789,148**

5.2.2.4 Wastewater Characteristics in the Yeşilırmak River Sub-basins

The wastewater discharges in each sub-basin were provided in Chapter 4 - Table 22. The wastewater discharge information and wastewater to stream flow rate ratio were used to investigate the relationship between micropollutant concentrations in sub-basins and wastewater characteristics of sub-basins with a correlation analysis (Figure 50). The null hypothesis (H_0) was set as the correlation between the concentration of micropollutants and wastewater characteristics occurred by chance, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the correlation was not by chance.

5.2.2.5 Groundwater Operation Sites in the Yeşilırmak River Sub-basins

Groundwater operation sites are areas in a basin, where groundwater is extracted for human consumption, agriculture, and industrial uses. The Yeşilırmak River Basin Master Plan (MoAF, 2016) was used to delineate the groundwater operation sites in the YRB, as given in Figure 55. The relationship between micropollutant concentrations in sub-basins and groundwater operation areas was investigated with a correlation analysis (Figure 50). The null hypothesis (H_0) was set as the correlation between the concentration of micropollutants and groundwater operation areas occurred by chance, and the significance level was adjusted to 0.05. The p-values less than 0.05 shows that the correlation was not by chance.

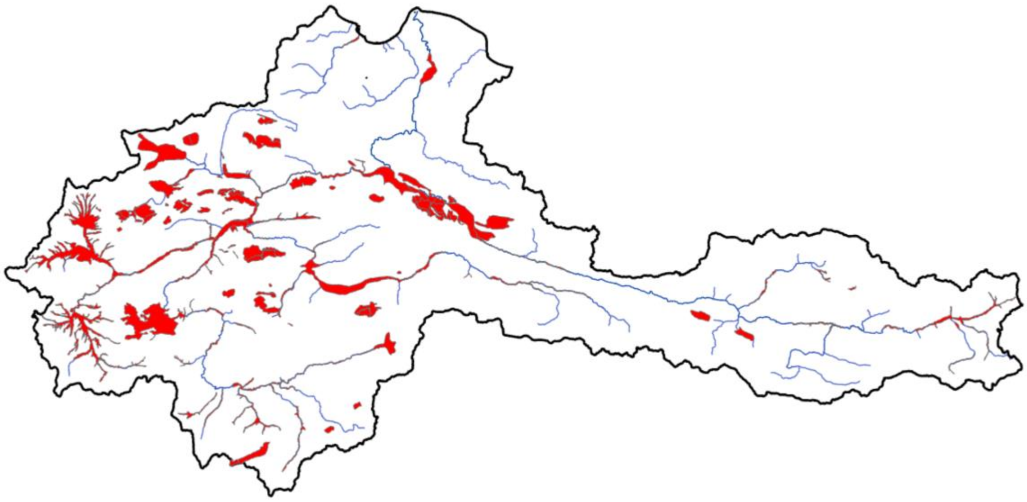


Figure 55. Groundwater Operation Site Area in the YRB

5.2.3 Risk-Based Point Source Management Methodology

The results of the source apportionment study were incorporated into the risk assessment to develop point source control strategies in the YRB. In risk assessment, micropollutants that were identified as the cause of concern at the point source effluents (Chapter 4.6.3) were taken into consideration. In line with the DF assessment methodology (Chapter 4.5.5), it was assumed that all untreated point sources were connected to a WWTP, which has an average treatment efficiency similar to already existing WWTPs. The methodology of the proposed risk-based point source management is presented in Figure 56.

Since the scope of this evaluation is to control micropollutants from point sources, the assessment starts with the predicted RQs of micropollutants from point sources. The RQs of micropollutants were evaluated according to Equation-26. If the predicted RQs of all micropollutants in a sub-basin are low ($RQ \leq 0.1$), applying DF_{10} to point sources in that sub-basin is considered applicable.

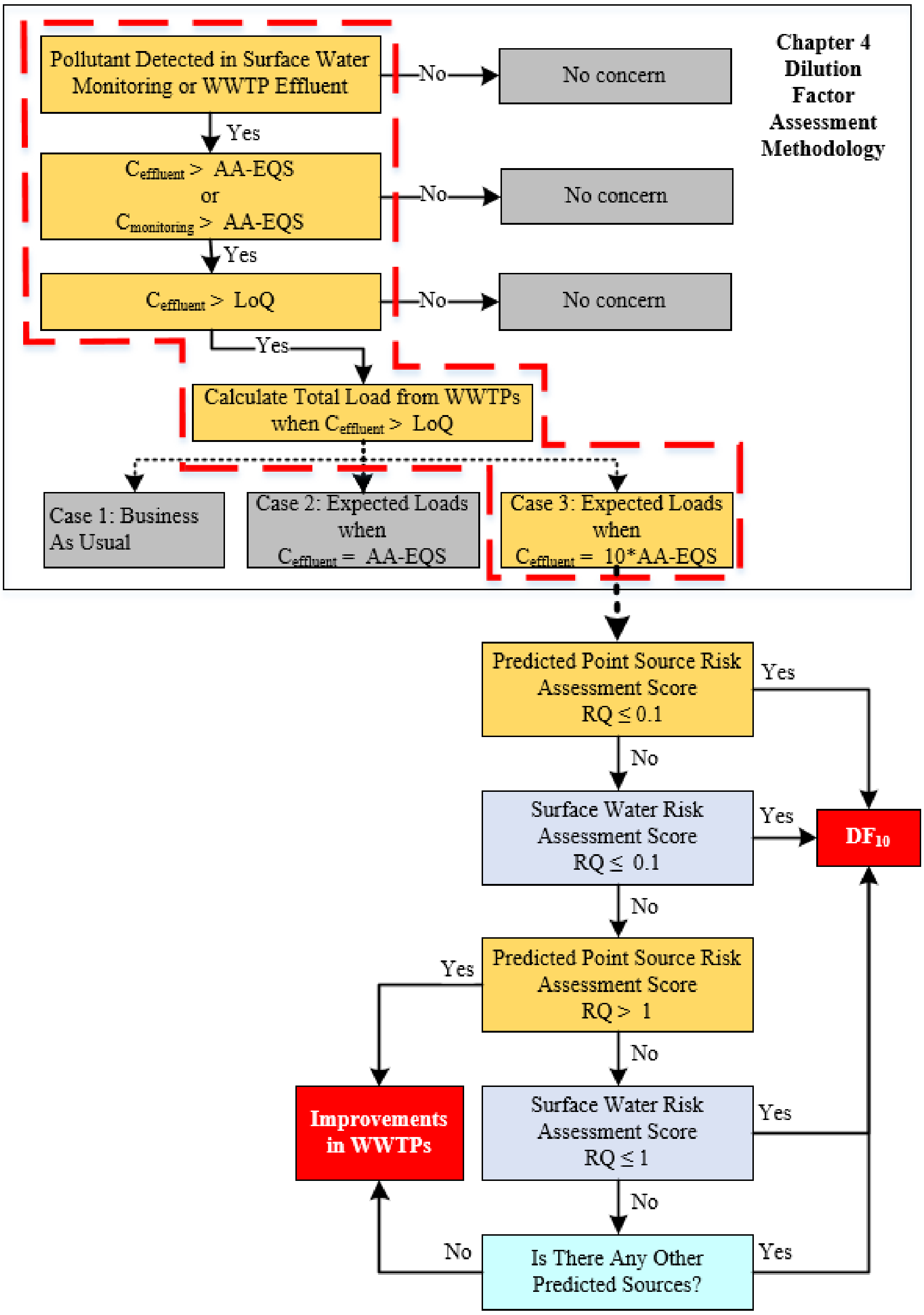


Figure 56. The Proposed Point Source Control Management Strategy Evaluation Methodology

If any RQ is greater than 0.1, then the surface water RQs are evaluated according to Equation-25, and if the surface water RQs of the respective micropollutants are low

($RQ \leq 0.1$), applying DF_{10} to points sources in that sub-basin is considered as applicable. If this condition fails, the predicted RQs of micropollutants from the point sources are evaluated once more. If the predicted RQs of any micropollutant in the sub-basin is high ($RQ > 0.1$), improvements are required at all WWTPs in the sub-basin, else it means that the predicted RQs of all micropollutant in the sub-basin are either medium or low ($RQ \leq 1$). In this condition, the surface water RQs of the respective micropollutants are evaluated once more and if the RQs are medium or low ($RQ \leq 0.1$), applying DF_{10} to point sources in that sub-basin is considered applicable. If this condition fails, it means that the surface water RQs of the respective micropollutants are high ($RQ > 1$) and the predicted RQs are either medium or low ($RQ \leq 1$). Finally, the results of the source apportionment study are evaluated with these results and if there is any other source (other than WWTPs) that could be responsible for high RQs in surface waters, applying DF_{10} to points sources in that sub-basin is considered applicable. However, if there is not any other source available to explain the high RQ of any micropollutant, then improvements are required at all WWTPs in the sub-basin. The risk evaluation of Si was excluded from assessments since it was thought to be natural, although any significant correlation was not found.

5.3 Results and Discussion

5.3.1 Risk Quotients of Micropollutants in Surface Water Monitoring Samples of the Yeşilırmak River

The detailed results of the surface water monitoring risk assessment are provided in Appendix N - Table A 16. The individual RQs of micropollutants that are the cause of concern in the YRB were calculated using the results of the surface water monitoring study according to Equation-25. The RQs of each micropollutant in surface water samples are given in Figure 57, and the distribution of RQs across the YRB sub-basins is given in Figure 58. Octylphenol, which was only quantified in the point source effluents, was excluded from the risk assessment of surface water samples. The red zone in the figures indicates high risk (RQ > 1), and the yellow zone indicates medium risk (0.01 < RQ ≤ 1). Among the micropollutants that are the cause of concern in the YRB, the result indicated that the selected micropollutants present a medium and high risk, while some of them could be considered as very high with an RQ ten times greater than the high-risk threshold (i.e. RQ > 10). Hexachlorocyclohexane, Ti, Fluoranthene, and As are the only micropollutants that did not show any high toxicity risk. The lowest RQ was calculated as 0.13 for Free CN, while the highest RQ was calculated for Cypermethrin as 569. Cypermethrin, Dichlorvos, Al, Zn, Fe, Benzo(a)pyrene, and PHCs could be evaluated as very high-risk micropollutants since their median RQs were higher than 10 at all surface water sampling stations. The lowest RQ for Cypermethrin was calculated as 60.4, with a median RQ of 133. Cd, Diflubenzuron, Nonylphenols, Free CN, and Ethalfluralin had a median RQ less than 1. However, they showed signs of high toxicity risk in some surface water samples. The variations in the RQs of Cd, Free CN, Br, Cr, and Co were higher than other micropollutants, which indicates that their peak concentrations also vary significantly among surface water sampling locations. On the other hand, the variation in Fluoranthene, Cu, PHCs, and Si was limited. The median RQs of the YRB sub-basins (Figure 58) were between the ranges of 1.7 and 25.9, while only sub-basins 13, 17, and 18 had a median RQ of greater than 10. While these three sub-basins could be evaluated as very high-risk sub-basins, none of the sub-basins indicate a medium or low-risk condition.

Cypermethrin and Dichlorvos have the highest RQs in almost all sub-basins except sub-basin 8, 10, 12, 13, and 17. In these sub-basins, Zn, Al, Al, Cd, and Zn have the highest RQ values, respectively. Among 24 micropollutants, 13 of them had significantly higher contributions to the total RQ across all sub-basins. These micropollutants were identified as Al, Cd, Cr, Cu, Cypermethrin, Dichlorvos, Fe, Ni, Pb, PHCs, Si, V, and Zn. Except for Dichlorvos, all of them show oxidative stress toxicity pathways, which enables the CA toxicity assessment.

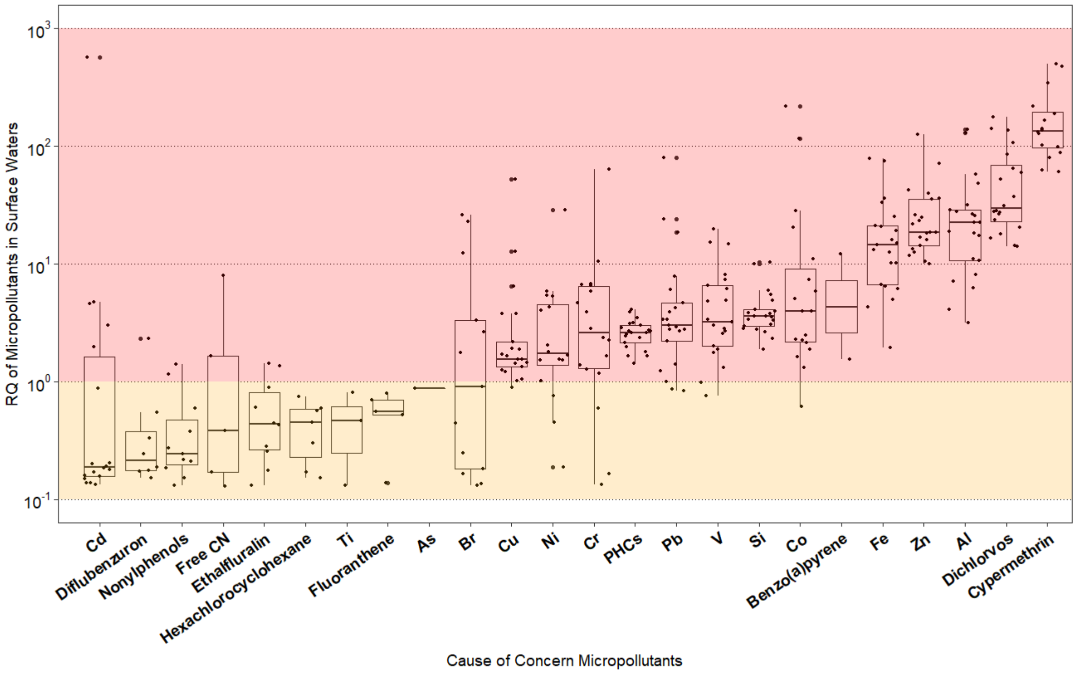


Figure 57. The RQs of Micropollutants in the Surface Water Monitoring Samples

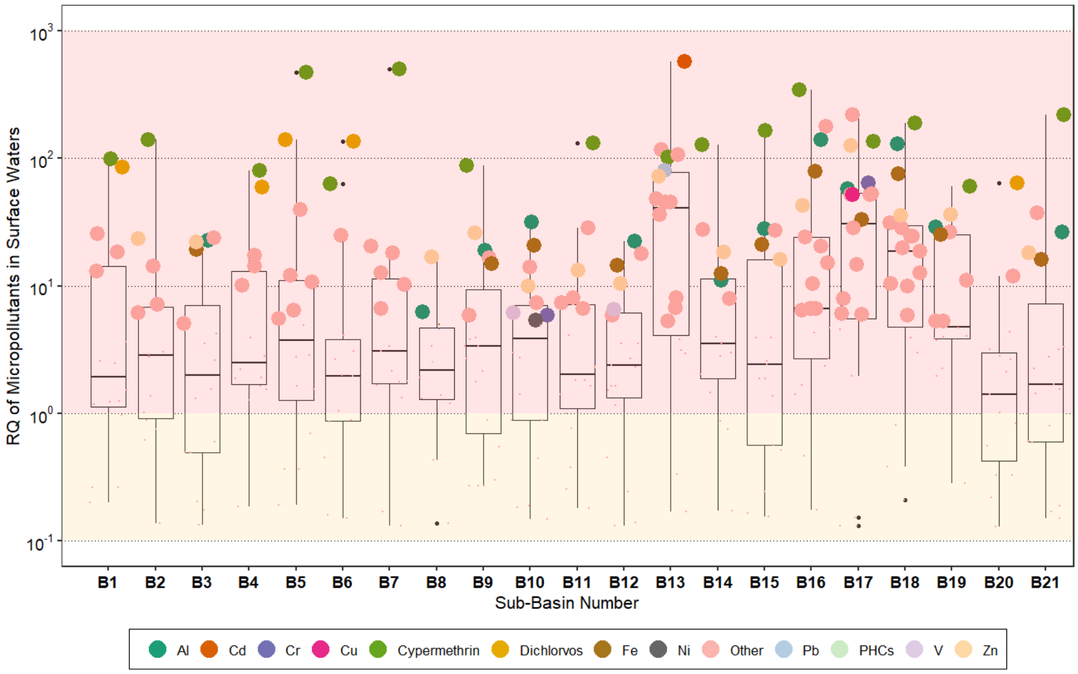


Figure 58. The RQs of Micropollutants in the Surface Water Monitoring Samples Across the YRB Sub-basins

5.3.2 Risk Quotients of Micropollutants from Point Source Effluents in the Yeşilırmak River

The detailed results of the estimated risks downstream of the point source effluents are provided in Appendix N - Table A 17. The individual RQs of micropollutants that are the cause of concern in the YRB were calculated using the results of the point source monitoring study according to Equation-26. The RQs of each micropollutant are given in Figure 59, and the distribution of RQs across the YRB sub-basins is given in Figure 60. Hexachlorocyclohexane and Diflubenzuron, which were only quantified in the surface water samples, were excluded from the risk assessment of point source effluents. The red zone in the figures indicates high risk ($RQ > 1$), the yellow zone indicates medium risk ($0.01 < RQ \leq 1$), and the green zone indicates low risk ($RQ \leq 0.01$). The total loads of micropollutants at the outfall of sub-basins were calculated with a conservative mass balance approach, without considering any decrease in their mass along the stream flow. The concentrations at each sub-basin's outfall were estimated using the stream flow rate with the MF condition. Similar to the results of the surface water risk assessment, the RQ of Cypermethrin was significantly higher than other micropollutants and categorized as high-risk since the median RQ value was calculated as 18 ($RQ > 10$). However, the RQs calculated at sub-basin outfalls of point source effluents were significantly lower than the surface water sample RQs. This indicates that even under a conservative mass balance approach, the chronic ecosystem RQs from point sources do not pose a high risk in the aquatic ecosystem due to the dilution effect.

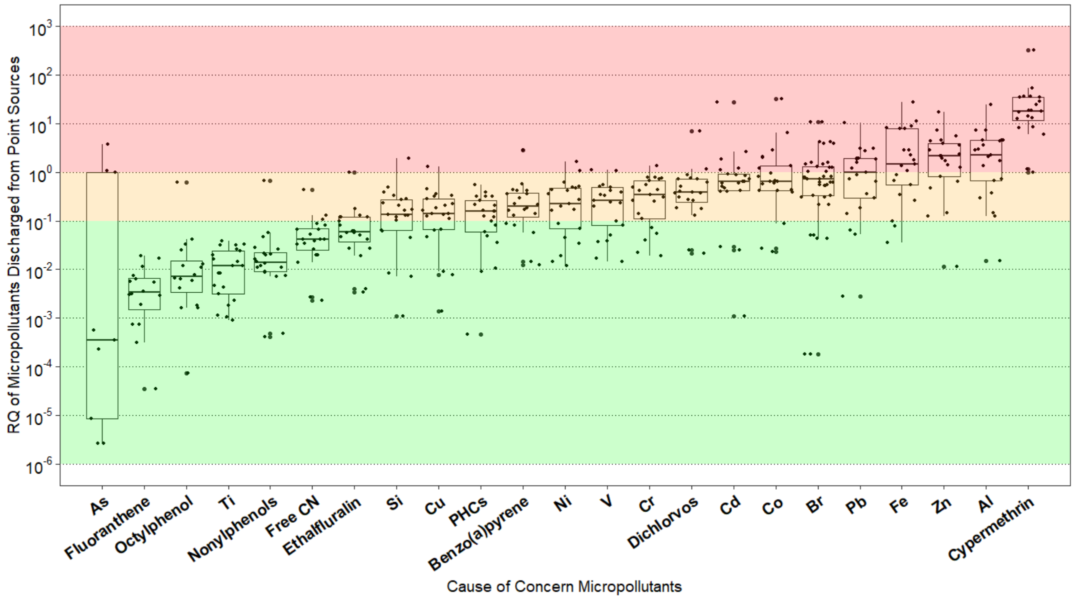


Figure 59. The RQs Estimated at Downstream of Point Sources in the YRB Sub-basin

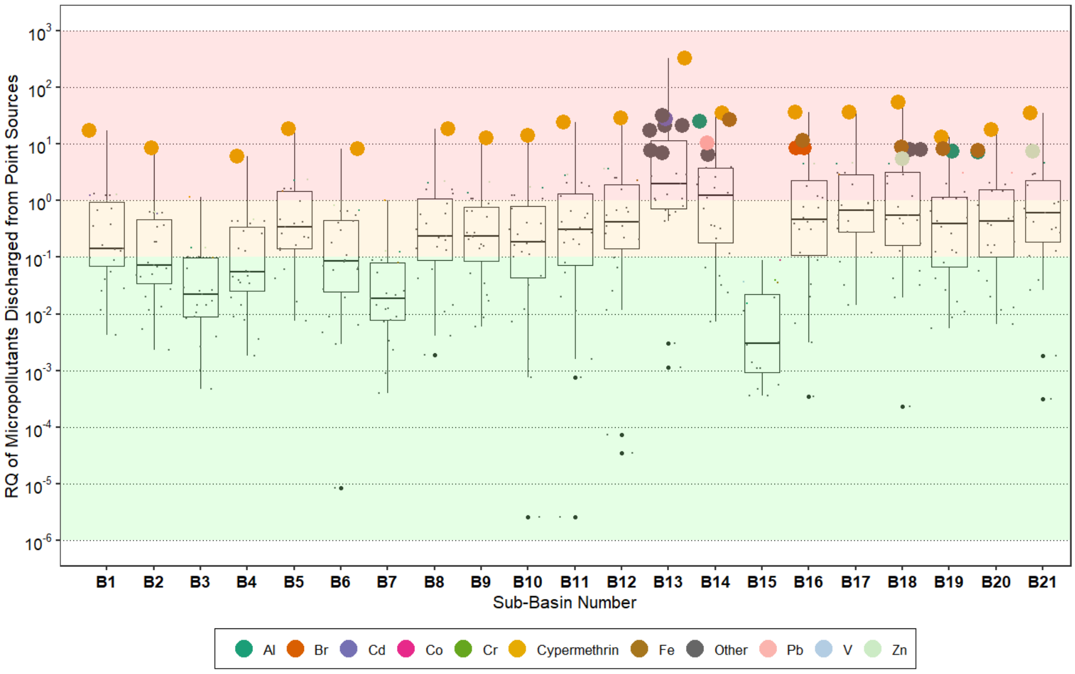


Figure 60. The RQs Estimated at Downstream of Point Sources in the YRB Sub-basin

Except for Cypermethrin, most of the micropollutants from point source effluents varied between low-risk and medium-risk. Fluoranthene and Ti are the only two micropollutants that had an RQ of less than 0.1 in all sub-basins. Al, Zn, and Fe were identified as high-risk micropollutants with median RQs between 1.45 and 2.29. As, Octylphenol, Nonylphenols, Free CN, and Ethalfluralin were identified as low-risk micropollutants from point source discharges with a median RQ of between 0.0003 and 0.06. The remaining micropollutants, Si, Cu, PHCs, Benzo(a)pyrene, Ni, V, Cr, Dichlorvos, Cd, Co, Br, and Pb were identified as medium-risk micropollutants with a median RQ between 0.13 and 0.98. However, Dichlorvos, Cd, Co, Br, and Pb showed significant signs of high-risk toxicity at some sub-basins. The variation among their concentration across sub-basins was limited except for As, which showed a significant variation across sub-basins, and had RQs ranging between 0.00002 and 3.72 (Figure 60). The median RQs of the YRB sub-basins are 0.03 and 1.63 for sub-basins 15 and 13, respectively. Similar to the surface water monitoring station risk assessment results, Cypermethrin had the highest RQ in all sub-basins except sub-basin 15, where Co had the highest RQ. Among the 21 sub-basins, only sub-basins 13 and 14 had a median RQ of greater than one and were identified as the high-risk sub-basins. Sub-basins 3, 6, 7, and 15 were identified as low-risk sub-basins with a median RQ of less than 0.08, while all RQs calculated in sub-basin 15 were less than 0.1. The remaining sub-basins were identified as medium-risk sub-basins, with median RQ values between 0.13 and 0.61 for sub-basins 1 and 17, respectively.

5.3.3 Total Risk Quotients of Micropollutants in the Yeşilırmak River

The total ecosystem RQs of the toxicity pathways in the YRB sub-basins were calculated according to the proposed methodology given in Equation-27 and the results are given in Figure 61. The highest total RQs in the YRB sub-basins are due to oxidative stress and mutagenicity. In five sub-basins, the dominant toxicity pathway was identified as mutagenicity (Sub-basins 1, 4, 5, 6, and 20), while in the remaining sub-basins, the dominant toxicity pathway was identified as oxidative stress. The total RQs were identified as high-risk (RQ > 10) in all sub-basins, where the minimum RQ was calculated as 63.6 in sub-basin 8, and the maximum RQ was calculated as 1189 in sub-basin 13.

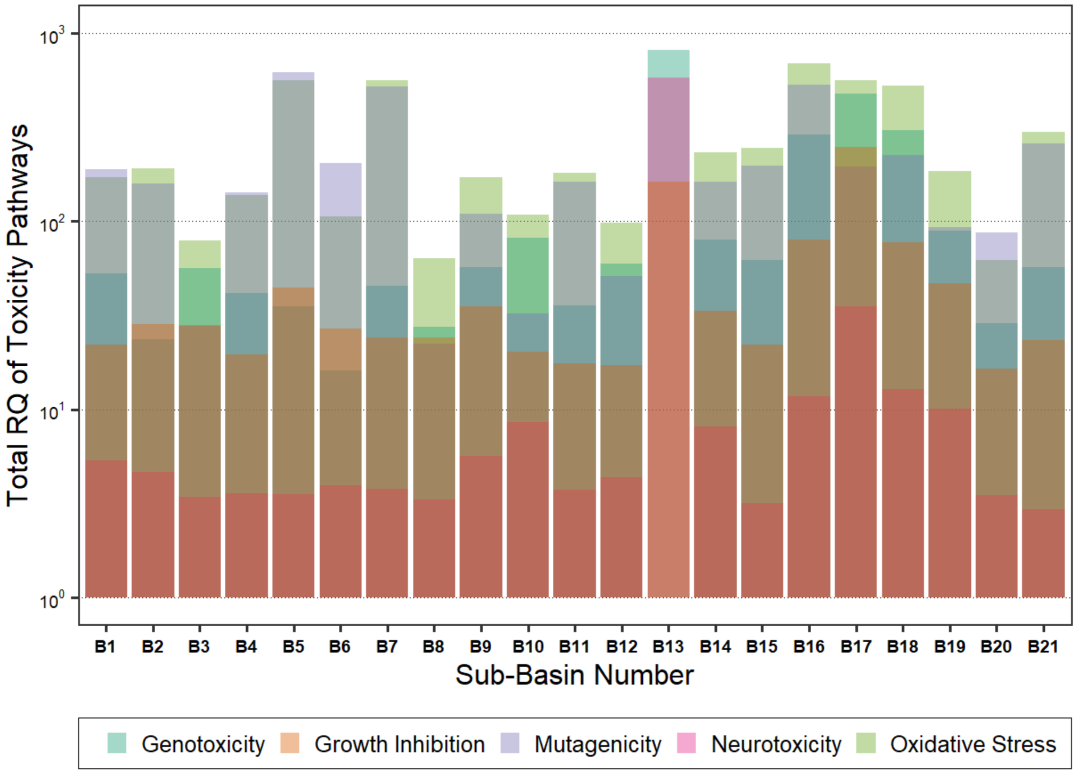


Figure 61. The Total RQ of Toxicity Pathways in the YRB Sub-basins

The most significant micropollutants contributing to the total RQ in the sub-basins are given in Figure 62. As already mentioned, the RQs of Cypermethrin, Dichlorvos, Al, Zn, and Fe are significantly higher than other micropollutants in the YRB sub-basins (Figure 57), and this was reflected in their contribution to the total RQ in sub-basins. The cumulative contribution of these five micropollutants is high enough to explain approximately 80% of the total risk in 15 sub-basins. In addition to these five pollutants, in sub-basins 8, 10, 12, 13, 14, and 17, the RQs of Br, Cr, Cu, PHCs, Pb, V, Ni, and Si also contributed to the total RQ significantly.

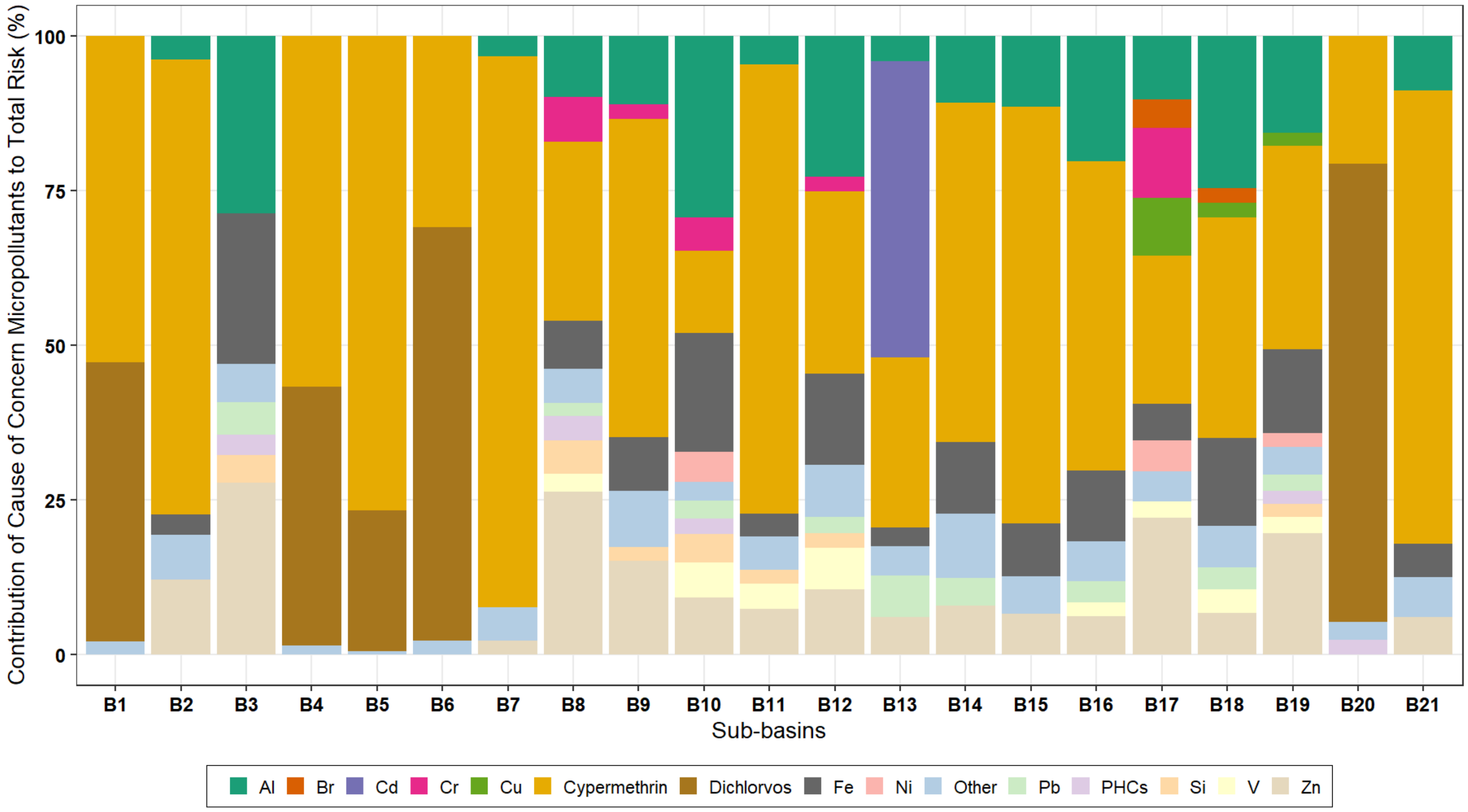


Figure 62. The Percent Contribution of Micropollutants to the Total RQ in the YRB Sub-basins

The results of the proposed RQ calculation methodology were compared to the calculation methodology given in Equation-20, where only the results of the surface water monitoring study were used to calculate the RQs. The differences between the two methods of total RQ calculation in the YRB sub-basins are given in Figure 63. The difference was less than 2% in 15 sub-basins. In sub-basins 8, 10, 12, 13, 14, and 20, the differences were 31%, 14%, 30%, 20%, 16%, and 24%, respectively. Except for sub-basin 14, Cypermethrin loads from point sources were the main reason for a significant portion of the difference. In sub-basin 14, Fe and Al loads significantly affected the total RQs. It can be evaluated that the proposed RQ calculation methodology does not have a significant change on the surface water RQ calculation methodology, since pollutants from point source effluents undergo dilution in surface waters. However, the proposed methodology could be beneficial to estimate elevated risks in the worst-case scenario.

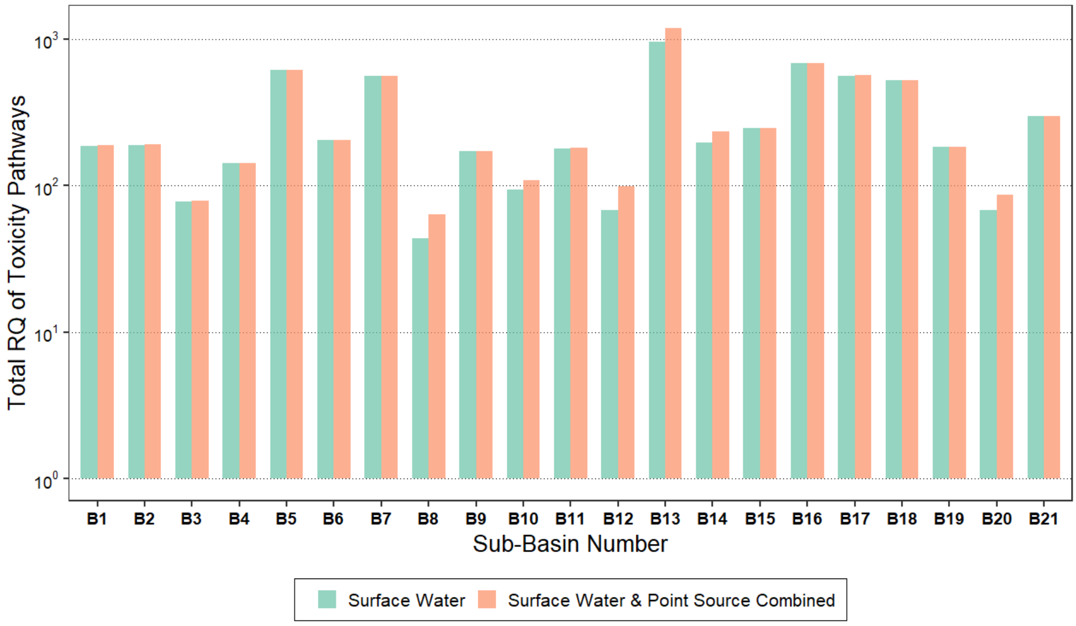


Figure 63. Comparison of Proposed RQs and Conservative RQs Calculation in the YRB Sub-basins

5.3.4 Results of the Source Apportionment in Yeşilırmak River Sub-basins

The results of the bivariate correlation analysis are provided in Appendix O - Figure A 6, with scatter plots, and the summary results are given in Table 30. Only the correlations between the concentration of pollutants and the basin characteristics were evaluated, and any relationships within these groups were neglected. For example, the correlation between population and the urban area was not investigated, since both of them are parts of basin characteristics. The only exception was the relationship between the groundwater operational area and the irrigation area, which was evaluated as a critical relationship to explain other correlations. All correlations with an R-value of greater than 0.5 were provided in Table 30, and as expected, any negative relationship was not found between basin characteristics and micropollutants. Only the results of the positive correlations with an R-value of greater than 0.5 were discussed below.

The first evaluation was made among total micropollutant concentrations and basin characteristics. Total fungicide concentration had a moderate correlation with population ($R = 0.51$, $p < 0.018$) and urban area size ($R = 0.68$, $p < 0.0006$) in the sub-basins. This relationship was not expected since fungicide usage is expected to be related to agricultural activities. The only explanation for this relationship was evaluated as an increase in usage with an increasing population, and an increased urban area due to high population. A second option was evaluated as accumulation from WWTPs. However, a relationship between wastewater amount and total fungicide concentration was not correlated. For total insecticides, a moderate correlation ($R = 0.5$, $p < 0.02$) was found with irrigation area size. Similarly, total herbicide concentration was correlated to herbicide use rate in the sub-basins ($R = 0.66$, $p < 0.0012$), while total metal concentration was correlated to urban area size ($R = 0.54$, $p < 0.11$), and agricultural area size ($R= 0.64$, $p < 0.0019$) in the sub-basins. The correlations between total insecticides and total herbicides were self-explanatory.

Table 30. The Summary Results of the Correlation Analysis

Variables	**Population**	**Urban Area (km^2)**	**Irrigation Area (km^2)**	**Herbicide Use Rate (gr/km^2)**	**Agricultural Area (km^2)**	**Industrial Area (km^2)**	**Mines & Landfill Area (km^2)**	**Wastewater (m^3/day)**	**Irrigation Area (%)**	**Agricultural Area (%)**	**Industrial Area (%)**	**Mines & Landfill Area (%)**	**Urban Area (%)**	**Groundwater Operation Area (%)**
Groundwater Operation Area (km^2)									0.6*					
Fungicides	0.51	0.68**												
Insecticides			0.5											
Herbicides				0.66*										
Metals		0.54			0.64*									
Al										0.6*	0.55			
As														0.59*
Br											0.59*		0.56*	0.65*
Cd						0.8**		0.6*	0.51		0.78**			
Co						0.54					0.56*	0.52		
Cr		0.58*	0.62*		0.54		0.54							

* p-value < 0.01; ** p-value < 0.001; the remaining correlations have a p-value <0.05

Table 30. The Summary Results of the Correlation Analysis (Continued)

Variables	**Population**	**Urban Area (km^2)**	**Irrigation Area (km^2)**	**Herbicide Use Rate (gr/km^2)**	**Agricultural Area (km^2)**	**Industrial Area (km^2)**	**Mines & Landfill Area (km^2)**	**Wastewater (m^3/day)**	**Irrigation Area (%)**	**Agricultural Area (%)**	**Industrial Area (%)**	**Mines & Landfill Area (%)**	**Urban Area (%)**	**Groundwater Operation Area (%)**
Cu												0.52		
Fe										0.61*			0.55*	
Ni						0.6	0.61							
Ti										0.79**			0.61*	
V										0.63*			0.51	0.5
Zn											0.53	0.63*		
Diflubenzuron			0.61*					0.55*						
Ethalfluralin				0.61*										
Nonylphenols													0.54	
Octylphenol										0.64*			0.58*	
Free CN										0.55			0.52	

* p-value < 0.01; ** p-value < 0.001; the remaining correlations have a p-value <0.05

The total metal correlation in agriculture was related to metal ions in plant nutrition products and PPPs, while urban sources were evaluated as surface run-off from urban areas, and diffuse pollution of traffic and combustion. An interesting relationship was observed while trying to identify which micropollutants were significant in explaining their correlations.

The main pollutant groups and the distribution of micropollutant concentrations in the YRB are provided in Figure 64. The micropollutants were shown on the x-axis, and their concentrations were log-scaled on the y-axis. Irrelevant to the micropollutant names, these results indicate that a few micropollutants significantly influence the total concentration of pollutant groups. The total concentration in two groups, industrial organic compounds and metalloids could be explained by the concentration of a single micropollutant, which are PHCs and Si, respectively.

The PHCs and Si are among the micropollutants that were identified as the cause of concern in the YRB. Ethalfluralin is the only herbicide identified as the cause of concern micropollutant and has the highest concentration among other herbicides, followed by Fluopyram and Atrazine-Desethyl. Among metals, Fe and Al had significantly higher concentrations in surface waters, and both of them were identified as the cause of concern in the YRB. The cause of concern insecticides (Hexachlorocyclohexane, Cypermethrin, Dichlorvos, and Diflubenzuron) had varying concentrations in the insecticide groups, where Diflubenzuron had the second highest median concentration among all insecticides. Finally, among herbicides, Ethalfluralin, which was identified as the cause of concern in the YRB, had the highest maximum and median concentration among other herbicides. The concentrations of the many cause of concern micropollutants were significantly higher than other micropollutants in the YRB, and their concentrations were evaluated as adequate to explain total concentration variations in the main micropollutant groups. Ethalfluralin was found to be moderately correlated with herbicide use rate in the YRB ($R = 0.61$, $p < 0.0037$). The relationship between pollutants that are the cause of concern in the YRB and land use characteristics helped identify potential sources of 16 micropollutants in addition to Ethalfluralin.

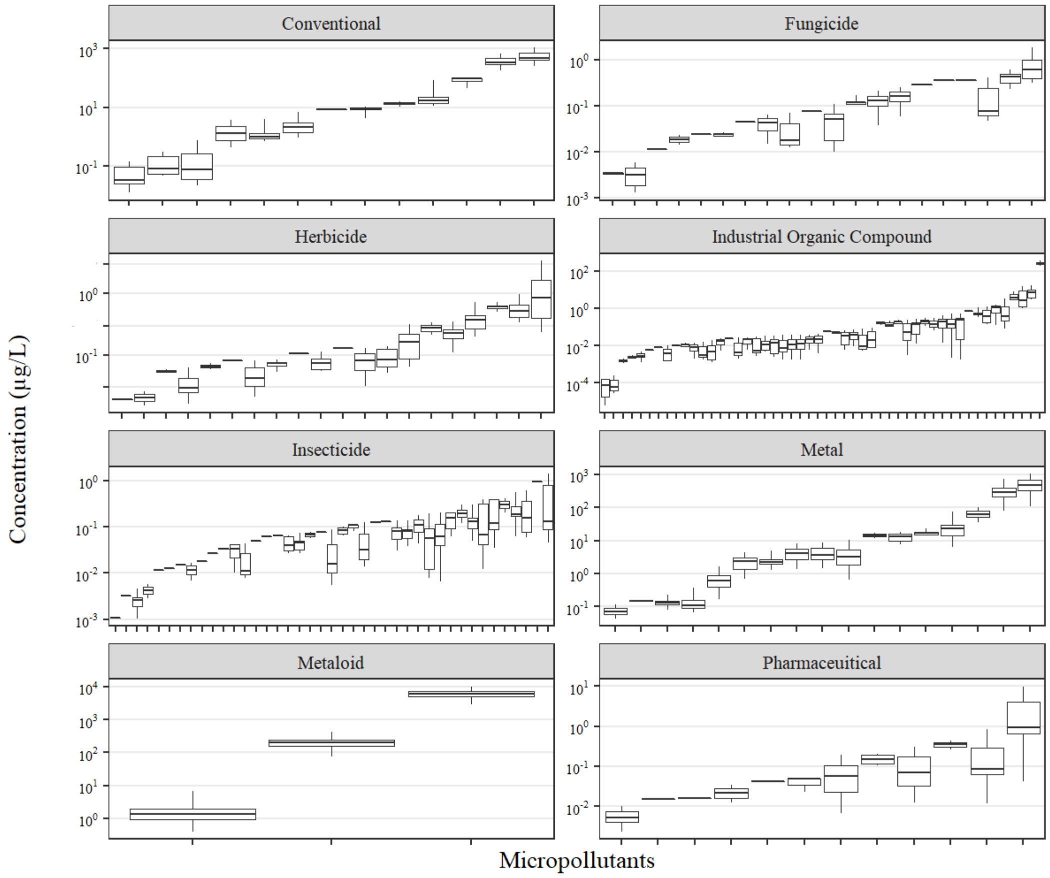


Figure 64. The Micropollutant Groups and the Distribution of Micropollutant Concentrations in the YRB

Among agricultural and agriculture-related activities and land uses, the percentage of agricultural area and its size in the sub-basins were significantly correlated to concentrations of Al ($R = 0.6$, $p < 0.042$), Cr, ($R = 0.54$, $p < 0.012$), Fe ($R = 0.61$, $p < 0.03$), Ti ($R = 0.79$, $p < 0.00002$), V ($R = 0.63$, $p < 0.0022$), Octylphenol ($R = 0.64$, $p < 0.0019$), and Free CN ($R = 0.55$, $p < 0.01$). All of these micropollutants are known to be used in PPPs. The irrigation activities in the YRB were correlated with groundwater operation area sizes ($R = 0.6$, $p < 0.041$). Irrigation return flows could carry organic and inorganic micropollutants, and irrigation was correlated with Cd ($R = 0.51$, $p < 0.018$), Cr ($R = 0.62$, $p < 0.0027$), and Diflubenzuron ($R = 0.61$, $p < 0.0032$) in the YRB sub-basins. The groundwater operation area size was also correlated with As ($R = 0.59$, $p < 0.005$), Br ($R = 0.65$, $p < 0.0015$), and V ($R = 0.5$, $p < 0.02$).

Among industrial activities, Al was correlated with the percentage of industrial area in the sub-basins ($R = 0.55$, $p < 0.011$). Both the industrial area size and its percentage in the sub-basins were correlated with Br ($R = 0.59$, $p < 0.0048$), Cd ($R = 0.8$, $p < 0.00001$), Co ($R = 0.56$, $p < 0.0077$), Ni ($R = 0.6$, $p < 0.041$), and Zn ($R = 0.53$, $p < 0.014$) concentrations in the sub-basins. The total area and ratio of mines and landfills in the YRB sub-basins were correlated with Co ($R = 0.52$, $p < 0.017$), Cr ($R = 0.54$, $p < 0.012$), Cu ($R = 0.52$, $p < 0.017$), Ni ($R = 0.61$, $p < 0.0035$), and Zn ($R = 0.63$, $p < 0.002$).

Among urban activities and land uses, the total wastewater flow rate was correlated with Cd ($R = 0.6$, $p < 0.041$), and Diflubenzuron ($R = 0.55$, $p < 0.009$) concentrations in the YRB sub-basins. Cd was also correlated with industrial activities and this may be used to justify the correlation of Cd with wastewater flow rate. However, the potential source for the correlation of Diflubenzuron with wastewater flowrate could not be identified. The size and percentage of urban area were correlated with Br ($R = 0.56$, $p < 0.008$), Cr ($R = 0.58$, $p < 0.005$), Fe ($R = 0.55$, $p < 0.009$), Ti ($R = 0.61$, $p < 0.003$), V ($R = 0.51$, $p < 0.019$), Nonylphenols ($R = 0.54$, $p < 0.012$), Octylphenols ($R = 0.58$, $p < 0.006$), and Free CN ($R = 0.52$, $p < 0.015$). The potential sources of these micropollutants were identified as industrial activities and PPCP usage.

5.3.5 Suggested Point Source Management Strategies

The proposed point source control management strategy was applied to the 20 micropollutants that are the cause of concern at the point source effluents of the YRB. These micropollutants and the sub-basins, where the estimated concentration of these pollutants exceeds the AA-EQS, are provided in Table 31. The RQs of these micropollutants in surface water samples, the predicted RQs of these micropollutants from point sources, predicted sources and suggested point source management strategies are also presented in Table 31. According to this methodology, five sub-basins require additional measures to control point source pollution in the YRB. These sub-basins were identified as sub-basins 13, 14, 16, 19, and 21.

In sub-basin 13, the predicted point source RQs of all micropollutants were medium or high (RQ > 0.1). The surface water RQs of all micropollutants were also medium or high except Benzo(a)pyrene, Ethalfluralin, Nonylphenols, and Octylphenol. These four micropollutants were evaluated as low RQ since they were not detected in any samples. Since the predicted point source RQs of Benzo(a)pyrene, Ethalfluralin, Al, Dichlorvos, Fe, Pb, Br, Cd, Co, and Zn were high (RQ > 1), they were evaluated as micropollutants that should be controlled at points source effluents and this concluded that WWTPs in sub-basin 13 should implement additional measures to control micropollutants. The results of the DF assessment (Table 25) also indicated that sub-basin 13 should be treated with caution since the effluent ratio is greater than 90% and the predicted surface water concentration of 19 micropollutants exceeded their respective AA-EQS limits.

In sub-basin 14, the predicted point source RQs, and surface water RQs of all micropollutants were medium or high (RQ > 0.1). Although the predicted point source RQs of Cr, V, Zn, and Al were medium (0.1 < RQ ≤ 1), their presence in surface waters could be explained by non-point sources, Since the predicted point source RQs of Co and Pb were high (RQ > 1), they were evaluated as micropollutants that should be controlled at points source effluents. This concluded that WWTPs in sub-basin 14 should implement additional measures to control micropollutants.

In sub-basin 16, the predicted point source RQs of all micropollutants were medium (0.1 < RQ ≤ 1). Since the surface water RQs of these micropollutants were high (RQ > 1), the predicted sources were evaluated. Although the predicted point source RQs of Br, Zn, and Fe were medium (0.1 < RQ ≤ 1), and their presence in surface waters could be explained by non-point sources, since industrial activities are predicted sources of Al and Co, WWTPs in sub-basin 16 should implement additional measures to control micropollutants.

Table 31. The Micropollutants Exceeding the AA-EQS Limit in the YRB Sub-Basins According to DF Assessment, Risk Assessment Results, Predicted Sources, and Suggested Management Strategies

Sub-basins	**Pollutants**	**Surface Water Quality RQ**	**Predicted Point Source RQ**	**Predicted Source**	**Management Strategy**
1	Zn	Very High	Medium	Mining	DF$_{10}$
	Si	High	Low		
2	Zn	Very High	Medium	Mining	DF$_{10}$
4	Zn	Very High	Low	Mining	DF$_{10}$
5	Zn	Very High	Medium	Mining	DF$_{10}$
8	Zn	Very High	Medium	Mining	DF$_{10}$
9	Zn	Very High	Medium	Mining	DF$_{10}$
10	Zn	High	Medium	Mining	DF$_{10}$
	Si	High	Low		
11	Zn	Very High	Medium	Mining	DF$_{10}$
	Si	High	Low		
12	Pb	High	Low		DF$_{10}$
	Al	Very High	Low	Agriculture & Possibly Industrial	
	Fe	Very High	Low	Agriculture	
	Zn	Very High	Medium	Mining	
	Cd	-	Low	Industrial & Possibly Irrigation	
	Co	High	Low	Industrial & Mining Activities	
	PHCs	High	Low		
	Si	High	Medium		
	Dichlorvos	Very High	Low		
13	Benzo(a)pyrene	-	High		Improvements in WWTPs
13	Ethalfluralin	-	High	Herbicide Usage & Agriculture	
13	Cu	High	Medium	Mining	
13	Ni	High	Medium	Industrial & Mining Activities	
13	Si	High	High		

Table 31. The Micropollutants Exceeding the AA-EQS Limit in the YRB Sub-Basins According to DF Assessment, Risk Assessment Results, Predicted Sources, and Suggested Management Strategies (Continued)

Sub-basins	Pollutants	Surface Water Quality RQ	Predicted Point Source RQ	Predicted Source	Management Strategy
13	V	High	Medium	Agriculture & Possibly Groundwater Use	Improvements in WWTPs
13	Al	Very High	High	Agriculture & Possibly Industrial	
13	Dichlorvos	Very High	High		
13	Fe	Very High	High	Agriculture	
13	Pb	Very High	High		
13	Nonylphenols	-	Medium	Urban Activities	
13	Octylphenol	-	Medium	Agriculture	
13	PHCs	High	Medium		
13	Cr	High	Medium	Irrigation & Mining	
13	Free CN	Medium	Medium	Agriculture & Urban Run-off	
13	Br	Very High	High	Groundwater / Possibly Agriculture	
13	Cd	Very High	High	Industrial & Possibly Irrigation	
13	Co	Very High	High	Industrial & Mining Activities	
13	Zn	Very High	High	Mining	
14	Co	High	High	Industrial & Mining Activities	Improvements in WWTPs
14	Cr	High	Medium	Irrigation & Mining	
14	V	High	Medium	Agriculture & Possibly Groundwater Use	
14	Zn	Very High	Medium	Mining	
14	Pb	High	High		
14	Al	Very High	Medium	Agriculture & Possibly Industrial	

Table 31. The Micropollutants Exceeding the AA-EQS Limit in the YRB Sub-Basins According to DF Assessment, Risk Assessment Results, Predicted Sources, and Suggested Management Strategies (Continued)

Sub-basins	**Pollutants**	**Surface Water Quality RQ**	**Predicted Point Source RQ**	**Predicted Source**	**Management Strategy**
16	Br	High	Medium	Groundwater / Possibly Agriculture	Improvements in WWTPs
16	Al	Very High	Medium	Agriculture & Possibly Industrial	
16	Co	Very High	Medium	Industrial & Mining Activities	
16	Zn	Very High	Medium	Mining	
16	Si	Very High	Medium		
16	Fe	Very High	Medium	Agriculture	
17	Zn	Very High	Medium	Mining	DF$_{10}$
18	Al	Very High	Medium	Agriculture & Possibly Industrial	DF$_{10}$
18	Br	Very High	Medium	Groundwater / Possibly Agriculture	
18	Fe	Very High	Medium	Agriculture	
18	Zn	Very High	Medium	Mining	
18	Si	High	Medium		
19	Pb	High	Medium		Improvements in WWTPs
20	Pb	Medium	Medium		DF$_{10}$
21	Al	Very High	Medium	Agriculture & Possibly Industrial	Improvements in WWTPs
21	Fe	Very High	Medium	Agriculture	
21	Zn	Very High	Medium	Mining	
21	Co	High	Medium	Industrial & Mining Activities	
21	Si	High	Medium		
21	Cd	Medium	Medium	Industrial & Possibly Irrigation	

Similarly, due to the presence of Al, Co, and Cd in sub-basin 21 surface water with high RQs ($RQ > 1$), and since their predicted sources are industrial activities, WWTPs in sub-basin 21 should implement additional measures to control micropollutants.

In sub-basin 19, the only micropollutant that exceeds the AA-EQS was evaluated as Pb. The predicted point source RQ, and surface water RQ of Pb were medium ($0.1 < RQ \leq 1$) and high ($RQ > 0.1$), respectively. Since any other source than the WWTPs could not be identified for its presence in surface waters, WWTPs in sub-basin 19 should implement additional measures to control micropollutants. Five sub-basins, which require additional measures to control point source pollution in the YRB, are given in Figure 65.

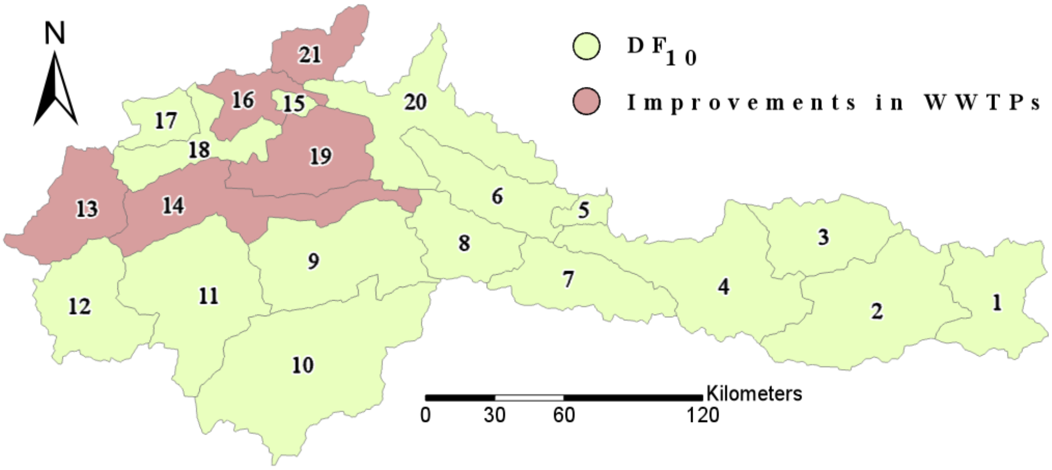


Figure 65. Sub-basins that Require Additional Measures to Control Point Source Pollution in the YRB

5.4 Conclusion

In this chapter, a risk assessment methodology was developed by combining surface water and point source risk assessment methodologies suggested by the EU WFD methodology (2000/60/EC). The RQs were calculated for the 25 micropollutants that were identified as the cause of concern in the YRB. The results indicated that for all the pollutants, risks caused by these pollutants in surface waters were medium-risk and high-risk for all sub-basins. The risks posed by all point sources in the YRB sub-basins were medium with minor exceptions. The micropollutants, Cypermethrin, Dichlorvos, Al, Zn, and Fe were found to be responsible for the risk in 15 sub-basins with a share of at least 80% of the total risk. This finding indicated that these pollutants must be controlled to reach good chemical status in surface waters.

A source apportionment study was carried out with a bivariate correlation analysis between micropollutant concentrations and basin characteristics in the YRB. The results highlighted the possible relationship between the concentration of PPPs and metals and the sub-basin characteristics such as the amount of PPP usage and the size of industrial areas.

The bivariate correlation analysis showed that the total concentration of main micropollutant groups (fungicides, herbicides, industrial organic compounds, insecticides, metals, metalloids, pharmaceuticals) could be represented by the concentration of selected few indicator micropollutants in each group. A significant portion of these pollutants was identified as pollutants that are the cause of concern in the YRB. It is suggested that by monitoring only this small group, it is possible to have an idea of total micropollutant concentrations in the YRB.

Basin characteristics correlated moderately with the concentrations of 17 micropollutants that are the cause of concern in the YRB. The sources of these micropollutants were predicted using the correlation between the basin characteristics and micropollutant concentrations. This information was combined with the results of the risk assessment to propose a point source management strategy in the YRB. By following the proposed methodology, five sub-basins were identified as high-risk regions, which require additional measures to control point source pollution in the YRB.

CHAPTER 6

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The EU WFD (2000/60/EC) and its transposition into the Turkish national legislation; the SWQR (Official Gazette No: 29797, Date: August 10, 2016) requires the micropollutants to be monitored and controlled to reach good chemical status in aquatic environments to establish mitigation and management strategies accordingly. In accordance with the SWQR, the occurrence of 45 priority substances and 250 river basin specific pollutants is to be controlled in surface and transitional waters.

The present study assessed the results of a two-year monitoring campaign covering major point source effluents and surface waters in the YRB including 45 priority substances and 250 river basin specific pollutants. The significance of all the micropollutants was evaluated based on their occurrence and concentration in the YRB surface waters, and adopting a screening approach the cause of concern micropollutants were identified to develop a cost-effective water quality monitoring program. It is believed that the screening approach developed could be established in other river basins for developing cost-effective water quality monitoring.

To develop a point source control strategy for reaching the target EQSs of the micropollutants, a DF-based control strategy was developed and the applicability of implementing a fixed DF of ten at point source effluents was tested. The fixed DF strategy was not found to be adequate to achieve “good surface water chemical status” in the YRB. Instead, it was found appropriate to use DF based on the flow of each point source and the river flow at the discharge point. When the use of MF and MLF for the evaluation of DFs for each point source was compared, it appeared that the most conservative approach should be the use of the MLF condition.

The relationship between stream flow rates and effluent flow rates was investigated by correlation analysis. The results revealed that high-capacity WWTPS had been built on relatively small streams in the YRB, therefore the effluents cannot undergo sufficient dilution after mixing with the surface waters, and this causes derogation in the surface water quality. The stream flow rates must be evaluated during the planning of WWTPs to reduce pressures on the aquatic ecosystem.

The ecotoxicological risks associated with the pollutants that are the cause of concern in the YRB were evaluated by developing a risk assessment methodology that combines surface water and point source risk assessment methodologies suggested by the EU WFD methodology (2000/60/EC). The risks caused by these pollutants in surface waters were medium or high-risk for all sub-basins, while the risks caused by point sources were medium with minor exceptions. The RQs of five micropollutants were significant enough to explain at least 80% of the variation in the total risk in 15 sub-basins. The control of these pollutants must be provided to reach good chemical status in surface waters.

A bivariate correlation analysis was conducted to reveal relationships between micropollutant concentrations and basin characteristics in the YRB. The amount of PPP usage and the size of industrial areas were highlighted as possible sources of PPPs and metals in the YRB. Selected few indicator micropollutants could be used to represent the total micropollutant concentration in the YRB, and by monitoring only this small group of micropollutants, it is possible to have an idea of total micropollutant concentrations in the YRB.

The concentrations of 17 micropollutants that are the cause of concern in the YRB correlated moderately with basin characteristics. This information was interpreted together with the results of the risk assessment to propose a point source management strategy. By following the proposed methodology, five sub-basins were identified as high-risk regions, which require additional measures to control point source pollution in the YRB.

As for the limitations of the current study, other than the methodological limitations discussed in Chapter 2 and Chapter 4, the development of a monitoring methodology and point source control strategy requires a substantial amount of data for an extended period. In addition to the quantity of available data, the quality and consistency of the measurements are essential parts of the management strategy. Additional monitoring studies and detailed flow measurements from the effluent locations are necessary to evaluate the findings in this study more accurately. The main findings discussed in Chapter 4 showed that there are significant knowledge gaps, which prevent the identification of sources and substance flow of micropollutants in the surface waters. The basin characteristics were estimated using CLC-2018 data and provincial PPPs usage data. This information could be refined by using local data to improve the quality of the bivariate analysis.

Due to these limitations, the studies mentioned below could not be carried out within the scope of this study and are referred to as recommendations for future studies:

- A routine point source monitoring in the YRB should be carried out with a sampling strategy to identify upstream pressures and downstream effects.
- Diffuse sources have a significant contribution to surface water pollution in the YRB. The source and extent of this pollution should be evaluated.
- High metal pollution throughout the YRB indicates signs of natural contamination however; the background concentrations evaluations could only be related to Al, Cu and Fe. Detailed studies regarding metal pollution in the YRB should be carried out.
- The ecotoxicological data of pollutants that are the cause of concern in the YRB should be studied to derive EQS specific to the river basin pollutants.

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APPENDICES

A. Treated and Untreated Point Sources

Table A 1. Point Source Discharges in the YRB

Facility	**Explanation**	**Wastewater Discharge (m^3/day)**	**Treatment Capacity (m^3/day)**	**East**	**North**	**Deep Sea Discharge**
Susa İçecek Sanayi ve Ticaret	Beverage Industry	0.002	0.002	40.444669	37.095253	
Bensu Kaynak Suları Eğitim Mataryelleri Hayvancılık Su Ürünleri Ticaret ve Sanayi	Beverage Industry	0.01	0.01	40.16905	36.66713	
Niksar Kaya Su Doğal Kaynak Suyu Üretim ve Dağıtım Sanayi ve Ticaret	Beverage Industry	0.01	0.01	40.491528	36.937663	
Murat Pazarlama Dağıtım Ticaret ve Sanayi	Beverage Industry	7.9	7.9	40.029142	38.020947	
Doğa Su Gıda Maddeleri San Tıc (Akdağ Su Fabrikası)	Beverage Industry	36.0	50.0	40.891239	36.056546	
Yuva Viyol ve Ambalaj Sanayi ve Ticaret Ltd.Şti.	Cellulose and Paper Industry	43.0	250.0	40.598362	34.912637	
Hayat Kağıt ve Enerji Sanayi Ticaret	Cellulose and Paper Industry	850.0	850.0	40.513673	34.914813	
SD Sarel Plastik Ve Ambalaj Geri Dönüşüm Mobilya Sanayi ve Ticaret	Chemical Industry	0.6	0.6	39.652178	35.869021	
Toros Tarım Sanayi ve Ticaret (Samsun Şubesi)	Chemical Industry	300.0	300.0	41.237966	36.457014	Yes
Gürmin Enerji Madencilik Sanayi ve Ticaret	Coal Preparation, Processing, and Energy Production Industry	37.0	37.0	40.876298	35.623668	
Bim Birleşik Mağazalar A.Ş.	Domestic Wastewater	1.5	5.0	40.46344	34.866413	
Şirinler Kuruyemiş Tarım, Gıda, Hayvancılık Yemekçilik Temizlik Hizmetleri İlaçlama , İnşaat Petrol Turizm İthalat İhracat ve Pazarlama Sanayi ve Ticaret	Domestic Wastewater	8.5	8.5	40.161881	34.846385	
Devlet Hava Meydanları İşletmesi Genel Müdürlüğü	Domestic Wastewater	20.0	20.0	40.823776	35.50095	
Fırat Elektrik Üretim ve Ticaret Anonim Şirketi	Domestic Wastewater	27.0	30.0	40.41322	37.227556	
Emmioğlu Mermer Madencilik İnşaat Taahhüt İnşaat Malzemeleri Mühendislik Akaryakıt Petrol Ürünleri Turizm İmalat İthalat İhracat Ticaret ve Sanayi Anonim Şirketi	Domestic Wastewater	29.0	40.0	40.442898	35.754018	
Botaş Boru Hatları ile Petrol Taşıma A.Ş.	Domestic Wastewater	30.0	30.0	41.359825	36.710132	
Doğuş YDA Adi Ortaklığı Tokat - Niksar Yolu Ana Şantiyesi	Domestic Wastewater	30.0	60.0	40.38916	36.696837	

Table A 1. Point Source Discharges in the YRB (Continued)

Facility	**Explanation**	**Wastewater Discharge (m^3/day)**	**Treatment Capacity (m^3/day)**	**East**	**North**	**Deep Sea Discharge**
Kavçim Çimento Sanayi ve Ticaret Anonim Şirketi	Domestic Wastewater	30.0	30.0	41.028167	36.100655	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Hamamayağı (Ladik) Paket AAT	Domestic Wastewater	100.0	100.0	40.97705	35.787653	
Havza Yurt Müdürlüğü Atıksu Arıtma Tesisi	Domestic Wastewater	150.0	150.0	40.989623	35.71007	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Çakmak AAT	Domestic Wastewater	194.0	255.0	41.116615	36.612443	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Dikbıyık AAT	Domestic Wastewater	200.0	600.0	41.216201	36.60909	
Çorum Mecitözü Kentsel AAT	Domestic Wastewater	360.0	725.0	40.5283	35.303919	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Asarcık AAT	Domestic Wastewater	422.0	600.0	41.02779	36.232753	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Ayvacık AAT	Domestic Wastewater	427.0	500.0	41.010762	36.627555	
Yozgat Aydıncık Kentsel AAT	Domestic Wastewater	450.0	450.0	40.152908	35.278904	
Samsun Büyükşehir Belediyesi Saski Genel Müdürlüğü Terme Sakarlı Paket AAT	Domestic Wastewater	600.0	600.0	41.144034	37.069773	
Ladik Akdağ Yatırım Turizm İnşaat Sanayi ve Ticaret A.Ş.	Domestic Wastewater	864.0	864.0	40.970908	35.785805	
Gümüşhane Köse Kentsel AAT	Domestic Wastewater	900.0	900.0	40.178792	39.658273	
Samsun Büyükşehir Belediyesi Saski Genel Müdürlüğü Terme Evci AAT	Domestic Wastewater	970.0	1,000.0	41.168571	37.040803	
Erzincan Refahiye Kentesel AAT	Domestic Wastewater	1,000.0	1,000.0	39.911684	38.765263	
Tokat Almus Kentsel AAT	Domestic Wastewater	1,000.0	1,000.0	40.38655	36.91272	
Gümüşhane Şiran Belediye Başkanlığı Kentsel AAT	Domestic Wastewater	2,230.0	2,535.6	40.174119	39.104639	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Havza AAT	Domestic Wastewater	3,555.1	3,555.1	40.94719	35.656358	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Terme Merkez AAT	Domestic Wastewater	7,750.0	8,878.0	41.216619	37.022028	Yes
Merzifon Belediyesi AAT	Domestic Wastewater	8,952.0	9,000.0	40.847222	35.477179	
Gümüşhane Kelkit Kentsel AAT	Domestic Wastewater	10,000.0	10,000.0	40.13885	39.421838	
Sivas Suşehri Kentsel AAT	Domestic Wastewater	10,000.0	10,000.0	40.191142	38.076865	
Tokat Erbaa Kentsel AAT	Domestic Wastewater	10,500.0	15,000.0	40.705234	36.554954	

Table A 1. Point Source Discharges in the YRB (Continued)

Facility	**Explanation**	**Wastewater Discharge (m^3/day)**	**Treatment Capacity (m^3/day)**	**East**	**North**	**Deep Sea Discharge**
Amasya Kentsel (Merkez) AAT	Domestic Wastewater	11,500.0	10,000.0	40.68022	35.880202	
Tokat Kentsel AAT	Domestic Wastewater	25,872.0	43,440.0	40.336397	36.473803	
Çorum Belediyesi (Merkez) AAT	Domestic Wastewater	60,000.0	64,800.0	40.48356	34.91397	
Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Samsun Doğu İleri Biyolojik AAT ve Derin Deniz Desarjı Faaliyeti	Domestic Wastewater	105,000.0	105,000.0	41.243879	36.429403	Yes
Tokat Zile Kentsel AAT	Domestic Wastewater	4,100	5,064	40.279091	35.910783	
Yozgat Saraykent Kentsel AAT	Domestic Wastewater	-	-	39.710206	35.511631	
Nebioğulları Geri Dönüşüm Et Ürünleri Gıda Tarım Hayvancılık İnşaat Nakliye Turizm Temizlik Sanayi Ve Ticaret	Food Industry	3.9	3.9	40.897938	35.634281	
Saray Petrol Turizm Gıda San.Tic.Ltd Şti.	Food Industry	5.0	20.0	40.436233	34.993022	
Olca Gıda ve Plastik Sanayi ve Ticaret	Food Industry	5.7	5.7	40.578095	36.913257	
Şebin Süt Ürünleri Gıda Hayvancılık İnşaat Sanayi ve Ticaret	Food Industry	6.8	6.8	40.304259	38.438546	
Ysm Süt ve Süt Ürünleri İmalat Gıda Yem Pazarlama San.Tic	Food Industry	8.3	8.3	41.147623	37.045114	
Özkaleli Gıda Üretim ve Petrol Ürünleri Pazarlama Sanayi ve Ticaret	Food Industry	8.6	8.6	40.288017	35.86689	
Hamza Alaş - Öz Niksar Gıda	Food Industry	11.9	11.9	40.579059	36.914047	
Olca Gıda Sanayi ve Ticaret	Food Industry	18.5	18.5	40.578095	36.913257	
Kozlu Gıda	Food Industry	24.0	48.0	40.665801	35.833049	
Oğuzlar Gıda Sanayi Pazarlama Ticaret Ltd. Şti.	Food Industry	25.0	25.0	41.11817	36.562013	
Güneş Fındık Tarım Ürünleri Ticaret Ve Sanayi Ltd.Şti.	Food Industry	27.2	27.2	41.206669	36.972408	
Karaçuha Tarım Ürünleri İthalat-İhracat Sanayi Ve Ticaret	Food Industry	27.2	27.2	41.212866	36.947851	
Elif Fındık Sanayi ve Ticaret	Food Industry	27.3	27.3	41.212665	36.951462	
S.S Yurtbaşi-Olgunlar-Ekecik-Ulucak Köyleri Tarımsal Kalkınma	Food Industry	29.1	29.1	39.918205	38.922885	
Yemsel Tavukçuluk	Food Industry	36.0	800.0	41.057673	36.093439	
Tatküpü Gıda Maddeleri Pazarlama Sanayi ve Ticaret	Food Industry	39.9	39.9	40.766323	35.708701	
Kalaycıoğlu Gıda Pazarlama Sanayi ve Ticaret	Food Industry	45.0	45.0	40.521316	34.914421	
Önder Aksoy Dua Et Besicilik Suluova Şubesi	Food Industry	45.0	45.0	40.740265	35.758326	

Table A 1. Point Source Discharges in the YRB (Continued)

Facility	**Explanation**	**Wastewater Discharge (m^3/day)**	**Treatment Capacity (m^3/day)**	**East**	**North**	**Deep Sea Discharge**
Seferağa Süt Ve Gıda Mamülleri Suluova Şubesi Sanayi Ticaret	Food Industry	50.0	50.0	40.859939	35.615607	
Zeki Kuloğlu- Kuloğlu Süt Mamülleri	Food Industry	60.0	60.0	40.591518	35.803286	
Aydınoğlu Un Gıda San Tıc As	Food Industry	120.0	240.0	40.980926	35.688479	
Et-Bir Suluova Kesimhane	Food Industry	120.0	240.0	40.823488	35.621773	
Kardez Su Ürünleri Sanayı Tıc Ltd Stı	Food Industry	130.0	130.0	41.170622	36.709714	
Niksar Bereket Süt Ürünleri Gıda Sanayi ve Ticaret Limited Şirketi	Food Industry	196.0	196.0	40.579715	36.914263	
Bakraç Süt Ürünleri	Food Industry	216.0	360.0	40.734291	35.770702	
Meray Yağ San ve Tic A.Ş.	Food Industry	240.0	650.0	40.861293	35.43173	
Dimes Tokat Taşlıçiftlik	Food Industry	360.0	600.0	40.329993	36.456141	
Ekur Et Entegre San. ve Tic. A.Ş.	Food Industry	600.0	800.0	40.786449	35.658248	
Otat Gıda Süt Ürünleri	Food Industry	1,150.0	1,680.0	40.974846	35.687107	
Amasya Şeker Fabrikaları A.Ş.	Food Industry	2,600.0	7,680.0	40.831988	35.643451	
Türkiye Şeker Fabrikaları A.Ş. (Turhal)	Food Industry	4,560.0	5,500.0	40.39866	36.085839	
Çorum Şeker Fabrikaları A.Ş.	Food Industry	4,800.0	4,800.0	40.478694	34.894551	
Türkiye Şeker Fabrikaları A.Ş. (Çarşamba)	Food Industry	4,800.0	4,800.0	41.174899	36.706514	
Mehmet Karaca: Tarım Makinaları	Metal Industry	0.5	0.5	40.115043	36.309404	
5 İnci Ana Jet Üs Komutanlığı	Metal Industry	20.0	20.0	40.83525	35.515873	
Terme Metal Sanayi ve Ticaret	Metal Industry	75.0	75.0	41.166301	37.054284	Yes
Eti Bakır Anonim Şirketi	Metal Industry	1,680.0	3,120.0	41.243073	36.456695	Yes
Özdemir Antimuan Madenleri A.Ş. Turhal Şb	Mining Industry	1,200.0	3,000.0	40.424244	36.110851	
Yeşilyurt Demir Çelik Endüstrisi ve Liman İşletmeleri Limited Şirketi	Mixed Industrial Wastewater	45.0	150.0	41.245978	36.444133	Yes
Kavak OSB	Mixed Industrial Wastewater	289.4	289.4	41.088157	36.048223	
Erbaa OSB	Mixed Industrial Wastewater	423.4	423.4	40.707004	36.558708	
Merzifon OSB	Mixed Industrial Wastewater	480.0	480.0	40.84691	35.477664	
Samsun Tekkeköy (Merkez) OSB	Mixed Industrial Wastewater	2,160.0	2,160.0	41.244115	36.428925	Yes
Altınbaş Petrol ve Ticaret A.Ş Samsun Şubesi	Oil Industry	4.0	4.0	41.249054	36.403274	Yes
Aygaz Samsun Dolum Tesisi	Oil Industry	20.0	20.0	41.243145	36.413808	Yes
Lesaffre Turquie Mayacılık Üretim ve Ticaret Anonim Şirketi (Özmaya)	Other Industrial Wastewaters (Cooling)	1,080.0	2,000.0	40.685537	35.904947	

Table A 1. Point Source Discharges in the YRB (Continued)

Facility	**Explanation**	**Wastewater Discharge (m^3/day)**	**Treatment Capacity (m^3/day)**	**East**	**North**	**Deep Sea Discharge**
Olmuksan International Paper Ambalaj Sanayi ve Ticaret Anonim Şirketi	Specific Industry Set by Ministry	480.0	770.0	40.524652	34.911817	
Akdağsan Gıda Tekstil Tarım Ürünleri Petrol Ticaret ve Sanayi	Textile Industry	1.9	1.9	39.652183	35.868509	
Onur Sentetik Tekstil Plastik Gıda Tarım Ürünleri Petrol Sanayi ve Ticaret	Textile Industry	8.4	8.4	39.655051	35.815811	
Beşgöz Karoser Otomotiv Sanayi ve Ticaret	Vehicle Manufacturing and Repair Industry	1.8	1.8	40.749693	35.73851	
Kastamonu Entegre Ağaç Sanayi ve Tic. Anonim Şirketi	Wood Products and Furniture Industry	40.0	50.0	41.142761	37.144686	

Table A 2. Untreated Point Source Discharges in the YRB

City	**District**	**Population**	**East**	**North**	**Domestic Wastewater (m^3/day)**	**Industrial Wastewater (m^3/day)**	**Total (m^3/day)**
Amasya	Damlaçimen	1,155	40.35420	35.43940	218.3		218.3
Amasya	Gediksaray	798	40.44639	35.62765	150.8		150.8
Amasya	Göynücek	2,525	40.39551	35.53342	477.2		477.2
Amasya	Gümüşhacıköy	14,028	40.86595	35.22928	2651.3	77.7	2729.0
Amasya	Aydınca	618	40.57387	36.13487	116.8		116.8
Amasya	Doğantepe	1,176	40.58720	35.60626	222.3		222.3
Amasya	Ezinepazar	1,702	40.56531	36.04790	321.7		321.7
Amasya	Uygur	954	40.55638	35.98255	180.3		180.3
Amasya	Yassıçal	1,142	40.65309	35.94915	215.8		215.8
Amasya	Yeşilyenice	1,304	40.69906	35.95287	246.5		246.5
Amasya	Ziyaret	3,675	40.67739	35.87217	694.6	2.4	697.0
Amasya	Kayadüzü	1,605	40.89020	35.59787	303.3		303.3
Amasya	Eraslan	1,098	40.72506	35.61256	207.5		207.5
Amasya	Suluova	37,155	40.82267	35.62095	7022.3	13.2	7035.5
Amasya	Akınoğlu	1,481	40.71564	36.20384	279.9		279.9
Amasya	Alpaslan	1,309	40.79503	36.34659	247.4		247.4
Amasya	Ballıdere	1,023	40.69145	36.27890	193.3		193.3
Amasya	Belevi	848	40.69614	36.21981	160.3		160.3
Amasya	Boraboy	824	40.81192	36.19545	155.7		155.7
Amasya	Destek	1,149	40.84423	36.18142	217.2		217.2
Amasya	Esençay	2,010	40.67206	36.38731	379.9		379.9
Amasya	Özbaraklı	1,095	40.69142	36.11209	207.0		207.0
Amasya	Taşova	9,722	40.76359	36.34567	1837.5	28.4	1865.9
Amasya	Uluköy	1,580	40.79353	36.40723	298.6		298.6
Çorum	Alaca	21,113	40.18287	34.86773	3990.4	0.9	3991.3
Çorum	Çopraşık	744	40.18078	35.07534	140.6		140.6
Çorum	Elvançelebi	444	40.56992	35.16210	83.9		83.9
Çorum	Mecitözü	4,900	40.52881	35.30665	926.1		926.1
Çorum	Düvenci	1,991	40.65737	35.16562	376.3		376.3
Çorum	Konaklı	1,035	40.63237	35.21837	195.6		195.6
Çorum	Seydim	862	40.54867	34.75056	162.9		162.9
Çorum	Aştavul	2,104	40.29912	35.29962	397.7		397.7
Çorum	Karahacip	1,908	40.25717	35.17345	360.6		360.6
Çorum	Ortaköy	2,320	40.27345	35.26642	438.5		438.5
Giresun	Alucra	4,250	40.32925	38.75817	803.3		803.3
Giresun	Yenice	858	40.09347	38.87949	162.2		162.2

Table A 2. Untreated Point Source Discharges in the YRB (Continued)

City	**District**	**Population**	**East**	**North**	**Domestic Wastewater (m^3/day)**	**Industrial Wastewater (m^3/day)**	**Total (m^3/day)**
Giresun	Şebinkarahisar	12,174	40.29059	38.43823	2300.9	3.3	2304.2
Gümüşhane	Deredolu	2,265	40.04128	39.52520	428.1		428.1
Gümüşhane	Gümüşgöze	2,237	40.17175	39.39320	422.8		422.8
Gümüşhane	Kaş	1,722	40.13042	39.51795	325.5		325.5
Gümüşhane	Öbektaş	2,915	40.14381	39.60556	550.9		550.9
Gümüşhane	Söğütlü	2,080	40.09745	39.24901	393.1		393.1
Gümüşhane	Ünlüpınar	2,385	40.21114	39.43148	450.8		450.8
Gümüşhane	Köse	3,481	40.19539	39.65870	657.9		657.9
Gümüşhane	Yeşilbük	1,768	40.21367	38.99298	334.2		334.2
Ordu	Akkuş	7,073	40.79298	37.01165	1336.8		1336.8
Ordu	Akpınar	2,644	40.88294	36.87272	499.7		499.7
Ordu	Salman	3,850	40.86989	36.82067	727.7		727.7
Ordu	Seferli	2,107	40.82571	36.82321	398.2		398.2
Samsun	Asarcık	2,435	41.03337	36.26141	460.2		460.2
Samsun	Ayvacık	6,107	41.01072	36.62771	1154.2		1154.2
Samsun	Ağcagüney	1,961	41.12797	36.61137	370.6		370.6
Samsun	Bafracalı	609	41.22573	36.73831	115.1		115.1
Samsun	Cumhuriyet	3,466	41.20497	36.68630	655.1		655.1
Samsun	Çarşamba	65,385	41.21922	36.72787	12357.8	190.1	12547.9
Samsun	Dikbıyık	2,177	41.22178	36.61246	411.5		411.5
Samsun	Hürriyet	1,643	41.34724	36.65492	310.5		310.5
Samsun	Kavak	8,924	41.07770	36.05750	1686.6	276.4	1963.1
Samsun	Salıpazarı	6,220	41.08813	36.82375	1175.6	27.2	1202.8
Samsun	Ambartepe	1,574	41.00536	36.96703	297.5		297.5
Samsun	Terme	31,163	41.21823	37.02076	5889.8		5889.8
Sivas	Akıncılar	2,797	40.08884	38.35031	528.6		528.6
Sivas	Doğanşar	1,419	40.21203	37.53781	268.2		268.2
Sivas	Gölova	2,197	40.05634	38.60856	415.2		415.2
Sivas	Koyulhisar	4,138	40.28425	37.81026	782.1		782.1
Sivas	Çataloluk	894	40.15550	38.04234	169.0		169.0
Sivas	Şeyhhalil	1,179	39.85287	36.13842	222.8		222.8
Sivas	Yavu	1,115	39.79631	36.20326	210.7		210.7
Sivas	Şerefiye	2,006	40.12106	37.75923	379.1		379.1
Tokat	Akarçay	1,937	40.34939	37.03406	366.1		366.1
Tokat	Ataköy	2,043	40.45031	36.91309	386.1		386.1
Tokat	Bağtaşı	2,002	40.21734	37.37576	378.4		378.4

Table A 2. Untreated Point Source Discharges in the YRB (Continued)

City	**District**	**Population**	**East**	**North**	**Domestic Wastewater (m^3/day)**	**Industrial Wastewater (m^3/day)**	**Total (m^3/day)**
Tokat	Cihet	2,032	40.28911	37.17976	384.0		384.0
Tokat	Çevreli	2,568	40.31334	36.86748	485.4		485.4
Tokat	Dikili	1,465	40.34056	37.07265	276.9		276.9
Tokat	Gölgeli	2,162	40.33162	37.06450	408.6		408.6
Tokat	Görümlü	2,056	40.33170	36.97415	388.6		388.6
Tokat	Kınık	1,628	40.31234	36.90092	307.7		307.7
Tokat	Ormandibi	2,028	40.30239	36.81506	383.3		383.3
Tokat	Artova	3,156	40.11148	36.30409	596.5		596.5
Tokat	Çelikli	1,237	40.07712	36.37495	233.8		233.8
Tokat	Başçiftlik	4,195	40.55984	37.21337	792.9		792.9
Tokat	Hatipli	2,387	40.54250	37.22276	451.1		451.1
Tokat	Akça	2,026	40.71548	36.45590	382.9		382.9
Tokat	Değirmenli	2,110	40.71767	36.47559	398.8		398.8
Tokat	Gökal	3,019	40.85034	36.69328	570.6		570.6
Tokat	Karayaka	2,912	40.73462	36.59378	550.4		550.4
Tokat	Koçak	1,146	40.64378	36.51170	216.6		216.6
Tokat	Tanoba	2,496	40.65539	36.40681	471.7		471.7
Tokat	Üzümlü	1,919	40.70753	36.64562	362.7		362.7
Tokat	Akbelen	851	40.44734	36.68778	160.8		160.8
Tokat	Avlunlar	1,582	40.52723	36.72251	299.0		299.0
Tokat	Büyükyıldız	2,001	40.36231	36.36515	378.2		378.2
Tokat	Çamlıbel	1,726	40.08848	36.47992	326.2		326.2
Tokat	Çat	3,288	40.28456	36.71748	621.4		621.4
Tokat	Emirseyit	2,020	40.35345	36.41523	381.8		381.8
Tokat	Güryıldız	2,004	40.35209	36.37123	378.8		378.8
Tokat	Kemalpaşa	1,243	40.35575	36.51134	234.9		234.9
Tokat	Yağmurlu	938	40.51820	36.81109	177.3		177.3
Tokat	Gökçeli	1,180	40.59078	36.73856	223.0		223.0
Tokat	Günebakan	1,952	40.69117	36.81617	368.9		368.9
Tokat	Gürçeşme	2,067	40.57623	36.80837	390.7		390.7
Tokat	Kuyucak	2,027	40.48924	37.05878	383.1		383.1
Tokat	Niksar	32,692	40.59606	36.90653	6178.8	2.4	6181.2
Tokat	Özalan	1,666	40.64939	37.15187	314.9		314.9
Tokat	Serenli	2,541	40.66098	36.87292	480.2		480.2
Tokat	Yazıcık	2,399	40.48198	37.11664	453.4		453.4
Tokat	Yolkonak	3,005	40.55579	36.88344	567.9		567.9

Table A 2. Untreated Point Source Discharges in the YRB (Continued)

City	District	Population	East	North	Domestic Wastewater (m^3/day)	Industrial Wastewater (m^3/day)	Total (m^3/day)
Tokat	Dereköy	2,064	40.24798	36.24751	390.1		390.1
Tokat	Pazar	4,979	40.28862	36.28226	941.0		941.0
Tokat	Üzümören	4,031	40.25064	36.19401	761.9		761.9
Tokat	Baydarlı	2,285	40.47787	37.48403	431.9		431.9
Tokat	Bereketli	2,305	40.51848	37.34187	435.6		435.6
Tokat	Bozçalı	2,747	40.53650	37.28115	519.2		519.2
Tokat	Büşürüm	1,935	40.46131	37.23194	365.7		365.7
Tokat	Cimitekke	2,188	40.49317	37.42490	413.5		413.5
Tokat	Çevrecik	2,149	40.44270	37.22675	406.2		406.2
Tokat	Hasanşeyh	3,104	40.47256	37.46934	586.7		586.7
Tokat	Kızılcaören	1,141	40.45614	37.52123	215.6		215.6
Tokat	Kuzbağı	769	40.44103	37.41542	145.3		145.3
Tokat	Nebişeyh	1,962	40.45375	37.36176	370.8		370.8
Tokat	Reşadiye	8,835	40.39428	37.34487	1669.8	5.7	1675.5
Tokat	Soğukpınar	1,124	40.38834	37.31178	212.4		212.4
Tokat	Yolüstü	2,107	40.44584	37.30270	398.2		398.2
Tokat	Dutluca	2,011	40.03042	36.02487	380.1		380.1
Tokat	Sulusaray	3,374	40.00037	36.07756	637.7		637.7
Tokat	Kat	2,027	40.31598	36.32698	383.1		383.1
Tokat	Şenyurt	2,207	40.31537	36.22865	417.1		417.1
Tokat	Turhal	63,600	40.41753	36.10784	12020.4	80.2	12100.6
Tokat	Ulutepe	614	40.41342	35.90387	116.0		116.0
Tokat	Yazıtepe	2,117	40.40909	36.26498	400.1		400.1
Tokat	Yenisu	2,071	40.46945	36.36359	391.4		391.4
Tokat	Çıkrık	1,088	40.03112	36.13276	205.6		205.6
Tokat	Kuşçu	2,104	40.03639	36.17192	397.7		397.7
Tokat	Yeşilyurt	5,268	40.01217	36.21914	995.7		995.7
Tokat	Yalınyazı	2,097	40.14862	35.76856	396.3		396.3
Tokat	Yıldıztepe	2,015	40.19078	35.89190	380.8		380.8
Yozgat	Akdağmadeni	24,956	39.66256	35.87717	4716.7	4.0	4720.6
Yozgat	Oluközü	1,664	39.68851	35.76067	314.5		314.5
Yozgat	Umutlu	2,072	39.75826	35.61926	391.6		391.6
Yozgat	Aydıncık	2,494	40.13651	35.28773	471.4		471.4
Yozgat	Baştürk	522	40.13503	35.35837	98.7		98.7
Yozgat	Baydiğin	3,272	40.20512	35.16137	618.4		618.4
Yozgat	Kazankaya	1,652	40.20931	35.32265	312.2		312.2

Table A 2. Untreated Point Source Discharges in the YRB (Continued)

City	District	Population	East	North	Domestic Wastewater (m^3/day)	Industrial Wastewater (m^3/day)	Total (m^3/day)
Yozgat	Kösrelik	713	40.13598	35.19001	134.8		134.8
Yozgat	Bayındırhüyük	932	40.07087	35.43798	176.1		176.1
Yozgat	Bazlambaç	508	40.16820	35.39351	96.0		96.0
Yozgat	Beyyurdu	895	39.96035	35.35756	169.2		169.2
Yozgat	Çekerek	10,961	40.03598	35.52048	2071.6	0.8	2072.4
Yozgat	Özükavak	2,099	40.02490	35.70057	396.7		396.7
Yozgat	Halıköy	2,390	40.00517	35.90737	451.7		451.7
Yozgat	Kadışehri	4,859	39.98726	35.79612	918.4		918.4
Yozgat	Çiçekli	1,166	39.82064	35.60117	220.4		220.4
Yozgat	Ozan	1,926	39.67439	35.56151	364.0		364.0
Yozgat	Ahmetfakılı	1,071	39.79567	35.40839	202.4		202.4
Yozgat	Araplı	1,659	39.83167	35.43817	313.6		313.6
Yozgat	Eymir	1,681	40.00820	35.19401	317.7		317.7
Yozgat	Gülşehri	1,161	39.79512	35.48420	219.4		219.4
Amasya	Amasya KSS		40.56509	35.79190		45.8	45.8
Amasya	Amasya OSB		40.56827	35.68405		103.7	103.7
Tokat	Niksar OSB		40.61979	36.81602		55.2	55.2
Amasya	Suluova OSB		40.82746	35.62007		179.3	179.3
Tokat	Turhal OSB		40.30218	36.18985		152.9	152.9

Table A 3. List of Industrial Facilities Discharging to Untreated Domestic Point Sources

Point Source	**Name o Facility Discharging to the Point Source**	**Industrial Sector**	**Wastewater (m^3/day)**
Akdağmadeni	Fatma Güler-Güler Tekstil Ürünleri İmalatı	Textile Industry	0.12
Akdağmadeni	Muammer Yıldız - Yıldız Ofset Matbaa	Urban Wastewater	0.19
Akdağmadeni	Sentekstil Konfeksiyon Plastik ve Eğitim Hizmetleri Sanayi ve Ticaret	Food Industry	2.38
Akdağmadeni	Hayati Sağlam	Metal Industry	0.06
Akdağmadeni	Kaya Duru	Machinery and Spare Parts Industry	0.12
Akdağmadeni	Yüce Zirai Aletleri Sanayi Ticaret	Chemical Industry	1.09
Alaca	Çınar Yeşilbaş Güneş Ofset ve Matbuacılık	Urban Wastewater	0.12
Alaca	Genç Bahçe Dekor Azem Bekdemir	Metal Industry	0.09
Alaca	İmamoğlu Zirve	Mining Industry	0.13
Alaca	Tahir Kokrmaz-Yunus Emre Pen	Chemical Industry	0.57
Amasya KSS	Ahmet Kahyaoğlu - Kısmet Cam Ticaret	Glass Industry	2.28
Amasya KSS	Dursun Cihan - Cihan Sera	Metal Industry	1.22
Amasya KSS	Er-San Metal - Sabri Bakır	Metal Industry	0.61
Amasya KSS	Işıltı Temizlik - İbrahim Ethem Kars	Textile Industry	0.19
Amasya KSS	Kırlangıç Metal Sanayi ve Ticaret	Metal Industry	0.98
Amasya KSS	Kıvanç Mobilya- Cezmi Ütnü	Wood Products and Furniture Industry	0.03
Amasya KSS	Nurettin Kahyaoğlu - Nazar Cam	Glass Industry	1.94
Amasya KSS	Oluzlular Ziraat Makineleri ve Aletleri Hırdavat Nakliye İnşaat Tarım Hayvancılık Ticaret ve Sanayi	Metal Industry	5.34
Amasya KSS	Recep Kuruçay (Kuruçay Ahşap Doğrama)	Wood Products and Furniture Industry	0.03
Amasya KSS	Yeşil Amasya Lokantacılık Gıda Ticaret	Urban Wastewater	32.66
Amasya KSS	Yiğit Torna - Mustafa Kocaköse	Metal Industry	0.57
Amasya OSB	Amasya OSB	Mixed Industrial Wastewater	102.16
Amasya OSB	Nesil Gıda Tekstil Ticaret Sanayi ve Pazarlama	Chemical Industry	1.44
Amasya OSB	Yılsar Gıda Yağ ve Tarım Ür.Nak.San.Tic.	Food Industry	0.09
Ziyaret	Ali İhsan Keleş - Sağlamsan	Metal Industry	0.22
Ziyaret	Enza Yatırım Gayrimenkul İnşaat Sanayi ve Ticaret	Chemical Industry	2.20
Çarşamba	Akcan Gıda İnşaat Turizm Nakliyat Taahhüt Sanayi ve Tic.	Urban Wastewater	21.92
Çarşamba	Asma Kuyumculuk Gıda Tarım Ürünleri Zirai Mücadele Nakliyat İnşaat Sanayi ve Ticaret Limited Şirketi Asma Fındık Fabrikası Şubesi	Food Industry	6.13
Çarşamba	Ayan Tarım Ürünleri Şehirler Arası Servis, Taşımacılık,Turizm ve Temizlik San. ve Tic.	Urban Wastewater	21.92
Çarşamba	Çarşamba Deniz Makina End. Tes .İm..Mont San ve Tic	Metal Industry	0.20
Çarşamba	Çarşamba Karisör Sanayi ve Tic.	Vehicle Manufacturing and Repair Industry	0.77
Çarşamba	Eyüp Polat Polatlar Ambalaj Atık Geri Dönişüm Sanayi	Chemical Industry	0.12

Table A 3. List of Industrial Facilities Discharging to Untreated Domestic Point Sources (Continued)

Point Source	**Name o Facility Discharging to the Point Source**	**Industrial Sector**	**Wastewater (m^3/day)**
Çarşamba	Güneş Karisör	Vehicle Manufacturing and Repair Industry	0.77
Çarşamba	Gürkan Tabela Gürkan Yılmaz	Chemical Industry	0.23
Çarşamba	Hasan Ayaydın Aydın Asansör	Machinary and Spare Parts Industry	0.16
Çarşamba	Hatice Kartal - Karadeniz Asansör	Machinary and Spare Parts Industry	0.16
Çarşamba	Kızılkaya Orman Ürünleri Sanayi ve Ticaret	Textile Industry	2.32
Çarşamba	Oğuz Bilek	Chemical Industry	0.12
Çarşamba	Özkrom Hidrolik Makina Kalıp Sanayi ve Dış Ticaret	Machinary and Spare Parts Industry	0.17
Çarşamba	Özovalı Süt Ürünleri İmalat Ticaret ve Sanayi	Food Industry	8.29
Çarşamba	Özyılmaz Fındık Sanayi ve Ticaret Çarşamba 1. Şubesi Merkez	Food Industry	27.25
Çarşamba	Özyılmaz Fındık Ticaret ve Sanayi Ltd.Şti.	Food Industry	1.70
Çarşamba	Pamuk Plastik Sanayi- Şakir Pamuk 1. Şubesi	Chemical Industry	1.66
Çarşamba	Samet Maral Maral Plastik Sanayi	Chemical Industry	0.12
Çarşamba	Şahin Yalıtım Sanayi Ticaret	Chemical Industry	1.52
Çarşamba	Şakir Pamuk - Pamuk Plastik	Chemical Industry	0.93
Çarşamba	Tozmaz İnşaat Sanayi ve Tic. Ltd Şti Yalıtım Şubesi	Chemical Industry	1.52
Çarşamba	Uğurlar Gübre Sebze Pazarlama ve Ticaret	Chemical Industry	9.47
Çarşamba	Yaşarlar Plastik - Sanayi Mustafa Yaşar	Chemical Industry	0.12
Çarşamba	Yılmaz Kardeşler Gıda Sanayi ve Ticaret Anonim Şirketi	Food Industry	27.25
Çarşamba	Yılmaz Tarım Ürünleri Ticaret ve Sanayi	Food Industry	27.25
Çarşamba	Yılpa İnşaat Taahhüt Fındık Un Sanayi ve Ticaret	Food Industry	6.13
Çarşamba	Zorlular Yemek Sanayi Toplu Taşımacılık Yedek Parça Hidrolik Pnömatik Devre Elemanları İnşaat Ticaret	Urban Wastewater	21.92
Çekerek	Eyyüp Yıldız -Yıldız Ofset	Urban Wastewater	0.16
Çekerek	Promix Petrol Sanayi Ticaret Anonim Şirketi - Yozgat Şubesi	Oil Industry	0.62
Gümüşhacıköy	Atlas Dunnage Ambalaj Sanayi ve Ticaret	Machinary and Spare Parts Industry	5.24
Gümüşhacıköy	Ceren Matbaası - Hüseyin Gündoğdu	Urban Wastewater	0.12
Gümüşhacıköy	Çaylı Kaynakcı - Recep Çaylı	Metal Industry	0.09
Gümüşhacıköy	Deko Plastik Ambalaj Sanayi ve Ticaret	Chemical Industry	0.28
Gümüşhacıköy	Erol Ofset & Matbaa	Urban Wastewater	0.03
Gümüşhacıköy	İçanadolu Kuruyemiş Sanayi ve Ticaret Limited Şirketi	Food Industry	6.13
Gümüşhacıköy	Keyiflen Kuruyemiş Aktariye Gıda İmalat Sanayi ve Ticaret	Food Industry	1.70
Gümüşhacıköy	Kırıcıoğlu Demir Doğrama-Mehmet Ali Kırıcıoğlu	Metal Industry	37.53

Table A 3. List of Industrial Facilities Discharging to Untreated Domestic Point Sources (Continued)

Point Source	Name o Facility Discharging to the Point Source	Industrial Sector	Wastewater (m^3/day)
Gümüşhacıköy	Modes Etiket ve Promosyon Hediyelik Eşya Sanayi ve Ticaret Limited Şirketi Gümüşhacıköy Şubesi	Chemical Industry	0.06
Gümüşhacıköy	Star Endüstriyel Ambalaj Sanayi Ticaret	Textile Industry	1.67
Gümüşhacıköy	Uğur Ertürk - Uğur Tarım Aletleri Bakım ve Onarım Atölyesi	Metal Industry	0.22
Gümüşhacıköy	Uysal Yemek Tarım Temizlik Turizm Gıda Hayvancılık Petrol Ürünleri İnşaat İthalat İhracat Nakliyat Tahhüt Sanayi ve Ticaret	Urban Wastewater	24.61
Kavak	Afacan Plastik Endüstryel Tem.ve Sağ.Ürün.İnşaat.San.Tic.Ltd.Şti	Chemical Industry	1.02
Kavak	Çetaş Cam Sanayi ve Ticaret (Kavak Şubesi)	Glass Industry	9.53
Kavak	Eko-Term Strafor, Ambalaj, İnşaat Sanayi ve Ticaret	Chemical Industry	0.85
Kavak	Ernur Tavukçuluk Konut- Yapı Hizmetleri Turizm Sanayi ve Ticaret	Food Industry	0.46
Kavak	Gin San Madeni Yağlar Geri Dönüşüm Nakliyat İnşaat Sanayi ve Ticaret	Oil Industry	0.12
Kavak	Kaypor Stropor Ambalaj İnşaat Sanayive Dış Ticaret	Chemical Industry	0.12
Kavak	Keprosan Plastik Profil Sanayi ve Ticaret	Chemical Industry	1.52
Kavak	Meşale Kazan Makina Bakır Sanayi ve Ticaret	Machinary and Spare Parts Industry	15.51
Kavak	Murat Makina Murat Aziret	Metal Industry	0.57
Kavak	Murzioğlu Mim. Strafor Yalıtım Gıda Tur. İnş. San ve Tic.	Chemical Industry	238.62
Kavak	Okyanus Grup İletişim Teknoloji İnşaat Gıda Sanayi ve Ticaret	Food Industry	1.70
Kavak	Sade Madeni Yağlar Gerı Dönüşüm Inşaat Naklıyat Sanayı ve Tıcaret	Oil Industry	1.09
Kavak	Saınt Gobaın Weber Yapı Kimyasalları Sanayi ve Ticaret (Kavak Şubesi)	Chemical Industry	1.03
Kavak	Sati Akca	Urban Wastewater	2.98
Kavak	Şelale Endüstriyel Görsel Metal Ürünler Sanayi ve Ticaret A.Ş.	Metal Industry	1.30
Niksar	Cemalettin Bilgin - Bilgin Matbaası	Urban Wastewater	0.16
Niksar	Gumen Bilgisayar Makine Matbaa Ayakkabı Gıda Sanayi Ticaret	Urban Wastewater	0.25
Niksar	Niksar Ayvaz İşletmesi	Beverage Industry	0.14
Niksar	Niksar Onur Gıda İnşaat Yakacak Malzemeleri San. ve Tic.	Food Industry	0.34
Niksar	Niktaş Gıda Sanayi ve Ticaret	Food Industry	0.71
Niksar	Osman Karaca-Karaca Tarım Makinaları İmalatı	Metal Industry	0.30
Niksar	Tahmiscioğlu Gıda İmalat Sanayi ve Ticaret	Food Industry	0.06
Niksar	Ömer Karaca	Metal Industry	0.48
Niksar OSB	Kv Gıda Sanayi ve Ticaret	Food Industry	2.38
Niksar OSB	Niksar OSB	Mixed Industrial Wastewater	52.77
Reşadiye	Ahmet Çuhadaroğlu İnşaat Otomotiv Turizm Tekstil ve Gıda Sanayi Ticaret Limited Şirketi Reşadiye Şubesi	Textile Industry	2.16

Table A 3. List of Industrial Facilities Discharging to Untreated Domestic Point Sources (Continued)

Point Source	**Name o Facility Discharging to the Point Source**	**Industrial Sector**	**Wastewater (m^3/day)**
Reşadiye	Cemil Demir - Sefa Lokantası	Urban Wastewater	3.56
Salıpazarı	Atalay Kuyumculuk Tarım Ürünleri Sanayi ve Ticaret	Food Industry	27.25
Suluova	Alçam Metal Yedek Parça Sanayi ve Ticaret Anonim Şirketi	Vehicle Manufacturing and Repair Industry	0.60
Suluova	Dağcılar Kabin ve Makina Sanayi Ticaret	Chemical Industry	2.04
Suluova	Demka Yemek Gıda Tarım Temizlik Hayvancılık İnşaat Elektrik Sanayi Ticaret	Urban Wastewater	2.26
Suluova	Final Av ve Balıkçılık Malz. Reklamcılık Hayvancılık İnş.Malz.Tarım Orman Ürünleri Bilardo Salonu Bilgi İşlem Gıda Mad.San.Tic.Ltd.Şti.	Textile Industry	0.22
Suluova	Final Av ve Balıkçılık Malzemeleri Reklamcılık Hayvancılık İnşaat Malz.Tarım Orman Ürünleri Bilardo Salonu Bilgi İşlem Gıda Mad. San.Tic.Ltd.Şti.	Textile Industry	0.06
Suluova	Halit Çetintaş	Food Industry	1.16
Suluova	Hasan Demir (Teknik Plastik ve Geri Dönüşüm)	Chemical Industry	1.00
Suluova	İbrahim Dalgıç	Metal Industry	0.03
Suluova	Kadir Şaduman Aktar - Aktarlar Teknik Makine Hidrolik	Machinery and Spare Parts Industry	0.16
Suluova	Mustafa Say	Metal Industry	0.12
Suluova	Neta Baskül - Necmettin Düz	Machinery and Spare Parts Industry	0.22
Suluova	Sabri Şimşek Aktel Tel Örme İmalatı ve Satışı	Metal Industry	0.06
Suluova	Sabri Tekne	Urban Wastewater	0.06
Suluova	Ustaoğlu Gıda,Hayvancılık,Nakliye Tarım Ürünleri Unlu Gıda Ambalaj Turizm Sanayi ve Ticaret Limited Şirketi	Food Industry	1.70
Suluova	Yanılma Gıda - Cahit Yanılma	Food Industry	2.53
Suluova	Zekeriya Caner Doğan - İlktat Süt	Food Industry	1.03
Suluova OSB	Kalkavan Gıda Ürünleri Eğitim Öğretim Faaliyetleri Tic. San. Ltd. Şti.	Food Industry	4.42
Suluova OSB	Pi-Pa Piliç Gıda Maddeleri Nakliye Pazarlama Ticaret ve Sanayi Limited Şirketi Suluova Şubesi	Food Industry	12.99
Suluova OSB	Sert Kardeşler Et, Gıda, Hayvancılık, Tarım Ürünleri İnşaat Tekstil Bayilik Turizm Sanayi ve Ticaret	Food Industry	31.72
Suluova OSB	Sörka Asansör Elektrik Mühendislik Kapı İmalatı İthalat İhracat Taahhüt Ticaret ve Sanayi	Machinery and Spare Parts Industry	0.52
Suluova OSB	Suluova OSB	Mixed Industrial Wastewater	122.44
Suluova OSB	Ulu Grup Mobilya Pvc Alüminyum Kapı Membran İnş.İt.İh.Paz.San.Tic.	Chemical Industry	0.78
Suluova OSB	Yedikır Kuruyemiş Gıda Ticaret ve Sanayi	Food Industry	6.47
Şebinkarahisar	Akif Karancı - Karancılar Tarım Makinaları İmalat Sanayi Ticaret	Metal Industry	0.41
Şebinkarahisar	Arzum Şarküteri Yöresel Ürünler - Yahya Özkara	Food Industry	0.35
Şebinkarahisar	Dursun Aygün- Aygünler Ticaret	Food Industry	1.36

Table A 3. List of Industrial Facilities Discharging to Untreated Domestic Point Sources (Continued)

Point Source	**Name o Facility Discharging to the Point Source**	**Industrial Sector**	**Wastewater (m^3/day)**
Şebinkarahisar	İlhan Kahraman	Metal Industry	0.13
Şebinkarahisar	Kadir Önbaş	Metal Industry	0.57
Şebinkarahisar	Şebinkarahisar Belediyesi Mıcır Yıkama, Eleme, Tasnifleme, Parke, Beton ve Asfalt Plenti Tesisi	Mining Industry	0.52
Taşova	Ha-Me-Ka İmalat-Uğur Kara	Metal Industry	0.19
Taşova	Kamadan Matbaa	Urban Wastewater	0.12
Taşova	Konyar Yemek Fabrikası	Urban Wastewater	25.50
Taşova	Mehmet Kamadan	Urban Wastewater	0.03
Taşova	Öztekin Tarım Alet ve Makinaları İmalatı	Metal Industry	0.57
Taşova	Şimşek Çelik Eşya Sanayi	Chemical Industry	0.11
Taşova	Şükrü Özdemir	Metal Industry	1.89
Turhal	Ahmet Kılıç Feza Asansör	Machinery and Spare Parts Industry	0.16
Turhal	Akyudum Gıda Pazarlama ve Sanayi A.Ş. Turhal Süt Fabrikası Şubesi	Food Industry	43.92
Turhal	Altın Parke İnşaat Taahhüt Tarım ve Orman Ürünleri Hayvancılık Nakliye Sanayi ve Ticaret	Wood Products and Furniture Industry	0.08
Turhal	Emre Cüez Ac Isı Yalıtım	Chemical Industry	0.71
Turhal	Ferhatoğulları Otomotiv Makina Nakliya Madencilik Yemek Hizmetleri Sanayi Ticaret	Machinery and Spare Parts Industry	0.17
Turhal	Gaffaroğlu Organik Gübre Sanayi - Hüseyin Tuncel	Chemical Industry	3.16
Turhal	Hacı Çakar-Turpiyer Isı Yalıtım Sistemleri	Chemical Industry	0.24
Turhal	Hacıbey Et ve Gıda Sanayi Kollektif Şirketi Sebahattin Oruç ve Ortakları	Food Industry	4.10
Turhal	Nuh Mehmet Kırıktaş - Turhal Plastik	Chemical Industry	1.40
Turhal	Turhal Makina Fabrikası	Metal Industry	6.88
Turhal	Turova Gıda Tarım Hayvancılık Nakliye Ambalaj Sanayi ve Ticaret	Food Industry	17.54
Turhal	Yavuz Dizer - Egemen Grup Asansör	Machinery and Spare Parts Industry	0.16
Turhal	Yeni Dadaş Ticaret - Abdullah Delerel	Textile Industry	1.72
Turhal OSB	Akar Un İnşaat Nakliyat Tarım Petrol Ürünleri İmalat ve Pazarlama Sanayi Ticaret Limited Şirketi Turhal Şubesi	Food Industry	0.22
Turhal OSB	Dörtler Kablo Sanayi ve Ticaret	Machinery and Spare Parts Industry	48.40
Turhal OSB	Kazova Gıda İthalat İhracaat İnşaat Turizm	Food Industry	5.11
Turhal OSB	Turhal OSB	Mixed Industrial Wastewater	99.17

B. Sectoral Wastewater Discharges from Wastewater Treatment Plants

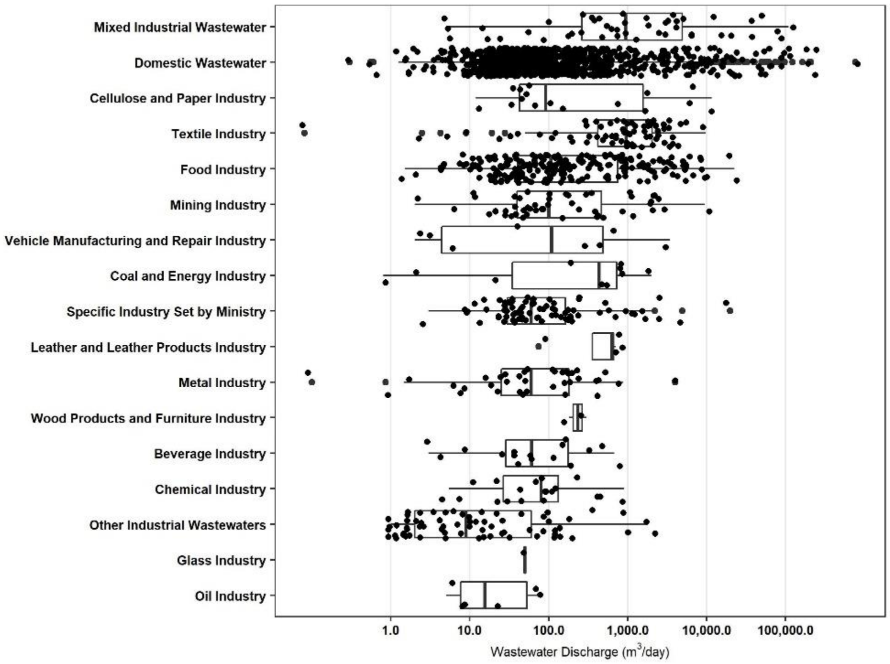


Figure A 1. Sectoral Wastewater Treatment Plant Discharges

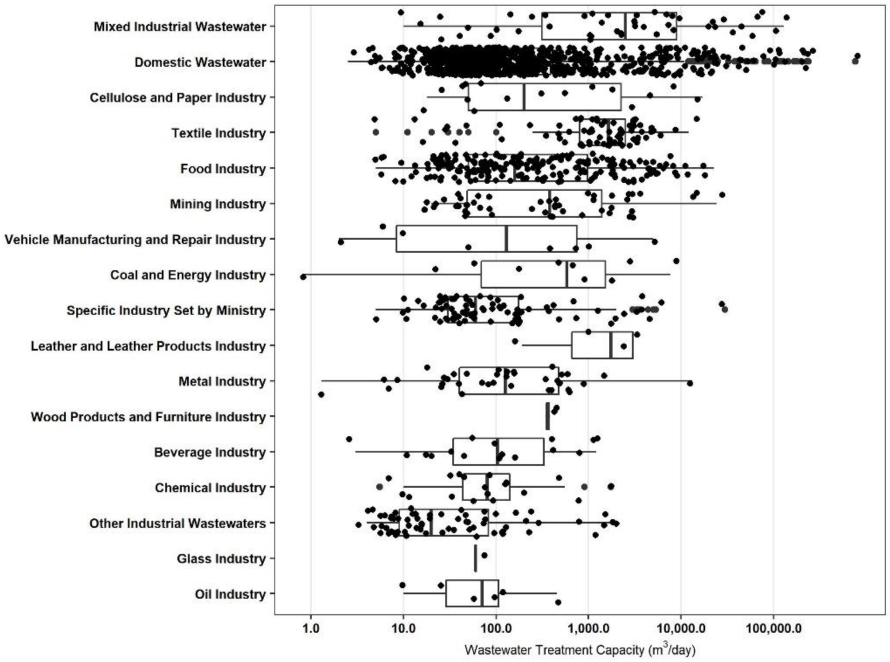


Figure A 2. Sectoral Wastewater Treatment Plant Capacities

C. Land Use Types in the Yeşilırmak River Basin

Table A 4. Land Use Types in the YRB

Land Use	Area (hm^2)	Percentage of Sub-Total	Percentage of Grand-Total
Forest	650		0.03
Rainfed (Fallow) / Forest	536	82.42	
Rainfed / Forest	114	17.58	
Irrigated Lands	307,192		13.32
Irrigated	73,017	23.77	
Irrigated (Intensive)	215,101	70.02	
Orchard (Irrigated)	691	0.22	
Vegetable (Irrigated)	18,383	5.98	
Abandoned Fields	120		0.01
Pastures	729,849		31.65
Meadow	718,398	98.43	
Pasture	7,487	1.03	
Shrubbery / Meadow	3,964	0.54	
Rainfed Lands	1,268,069		54.99
Hazelnut Plantation	705	0.06	
Orchard (Rainfed)	2,979	0.23	
Rainfed	302,232	23.83	
Rainfed (Fallow)	912,749	71.98	
Rainfed (Fallow) / Meadow	34,898	2.75	
Rainfed (Fallow) / Shrubbery	4,371	0.34	
Rainfed / Meadow	324	0.03	
Vegetable (Rainfed)	9,636	0.76	
Vegetable (Rainfed) / Orchard (Rainfed)	47	0.00	
Vegetable (Rainfed) / Shrubbery	128	0.01	
Grand Total	2,305,879		100.00

D. Monitoring Stations in Yeşilırmak River Basin

Table A 5. Yeşilırmak River Basin Surface Water Monitoring Stations

Station Code	Description	North	East	Added In Sampling Campaign
YESIL-1	SHW Stream Gauging Station	40.190833	39.711389	1
YESIL-2	SHW Stream Gauging Station	40.108056	39.299167	1
YESIL-3	MoAF Operational Monitoring Station	40.137500	38.554722	1
YESIL-4	Şebinkarahisar-Kılıçkaya Dam	40.222778	38.398611	1
YESIL-5	SHW Water Quality Station	40.226667	38.023333	1
YESIL-6	SHW Water Quality Station	40.128889	37.753333	1
YESIL-7	Reşadiye-3 Dam Environmental Flow	40.382222	37.356389	1
YESIL-8	Reşadiye Downstream	40.394722	37.323333	1
YESIL-9	Delice Creek Downstream	40.401389	37.293333	1
YESIL-10	MoAF Operational Monitoring Station	40.475000	37.008611	1
YESIL-11	MoAF Operational Monitoring Station	40.350278	36.628333	1
YESIL-12	Almus Dam Upstream	40.338056	36.891667	1
YESIL-13	SHW Stream Gauging Station	40.311667	37.126111	1
YESIL-14	MoAF Operational Monitoring Station	40.292500	36.282500	1
YESIL-15	Süreyyabey Dam Upstream	39.916944	35.646667	1
YESIL-16	SHW Water Quality Station	39.995833	36.070833	1
YESIL-17	Tokat-Turhal Upstream	40.379167	36.088889	1
YESIL-18	SHW Water Quality Station	40.421944	36.112778	1
YESIL-19	SHW Stream Gauging Station	40.619444	35.810556	1
YESIL-20	MoAF Operational Monitoring Station	40.675833	35.834167	1
YESIL-21	Çekerek Creek-Çorum Creek-Deliçay Junction	40.563333	35.761667	1
YESIL-22	SHW Stream Gauging Station	40.530278	35.638889	1
YESIL-23	Çekerek Creek-Çorum Creek Junction	40.468056	35.577778	1
YESIL-24	SHW Water Quality Station	40.450278	35.416917	1
YESIL-25	MoAF Operational Monitoring Station	40.378889	35.057500	1
YESIL-26	SHW Water Quality Station	40.339722	35.063889	1
YESIL-27	SHW Stream Gauging Station	40.226667	35.326944	1
YESIL-28	SHW Stream Gauging Station	40.105278	34.941944	1
YESIL-29	SHW Water Quality Station	40.386667	34.639167	1
YESIL-30	MoAF Operational Monitoring Station	40.573611	34.974722	1
YESIL-31	Merzifon Upstream	40.780000	35.492500	1
YESIL-32	MoAF Operational Monitoring Station	40.765278	35.623889	1
YESIL-33	SHW Water Quality Station	40.748333	36.024167	1
YESIL-34	Taşova Upstream	40.741389	36.266389	1
YESIL-35	MoAF Operational Monitoring Station	40.745833	36.362222	1
YESIL-36	Hasan Uğurlu Dam Upstream	40.773889	36.509167	1

Table A 5. Yeşilırmak River Basin Surface Water Monitoring Stations (Continued)

Station Code	Description	North	East	Added In Sampling Campaign
YESIL-37	MoAF Operational Monitoring Station	40.703056	36.575278	1
YESIL-38[1]	MoAF Operational Monitoring Station	40.736940	36.717860	1
YESIL-39	SHW Water Quality Station	40.666389	36.696944	1
YESIL-40	Ladik Lake Downstream	40.925036	36.021111	1
YESIL-41	MoAF Operational Monitoring Station	41.270833	36.345278	1
YESIL-42	MoAF Operational Monitoring Station	41.228611	36.586389	1
YESIL-43	MoAF Operational Monitoring Station	41.203611	36.727222	1
YESIL-95	Tokat WWTP - DİMES Mid-Point	40.341000	36.509389	6
YESIL-96[2]	Meray Yağ Upstream	40.809875	35.410306	6
YESIL-97	Merzifon OIZ ve Meray Yağ Mid-Point	40.805844	35.420706	6
YESIL-98	Meray Yağ Tributary	40.805462	35.412894	6
YESIL-99	Özdemir Antimuan Downstream	40.432571	36.116737	6
YESIL-109	Havza WWTP Downstream	40.946983	35.656210	6
YESIL-111[3]	Aktan Gıda Downstream	40.884275	35.635308	6
YESIL-113[3]	Beşgöz Araboğulları Downstream	40.917721	35.648131	6
YESIL-115[3]	Gürmin Enerji Downstream	40.881773	35.632456	6
YESIL-117[3]	Otat Gıda Downstream	40.975040	35.687155	6
YESIL-119[3]	Temiz Et Ürünleri Downstream	40.997111	35.662839	6
YESIL-120	Tokat Downstream	40.338333	36.424444	6
YESIL-121[2]	Çorum Upstream	40.573611	34.974722	6
YESIL-122	Kozlu Gıda Downstream	40.804444	35.662222	6
YESIL-123	Et-Bir Downstream	40.825556	35.620556	6
YESIL-124	Olmuksa Downstream	40.694167	34.913611	7
YESIL-125	Bakraç Süt Downstream	40.727778	35.770833	7
YESIL-126	Turhal Şeker Downstream	40.397778	36.085556	7
YESIL-128	Amasya Şeker Downstream	40.833333	35.621111	7
YESIL-130[3]	Aydınoğlu Un Gıda Downstream	40.981192	35.688048	7
YESIL-132[3]	Doğa Su Downstream	40.893333	36.053333	7
YESIL-134[3]	Akçansa Çimento Downstream	40.912781	35.894430	7
YESIL-138[3]	Dem-Ak Madencilik Downstream	40.579694	35.342321	7
YESIL-140[3]	Makro-Win Downstream	40.514420	34.948494	7
YESIL-142[3]	Özpar Plastik Downstream	41.292737	36.252044	7
YESIL-144[3]	Ekmekçioğulları Downstream	40.510479	34.910806	7

[1] Canceled due to accessibility problems

[2] Canceled due to no flow conditions

[3] Canceled due to ending of point source monitoring

Table A 6. Yeşilırmak River Basin Domestic and Urban Wastewater Treatment Plant Monitoring Stations

Station Code	Description	North	East	Added In Sampling Campaign
YEŞİL-44[1]	Demircili WWTP Effluent	40.502222	37.520833	3
YEŞİL-45	Tokat WWTP Effluent	40.339722	36.473889	3
YEŞİL-46[2]	Çaylı WWTP Effluent	40.372047	36.163779	3
YEŞİL-47	Erbaa WWTP Effluent	40.706667	36.555000	3
YEŞİL-48	Çorum WWTP Effluent	40.485000	34.915556	3
YEŞİL-49[2]	Güzelbeyli WWTP Effluent	40.145169	36.008185	3
YEŞİL-50[2]	Evrenköy WWTP Effluent	40.148644	35.872856	3
YEŞİL-51[1]	Büyükhırka WWTP Effluent	39.996256	35.791254	3
YEŞİL-52[1]	Kazankaya WWTP Effluent	40.210278	35.322500	3
YEŞİL-53[1]	Aydıncık WWTP Effluent	40.152778	35.278889	3
YEŞİL-54[1]	Ozan WWTP Effluent	39.674722	35.562222	3
YEŞİL-55[1]	Oluközü WWTP Effluent	39.689444	35.761389	3
YEŞİL-56[2]	Ağcagüney WWTP Effluent	41.117500	36.612778	3
YEŞİL-57[3]	Terme WWTP Effluent	41.220000	37.023333	3
YEŞİL-75	Mecitözü Belediyesi WWTP Effluent	40.524933	35.297087	5
YEŞİL-104	Tokat WWTP Influent	40.339722	36.473889	6
YEŞİL-105	Çorum WWTP Influent	40.485000	34.915556	6
YEŞİL-106	Amasya WWTP Influent	40.679901	35.879433	6
YEŞİL-107	Amasya WWTP Influent	40.679901	35.879433	6
YEŞİL-108	Havza WWTP Influent	40.946983	35.656210	6

[1] Canceled due to no flow condition

[2] Canceled due to being under construction

[3] Canceled due to deep sea discharge

Table A 7. Yeşilırmak River Basin Industrial Wastewater Treatment Plant Monitoring Stations

Station Code	**Description**	**North**	**East**	**Added In Sampling Campaign**
YEŞİL-58	Merzifon OSB	40.858726	35.463237	3
YEŞİL-59	Samsun Merkez OSB	41.227290	36.425531	3
YEŞİL-60	DIMES Gıda	40.333411	36.535544	3
YEŞİL-61	Turhal Şeker Fabrikası	40.394439	36.080337	3
YEŞİL-62	Özdemir Antimuan Madenleri	40.423440	36.110838	3
YEŞİL-63[1]	Hayat Kağıt ve Enerji.	40.512688	34.914473	3
YEŞİL-64[1]	Pan-Et Hayvan Kesim ve Et Ürünleri	40.838309	35.633073	3
YEŞİL-65	Meray Yağ	40.860281	35.431734	3
YEŞİL-66[3]	Eski Çeltek Kömür İşletmesi	40.868421	35.639073	3
YEŞİL-67[1]	Çarşamba Şeker Fabrikası	41.170326	36.706233	3
YEŞİL-68[1]	Samsun Mezbahane ve Et Entegre Sanayii	41.258967	36.345313	3
YEŞİL-69	Olmuksa International Paper Sabancı Ambalaj	40.525577	34.914168	4
YEŞİL-70	Özmaya	40.686941	35.906630	4
YEŞİL-71[1]	Eti-Bakır Anonim Şirketi	41.242688	36.461870	4
YEŞİL-72[3]	Nesko Maden	40.290952	38.296925	4
YEŞİL-73	Yemsel Tavukçuluk Hayvancılık	41.060149	36.094598	4
YEŞİL-74[2]	Hasanusta Gıda Sanayi	40.911482	35.664800	4
YEŞİL-76	Yuva Viyol Ve Ambalaj	40.598739	34.912361	5
YEŞİL-77	Et-Bir Suluova Kesimhane	40.823054	35.636581	5
YEŞİL-78	Kozlu Gıda	40.654978	35.840261	5
YEŞİL-79	Bakraç Süt Ürünleri	40.734038	35.770572	5
YEŞİL-102	Meray Yağ Atıksu Arıtma Tesisi Giriş	40.860281	35.431734	6
YEŞİL-103	Merzifon OSB Atıksu Arıtma Tesisi Giriş	40.858726	35.463237	6
YEŞİL-110[2]	Aktan Gıda San.	40.884275	35.635308	6
YEŞİL-112[2]	Beşgöz Araboğulları Unculuk Sanayi	40.917721	35.648131	6
YEŞİL-114[3]	Gürmin Enerji Madencilik San.	40.881773	35.632456	6
YEŞİL-116	Otat Gıda Sanayi	40.975040	35.687155	6
YEŞİL-118[2]	Temiz Et Ürünleri	40.997111	35.662839	6
YEŞİL-127	Amasya Şeker Fabrikası	40.833889	35.640556	7
YEŞİL-129	Aydınoğlu Un Gıda Sanayi	40.981389	35.688889	7
YEŞİL-131	Doğa Su Gıda Maddeleri	40.900000	36.053333	7

Table A 7. Yeşilırmak River Basin Industrial Wastewater Treatment Plant Monitoring Stations (Continued)

Station Code	**Description**	**North**	**East**	**Added In Sampling Campaign**
YEŞİL-133[2]	Akçansa Çimento Sanayi	40.935556	35.886389	7
YEŞİL-137[2]	Dem-Ak Madencilik	40.579694	35.342321	7
YEŞİL-139[2]	Makro-Win Yapı Malzemeleri	40.514420	34.948494	7
YEŞİL-141[2]	Özpar (Parlar) Plastik	41.292737	36.252044	7
YEŞİL-143[2]	Ekmekçioğulları Çinko Bakır Kurşun San.	40.510479	34.910806	7
YEŞİL-145[2]	Gülşim Un ve İrmik	40.804801	35.659994	7
YEŞİL-146[2]	Kanoğlu Un Gıda Tarım	41.002214	35.822515	7
YEŞİL-147[2]	Nur Un Sanayi ve Ticaret	-	-	7
YEŞİL-148[2]	Yeni Teşvikiye Yem Sanayi	40.943291	35.656811	7

[1] Canceled due to the facility being closed during monitoring campaigns

[1] Canceled due to the facility being closed permanently

[3] Canceled due to no flow condition

E. Environmental Quality Standards Defined in the Regulation on Surface Water Quality for Conventional Parameters, Priority Substances, and River Basin Specific Pollutants

Table A 8. General Chemical and Physicochemical Parameters and Their Environmental Quality Standards (Annex V Table 2 of Surface Water Quality Regulation)

Su Kalite Parametreleri	**Su Kalite Sınıfları (a)**		
	I (çok iyi)	**II (iyi)**	**III (orta)**
Renk (m^{-1})	RES 436 nm: ≤ 1,5 RES 525 nm: ≤ 1,2 RES 620 nm: ≤ 0,8	RES 436 nm: 3 RES 525 nm: 2,4 RES 620 nm: 1,7	RES 436 nm: > 4,3 RES 525 nm: > 3,7 RES 620 nm: 2,5
pH	6-9	6-9	6-9
İletkenlik (µS/cm)	< 400	1000	> 1000
Yağ ve Gres (mg/L)	< 0,2	0,3	> 0,3
Çözünmüş oksijen (mg/L)	> 8	6	< 6
Kimyasal oksijen ihtiyacı (KOİ) (mg/L)	< 25	50	> 50
Biyokimyasal oksijen ihtiyacı (BOİ$_5$) (mg/L)	< 4	8	>8
Amonyum azotu (mg NH$_4^+$-N/L)	< 0,2	1	>1
Nitrat azotu (mg NO$_3^-$-N/L)	< 3	10	> 10
Toplam kjeldahl-azotu (mg N/L) (b)	< 0,5	1,5	> 1,5
Toplam azot (mg N/L) (c)	< 3,5	11,5	> 11,5
Orto fosfat fosforu (mg o-PO$_4$-P/L)	< 0,05	0,16	> 0,16
Toplam fosfor (mg P/L)	< 0,08	0,2	> 0,2
Florür (µg/L)	≤ 1000	1500	> 1500
Mangan (µg/L)	≤ 100	500	> 500
Selenyum (µg/L)	≤ 10	15	> 15
Sülfür (µg/L)	≤ 2	5	> 5

(a) Kalite sınıflarına göre suların kullanım maksatları:

I. Sınıf - Yüksek kaliteli su (I. sınıf su kalitesinde olması “Çok İyi” su durumunu ifade etmektedir.);

1) İçme suyu olma potansiyeli yüksek olan yerüstü suları,
2) Yüzme gibi vücut teması gerektirenler dâhil rekreasyonel maksatlar için kullanılabilir su,
3) Alabalık üretimi için kullanılabilir nitelikte su,
4) Hayvan üretimi ve çiftlik ihtiyacı için kullanılabilir nitelikte su,

II. Sınıf - Az kirlenmiş su (II. sınıf su kalitesinde olması “İyi” su durumunu ifade etmektedir.);

1) İçme suyu olma potansiyeli olan yerüstü suları,
2) Rekreasyonel maksatlar için kullanılabilir nitelikte su,
3) Alabalık dışında balık üretimi için kullanılabilir nitelikte su,
4) Mer’i mevzuat ile tespit edilmiş olan sulama suyu kalite kriterlerini sağlamak şartıyla sulama suyu,

III. Sınıf - Kirlenmiş su (III. sınıf su kalitesinde olması “Orta” su durumunu ifade etmektedir.);

Gıda, tekstil gibi nitelikli su gerektiren tesisler hariç olmak üzere, uygun bir arıtmadan sonra su ürünleri yetiştiriciliği için kullanılabilir nitelikte su ve sanayi suyu,

ifade etmektedir.

(b) TKN: NH$_3$-N + Organik Azot

(c) TN: TKN + NO$_3$-N + NO$_2$-N

Table A 9. Priority Substances and Their Environmental Quality Standards (Annex V Table 5 of Surface Water Quality Regulation)

No	**Madde Adı**	**CAS No**	**YO-ÇKS Nehirler/Göller (µg/L)**	**MAK-ÇKS Nehirler/Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
1	Alaklor	15972-60-8	0,3	0,7	0,3	0,7
2	Antrasen	120-12-7	0,1	0,4	0,1	0,4
3	Atrazin	1912-24-9	0,6	2,0	0,6	2,0
4	Benzen	71-43-2	10	50	8	50
5	Bromlu difenileter[1]	32534-81-9	-	0,14	-	0,014
6	Kadmiyum ve bileşikleri[2]	7440-43-9	< 0,08 (Sınıf 1) 0,08 (Sınıf 2) 0,09 (Sınıf 3) 0,15 (Sınıf 4) 0,25 (Sınıf 5)	< 0,45 (Sınıf 1) 0,45 (Sınıf 2) 0,6 (Sınıf 3) 0,9 (Sınıf 4) 1,5 (Sınıf 5)	0,2	< 0,45 (Sınıf 1) 0,45 (Sınıf 2) 0,6 (Sınıf 3) 0,9 (Sınıf 4) 1,5 (Sınıf 5)
7	C10-13-Kloroalkanlar	85535-84-8	0,4	1,4	0,4	1,4
8	Klorfenvinfos	470-90-6	0,1	0,3	0,1	0,3
9	Klorpirifos (Klorpirifos-etil)	2921-88-2	0,03	0,1	0,03	0,1
10	1,2-dikloroetan	107-06-2	10	-	10	-
11	Diklorometan	75-09-2	20	-	20	-
12	Di(2-etilhekzil)fitalat (DEHP)	117-81-7	1,3	-	1,3	-
13	Diuron	330-54-1	0,2	1,8	0,2	1,8
14	Endosulfan	115-29-7	0,005	0,01	0,0005	0,004
15	Floranten	206-44-0	0,0063	0,12	0,0063	0,12
16	Hekzakloro-benzen	118-74-1	-	0,05	-	0,05
17	Hekzakloro-bütadien	87-68-3	-	0,6	-	0,6
18	Hekzakloro-siklohekzan	608-73-1	0,02	0,04	0,002	0,02
19	Isoproturon	34123-59-6	0,3	1,0	0,3	1,0

Table A 9. Priority Substances and Their Environmental Quality Standards (Annex V Table 5 of Surface Water Quality Regulation) (Continued)

No	Madde Adı	CAS No	YO-ÇKS Nehirler/Göller (µg/L)	MAK-ÇKS Nehirler/Göller (µg/L)	YO-ÇKS Kıyı ve Geçiş Suları (µg/L)	MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)
20	Kurşun ve bileşikleri[3]	7439-92-1	1,2	14	1,3	14
21	Cıva ve bileşikleri	7439-97-6	-	0,07	-	0,07
22	Naftalin	91-20-3	2	130	2	130
23	Nikel ve bileşikleri[3]	7440-02-0	4	34	8,6	34
24	Nonilfenoller (4-Nonilfenol)	84852-15-3	0,3	2,0	0,3	2,0
25	Oktilfenol ((4-(1,1' ,3,3' -tetrametilbütil)-fenol))	140-66-9	0,1	-	0,01	-
26	Pentakloro-benzen	608-93-5	0,007	-	0,0007	-
27	Pentakloro-fenol	87-86-5	0,4	1	0,4	1
28	Poliaromatik hidrokarbonlar (PAH)	-	-	-	-	-
	Benzo(a)piren	50-32-8	$1,7 \times 10^{-4}$	0,27	$1,7 \times 10^{-4}$	0,027
	Benzo(b)floranten	205-99-2	-	0,017	-	0,017
	Benzo(k)floranten	207-08-9	-	0,017	-	0,017
	Benzo(g,h,i)perilen	191-24-2	-	$8,2 \times 10^{-3}$	-	$8,2 \times 10^{-4}$
	Indeno(1,2,3-cd)piren	193-39-5	-	-	-	-
29	Simazin	122-34-9	1	4	1	4
30	Tributilkalay bileşikleri (Tributilkalay-katyonu)	36643-28-4	0,0002	0,0015	0,0002	0,0015
31	Trikloro-benzenler	12002-48-1	0,4	-	0,4	-
32	Trikloro-metan	67-66-3	2,5	-	2,5	-
33	Trifluralin	1582-09-8	0,03	-	0,03	-
34	Dikofol	115-32-2	$1,3 \times 10^{-3}$	-	$3,2 \times 10^{-5}$	-
35	Perflorooktan sülfonik asit ve türevleri	1763-23-1	$6,5 \times 10^{-4}$	36	$1,3 \times 10^{-4}$	7,2

Table A 9. Priority Substances and Their Environmental Quality Standards (Annex V Table 5 of Surface Water Quality Regulation) (Continued)

No	**Madde Adı**	**CAS No**	**YO-ÇKS Nehirler/Göller (µg/L)**	**MAK-ÇKS Nehirler/Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
	(PFOS)					
36	Kinoksifen	124495-18-7	0,15	2,7	0,015	0,54
37	Dioksinler ve dioksin benzeri bileşikler[4]		-	-	-	-
38	Aklonifen	74070-46-5	0,12	0,12	0,012	0,012
39	Bifenoks	42576-02-3	0,012	0,04	0,0012	0,004
40	Sibutrin	28159-98-0	0,0025	0,016	0,0025	0,016
41	Sipermetrin[5]	52315-07-8	8×10^{-5}	6×10^{-4}	8×10^{-6}	6×10^{-5}
42	Diklorvos	62-73-7	6×10^{-4}	7×10^{-4}	6×10^{-5}	7×10^{-5}
43	Hekzabromo-siklododekanlar (HBCDD)[6]		0,0016	0,5	0,0008	0,05
44	Heptaklor ve heptaklor epoksit	76-448/1024-57-3	2×10^{-7}	3×10^{-4}	1×10^{-8}	3×10^{-5}
45	Terbutrin	886-50-0	0,065	0,34	0,0065	0,034

[*] 2013/39/EU sayılı Avrupa Birliği Direktifi'nde listelenen öncelikli maddeler ve çevresel kalite standartlarını ifade eder.

[1] Bromludifenileterler için verilen ÇKS değeri 28, 47, 99, 100, 153 ve 154 numaralı konjinerlerin toplamının konsantrasyonunu ifade eder.

[2] Sınıf 1: <40 mg $CaCO_3$/L; Sınıf 2: 40-50 mg $CaCO_3$/L; Sınıf 3: 50-100 mg $CaCO_3$/L; Sınıf 4: 100-200 mg $CaCO_3$/L; Sınıf 5: ≥200 mg $CaCO_3$/L

[3] ÇKS'ler bu maddelerin biyolojik olarak kullanılabilir konsantrasyonlarını ifade eder.

[4] 7 adet poliklorlu dibenzo-p-dioksin (PCDDs): 2,3,7,8-T4CDD (CAS 1746-01-6), 1,2,3,7,8-P5CDD (CAS 40321-76-4), 1,2,3,4,7,8- H6CDD (CAS 39227-28-6), 1,2,3,6,7,8-H6CDD (CAS 57653-85-7), 1,2,3,7,8,9-H6CDD (CAS 19408-74-3), 1,2,3,4,6,7,8-H7CDD (CAS 35822-46-9), 1,2,3,4,6,7,8,9-O8CDD (CAS 3268-87-9)

10 adet poliklorlu dibenzofuran (PCDFs): 2,3,7,8-T4CDF (CAS 51207-31-9), 1,2,3,7,8-P5CDF (CAS 57117-41-6), 2,3,4,7,8-P5CDF (CAS 57117-31-4), 1,2,3,4,7,8-H6CDF (CAS 70648-26-9), 1,2,3,6,7,8-H6CDF (CAS 57117-44-9), 1,2,3,7,8,9-H6CDF (CAS 72918- 21-9), 2,3,4,6,7,8-H6CDF (CAS 60851-34-5), 1,2,3,4,6,7,8-H7CDF (CAS 67562-39-4), 1,2,3,4,7,8,9-H7CDF (CAS 55673-89-7), 1,2,3,4,6,7,8,9-O8CDF (CAS 39001-02-0)

12 adet dioksin benzeri poliklorlu bifenil (PCB-DL): 3,3',4,4'-T4CB (PCB 77, CAS 32598-13-3), 3,3',4',5-T4CB (PCB 81, CAS 70362- 50-4), 2,3,3',4,4'-P5CB (PCB 105, CAS 32598-14-4), 2,3,4,4',5-P5CB (PCB 114, CAS 74472-37-0), 2,3',4,4',5-P5CB (PCB 118, CAS 31508-00-6), 2,3',4,4',5'-P5CB (PCB 123, CAS 65510-44-3), 3,3',4,4',5-P5CB (PCB 126, CAS 57465-28-8), 2,3,3',4,4',5-H6CB (PCB 156, CAS 38380-08-4), 2,3,3',4,4',5'-H6CB (PCB 157, CAS 69782-90-7), 2,3',4,4',5,5'-H6CB (PCB 167, CAS 52663-72-6), 3,3',4,4',5,5'-H6CB (PCB 169, CAS 32774-16-6), 2,3,3',4,4',5,5'-H7CB (PCB 189, CAS 39635-31-9).

[5] 52315-07-8 numaralı CAS Numarası sipermetrinin, alfa sipermetrin (CAS 67375-30-8), beta sipermetrin (CAS 65731-84-2), teta sipermetrin (CAS 71697-59-1) ve zeta sipermetrinden (CAS 52315-07-8) oluşan bir izomer karışımını ifade eder.

[6] 1,3,5,7,9,11-Hekzabromosiklododekan (CAS 25637-99-4), 1,2,5,6,9,10-Hekzabromosiklododekan (CAS 3194-55-6), α-Hekzabromosiklododekan (CAS 134237-50-6), β-Hekzabromosiklododekan (CAS 134237-51-7) ve γ-Hekzabromosiklododekanı (CAS 134237-52-8) ifade eder.

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
1	1,1-Dikloroetan	75-34-3	1000	10000	1000	10000
2	1,2,4,5-tetraklorobenzen	95-94-3	6	24	6	24
3	1,2,4-trimetilbenzen	95-63-6	7,4	516	0,3	516
4	1,3,5-trimetilbenzen; Mesitilen	108-67-8	9	150	0,8	150
5	1,3-diklorobenzen	541-73-1	58	599	58	599
6	1,4-diklorobenzen	106-46-7	38	284	38	284
7	17-alfa-etinilestradiyol	57-63-6	0,5	0,9	0,5	0,9
8	17-beta-estradiyol	50-28-2	0,5	0,5	0,5	0,5
9	1-kloro-2,4-dinitrobenzen	97-00-7	5	20	5	20
10	1-Kloronaftalin	90-13-1	0,7	7	0,7	7
11	1-metilnaftalin	90-12-0	1,5	29	1,5	29
12	2,3,4,5,6-Pentaklorotoluen; Pentaklorotoluen	877-11-2	1,3	1,3	0,004	0,07
13	2,4,6-tri-tert-butilfenol	732-26-3	0,06	0,6	0,06	0,6
14	2,6-di-ter-butilfenol; 2,6-di-tersiyer-butilfenol	128-39-2	7,6	76	7,6	76
15	2,6-ksilenol	576-26-1	54	112	1,1	112
16	2-amino-4-klorofenol	95-85-2	10	100	10	100
17	2-kloronaftalin	91-58-7	1,6	40	1	40
18	3,6-dimetilfenantren	1576-67-6	2	2	0,05	0,13
19	4,4'-DDD	72-54-8	0,025	0,025	0,01	0,025
20	4,4'-Dibromodifenil eter	2050-47-7	1,5	1,5	0,004	0,07
21	4,5-dikloro-2-oktil-2H-izotiyazol-3-on	64359-81-5	0,17	0,34	0,17	0,34
22	4-Aminoazobenzen	60-09-3	0,7	46	0,7	7
23	4-Kloro-3-metilfenol; Paraklorometakresol	59-50-7	37	366	37	366
24	4-kloroanilin	106-47-8	0,005	85	0,26	85
25	Aldrin	309-00-2	0,01	-	0,01	-
26	Alüminyum*	7429-90-5	2,2	27	2,2	22
27	Antimon*	7440-36-0	7,8	103	4,5	45
28	Arsenik*	7440-38-2	53	53	10	20
29	Asenaften	83-32-9	6	66	6	66

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
30	Asetaklor; 2-kloro-N-(etoksimetil)-N-(2-etil-6-metilfenil)asetamid	34256-82-1	0,3	10,1	0,3	10,1
31	Azinfos-metil	86-50-0	0,05	0,4	0,05	0,4
32	Bakır*	7440-50-8	1,6	3,1	1,3	5,7
33	Baryum	7440-39-3	680	680	680	680
34	Benzil benzoat	120-51-4	1000	10000	1000	10000
35	Benzilbutilfitalat (BBP)	85-68-7	2,7	44	2,7	27
36	Benzo(a)floren	238-84-6	0,1	1	0,1	1
37	Benzo(e)piren	192-97-2	0,6	0,6	0,05	0,05
38	Berilyum	7440-41-7	2,5	3,9	2,5	3,9
39	Bifenil	92-52-4	46	87	46	87
40	Bis(2-etilhekzil) terefitalat	6422-86-2	0,1	0,15	0,1	0,15
41	Bisfenol-A	80-05-7	6,5	252	6,5	65
42	Bor*	7440-42-8	707	1472	707	1472
43	Bromür	7726-95-6	31	46	31	46
44	Çinko*	7440-66-6	5,9	231	5,33	76
45	DDT (toplam)	50-29-3	0,01	0,65	0,01	0,1
46	Dekametilsiklopentasiloksan ; Siloksan-D5	541-02-6	0,6	0,6	0,6	0,6
47	Demeton	8065-48-3	20	20	20	20
48	Demir*	7439-89-6	36	101	36	101
49	Diazinon	333-41-5	0,9	4	0,9	4
50	Dibutilfitalat (DBP)	84-74-2	16	96	1,5	96
51	Dibutilkalay oksit	818-08-6	4	67	4	40
52	Dieldrin	60-57-1	0,02	0,93	0,02	0,93
53	Dietil Fitalat	84-66-2	72	1920	72	1920
54	Difenil eter; difenil oksit	101-84-8	6	60	1	60
55	Difenilamin	122-39-4	37	100	44	440
56	Diizobütil adipat	141-04-8	8,7	9	11	11
57	Diklofenak	15307-79-6	100	100	100	100
58	Dioktil fitalat (DnOP)	117-84-0	1680	16800	1680	16800
59	EDTA	60-00-4	39	39	39	39
60	Endrin	72-20-8	0,01	-	0,01	-

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
61	Etilentiyoüre (ETU); İmidazolidin-2-tiyon; Etilentiyoüre (ETU)	96-45-7	248	2000	248	2000
62	Fenantren	85-01-8	1,4	11,2	1,4	11,2
63	Fenitrotiyon (ISO); O,O-dimetil O-4-nitro-m-tolil fosforotiyoat	122-14-5	3,5	103	3,5	103
64	Fentiyon	55-38-9	0,05	1,1	0,05	1,1
65	Floren	86-73-7	3,4	47	3,4	47
66	Gümüş*	7440-22-4	1,5	1,5	1,5	1,5
67	Izopropilbenzen	98-82-8	35	260	35	260
68	İsodrin	465-73-6	0,01	-	0,01	-
69	Kalay*	7440-31-5	13	13	13	13
70	Karbontetraklorür	56-23-5	7,2	130	7,2	130
71	Klofibrik asit	882-09-7	0,3	89	0,5	89
72	Kloroasetik asit	79-11-8	0,5	5	0,5	5
73	Klorotalonil	1897-45-6	0,3	4,2	0,3	2
74	Kobalt*	7440-48-4	0,3	2,6	0,3	2,6
75	Krisen	218-01-9	1,9	19	1,9	19
76	Krom*	7440-47-3	1,6	142	4,2	88
77	Ksilen (m)	108-38-3	24	273	1,4	273
78	Ksilen (o)	95-47-6	24	585	1,8	585
79	Ksilen misk	81-15-2	5,6	56	5,6	56
80	Linuron	330-55-2	3	7	3	7
81	Merkaptobenzotiyazol (MBT); Benzotiyazol-2-tiyol; 2-Merkaptobenzotiyazol (MBT)	149-30-4	50	50	50	50
82	N,N,N',N'-tetrametil-4,4'-metilenedianilin (Michler's bazı)	101-61-1	20	20	0,26	3
83	n-bütilkalay triklorür	1118-46-3	1,2	12	1,2	12
84	Nitrobenzen	98-95-3	187	3516	187	3516
85	p-(1,1-dimetilpropil)fenol	80-46-6	9	14	0,07	14
86	Poliklorlubifeniller (PCB'ler)	1336-36-3	0,31	0,37	0,07	0,14

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
87	PCB 101	37680-73-2	0,25	0,25	0,01	0,02
88	PCB 138	35065-28-2	0,01	0,02	0,01	0,02
89	PCB 153	35065-27-1	0,01	0,02	0,01	0,02
90	PCB 180	35065-29-3	0,01	0,02	0,01	0,02
91	PCB 28	7012-37-5	0,01	0,02	0,01	0,02
92	PCB 31	16606-02-3	0,01	0,02	0,01	0,02
93	PCB 52	35693-99-3	0,01	0,02	0,01	0,02
94	Perilen	198-55-0	0,6	0,6	0,01	0,03
95	Permetrin	52645-53-1	0,12	0,12	0,12	0,12
96	Petrol Hidrokarbonları	-	96	100	96	100
97	Piren	129-00-0	0,1	0,4	0,02	0,4
98	Piriproksifen	95737-68-1	0,02	7,5	0,02	7,5
99	Prokloraz; N-propil-N-[2-(2,4,6-triklorofenoksi)etil]-1H-imidazol-1-karboksamid	67747-09-5	11	13	11	13
100	Propetamfos	31218-83-4	0,05	0,7	1,5	15
101	Propilbenzen	103-65-1	0,2	1,7	0,2	1,7
102	Serbest CN	57-12-5	1,2	6	1,2	6
103	Silisyum	7440-21-3	1830	1830	610	6891
104	Stiren; Vinilbenzen	100-42-5	6,3	575	5,1	575
105	Sülfametoksazol	723-46-6	5	50	5	50
106	Ter-bütil-4-metoksifenol	25013-16-5	0,9	9	0,9	9
107	Tetrabromobisfenol A (TBBP-A)	79-94-7	2	20	2	20
108	Titanyum*	7440-32-6	26	42	26	42
109	Triadimenol; α-ter-bütil-β-(4-klorofenoksi)-1H-1,2,4-triazol-1-etanol	55219-65-3	32	250	1,5	15
110	Tribromodifenil eter	49690-94-0	1,6	1,6	0,004	0,08
111	Tributil fosfat	126-73-8	53	326	53	326
112	Tridekan	629-50-5	0,05	0,05	0,05	0,05
113	Trifenilkalay; Fentin	668-34-8	0,5	0,5	0,5	0,5
114	Trikloroetilen (TRI)	79-01-6	177	8163	177	8163
115	Triklosan	3380-34-5	0,12	1,1	0,12	1,1
116	Tris(nonilfenil) fosfit	26523-78-4	10	10	10	10
117	Vanadyum*	7440-62-2	1,6	97	1,6	16

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (μg/L)**	**MAK-ÇKS Nehirler/ Göller (μg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (μg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (μg/L)**
118	2,4,5-triklorofenoksiasetikasit (2,4,5-t)	93-76-5	400	829	1	829
119	2,4-d isooktil ester	25168-26-7	0,2	26	2,8	26
120	2,4-d; (2,4-diklorofenoksi)asetik asit	94-75-7	5,3	583	5,3	583
121	2-metil-4,6-dinitro-fenol DNOK	534-52-1	20	23	20	23
122	Asetamiprid	135410-20-7	42	42	42	42
123	Atrazin-desetil	6190-65-4	0,3	3	0,3	3
124	Azoksistrobin	131860-33-8	0,2	6	0,2	6
125	Bentazon	25057-89-0	4,5	832	4,5	832
126	Lindan (γ-bhc, 1α,2α,3β,4α,5α,6β-hekzaklorosiklohekzan)	58-89-9	1,4	4	1,4	1,4
127	Boskalid	188425-85-6	19	113	19	113
128	Bromofos-etil	4824-78-6	0,01	0,1	0,01	0,1
129	Bromofos-metil	2104-96-3	0,001	0,1	0,001	0,01
130	Bromopropilat	18181-80-1	0,12	23	0,12	1,2
131	Bromoksinil	1689-84-5	36	262	0,8	262
132	Buprofezin	69327-76-0	3,5	3,5	3,5	3,5
133	Butralin	33629-47-9	0,1	4,1	0,1	4,1
134	Kadusafos	95465-99-9	0,01	0,02	0,01	0,02
135	Kaptan	133-06-2	1,6	8,5	1,6	8,5
136	Karbaril	63-25-2	9	34	0,04	34
137	Karbendazim	10605-21-7	2,7	77	2,7	77
138	Karbofuran	1563-66-2	2,3	2,3	0,05	1,6
139	Karboksin; vitavaks	5234-68-4	11	11	5	5
140	Klorantraniliprol	500008-45-7	0,09	1,4	12	12
141	Klorobenzilat	510-15-6	6	60	0,8	8
142	Klordan	57-74-9	42	42	42	42
143	Klorfenapir	122453-73-0	0,007	0,4	0,007	0,4
144	Kloridazon; pirazon	1698-60-8	6	6	0,01	0,1
145	Klorsulfuron	64902-72-3	0,02	0,6	2000	2000
146	Klofentezin	74115-24-5	0,12	0,5	0,025	0,25
147	Klopiralid	1702-17-6	200	200	200	200

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
148	Klotianidin	210880-92-5	1,2	1,2	1,2	1,2
149	Siklanilid	113136-77-9	2,5	10	2,5	10
150	Siflutrin; beta siflutrin	68359-37-5	0,001	0,003	0,001	0,003
151	Siprodinil	121552-61-2	4,3	21	4,3	21
152	Siromazin	66215-27-8	0,2	16	0,3	3
153	4,4′-dde; 1,1-dikloro-2,2-bis(4-klorofenil) etin	72-55-9	0,02	0,2	0,02	0,2
154	Diklobenil	1194-65-6	0,6	187	74	187
155	Dietofenkarb	87130-20-9	0,7	910	0,7	7
156	Difenokonazol	119446-68-3	0,2	5,5	0,2	5,5
157	Diflubenzuron	35367-38-5	0,13	0,13	0,02	0,02
158	Diflufenikan	83164-33-4	0,01	0,01	0,01	0,01
159	Dimetenamid	87674-68-8	0,4	1,5	0,4	1,5
160	Dimetoat	60-51-5	15	15	15	15
161	Dimetomorf	110488-70-5	3,5	61	3,5	61
162	Dimetilaminosulfanilid	4710-17-2	100	9560	100	1000
163	Dinobuton	973-21-7	0,05	0,5	0,05	0,5
164	Epoksikonazol	133855-98-8	0,8	0,8	0,03	0,3
165	Etalfluralin	55283-68-6	0,3	0,5	0,5	0,5
166	Etofumesat	26225-79-6	48	324	48	324
167	Etoprofos	13194-48-4	0,21	6,4	0,21	0,35
168	Fenamifos	22224-92-6	0,01	0,08	0,01	0,08
169	Fenarimol	60168-88-9	0,07	0,07	0,07	0,07
170	Fenbutatin ksit	13356-08-6	0,1	0,5	0,1	0,5
171	Feneksamid	126833-17-8	28	28	28	28
172	Fenpropatrin	39515-41-8	0,01	0,01	0,01	0,01
173	Fenpropimorf	67564-91-4	0,1	30	0,1	1
174	Fluazifop-p-butil	79241-46-6	4,8	53	4,8	48
175	Fludioksonil	131341-86-1	1,2	3,1	1,2	3,1
176	Fluopiram	658066-35-4	50	275	22	43
177	Flukinkonazol	136426-54-5	3,1	3,1	3,1	3,1
178	Fluroksipir	69377-81-7	5600	5600	5600	5600
179	Flutolanil	66332-96-5	55	975	0,6	0,6
180	Flutriafol	76674-21-0	25	79	25	79
181	Fosetil al	39148-24-8	25	330	25	330
182	Fostiazat	98886-44-3	42	42	42	42

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
183	Hekzakonazol	79983-71-4	11	115	11	115
184	Hekzitiazoks	78587-05-0	0,4	0,4	0,4	0,4
185	Imazalil	35554-44-0	50	73	50	73
186	Imazapir	81334-34-1	1900	1900	1590	1840
187	Imidakloprid	138261-41-3	0,14	1,4	0,14	1,4
188	Lenasil	2164-08-1	1	1	1	1
189	Malation	121-75-5	42	42	42	42
190	Mandipropamid	374726-62-2	46	250	46	250
191	Mepikuat klorit	24307-26-4	20	20	20	20
192	Mesotrion	104206-82-8	44	705	44	705
193	Metalaksil	57837-19-1	17	5320	1	10
194	Metam potasyum	137-41-7	24	240	24	240
195	Metamitron	41394-05-2	2	4,5	2	4,5
196	Metazaklor	67129-08-2	42	42	42	42
197	Metamidofos	10265-92-6	0,2	0,2	0,2	0,2
198	Metidation	950-37-8	42	42	42	42
199	Metomil	16752-77-5	42	42	42	42
200	Metoksifenozid	161050-58-4	11	110	11	110
201	Metolaklor	51218-45-2	3,3	88	3,3	88
202	Metrafenon	220899-03-6	12	13	1	13
203	Molinat	2212-67-1	136	460	136	460
204	Monokrotofos	6923-22-4	0,4	45	1	45
205	Miklobutanil	88671-89-0	9,6	9,6	9,6	9,6
206	Nikosulfuron	111991-09-4	0,05	0,2	0,05	0,2
207	Nitrofen	1836-75-5	0,2	90	0,2	2
208	Ometoat	1113-02-6	16	16	85	85
209	Okzadiazon	19666-30-9	0,3	9	0,3	9
210	Okzadiksil	77732-09-3	306	306	306	306
211	Paration-metil	298-00-0	1,4	2,5	0,01	2,5
212	Penkonazol	66246-88-6	1,2	1,9	1,2	1,9
213	Pendimetalin	40487-42-1	0,5	8	0,5	8
214	Fentoat	2597-03-7	0,05	0,5	0,05	0,5
215	Pikloram	1918-02-1	55	1401	12	120
216	Piperonil butoksit	51-03-6	3,3	350	0,8	350
217	Pirimikarb	23103-98-2	3,3	21	3,3	21
218	Prosimidon	32809-16-8	12	12	12	12

Table A 10. River Basin Specific Pollutants and Their Environmental Quality Standards (Annex V Table 4 of Surface Water Quality Regulation) (Continued)

No	**Kimyasal Adı**	**CAS No**	**YO-ÇKS Nehirler/ Göller (µg/L)**	**MAK-ÇKS Nehirler/ Göller (µg/L)**	**YO-ÇKS Kıyı ve Geçiş Suları (µg/L)**	**MAK-ÇKS Kıyı ve Geçiş Suları (µg/L)**
219	Prometrin	7287-19-6	0,3	2	0,3	2
220	Propamokarb HCL	25606-41-1	2240	3914	185	3914
221	Propazin	139-40-2	0,3	4,1	0,3	4,1
222	Profam	122-42-9	1	989	1	10
223	Propikonazol	60207-90-1	0,7	50	0,7	50
224	Propizamid	23950-58-5	23	112	23	112
225	Protiofos	34643-46-4	0,1	16	0,1	16
226	Piraklostrobin	175013-18-0	0,08	0,08	0,08	0,08
227	Piridaben	96489-71-3	0,25	0,25	0,25	0,25
228	Pirimetanil	53112-28-0	12	139	12	139
229	Kuinalfos	13593-03-8	0,2	1,4	0,2	1,4
230	Kuizalofop-p-etil	100646-51-3	1	1	1	1
231	Spiroksamin	118134-30-8	42	42	42	42
232	Tebukonazol	107534-96-3	23	121	1,6	121
233	Tebutiuron	34014-18-1	0,18	7,4	0,18	7,4
234	Teknazen	117-18-0	1	10	1	10
235	Teflutrin	79538-32-2	0,002	0,002	0,002	0,002
236	Terbutilazin	5915-41-3	0,2	3,5	0,01	3,5
237	Tiabendazol	148-79-8	0,5	28	0,5	28
238	Tiakloprid	111988-49-9	0,13	2	0,13	2
239	Tiametokzam	153719-23-4	20	20	20	20
240	Tidiazuron	51707-55-2	10	61	10	61
241	Tiometon	640-15-3	0,01	47	0,01	0,1
242	Tiofanat-metil	23564-05-8	42	42	42	42
243	Tolklofos-metil	57018-04-9	1,2	7	1,2	7
244	Tolfenpirad	129558-76-5	0,2	0,2	0,2	0,2
245	Triasulfuron	82097-50-5	0,012	0,12	1,8	1,8
246	Tribenuron-metil	101200-48-0	0,04	0,08	0,04	0,08
247	Trifloksistrobin	141517-21-7	42	42	42	42
248	Triflumuron	64628-44-0	0,23	0,23	0,23	0,23
249	Trinekzapak-etil	95266-40-3	13	86	13	86
250	Vinklozolin	50471-44-8	1,1	84	1,1	84

* Havza bazında arkaplan konsantrasyonunun belirlenmesinin ardından Ek-2'de belirtildiği şekilde değerlendirme yapılır. Ayrıca, metallerin biyolojik olarak birikimi veya sucul ortama karışması açısından sertlik, pH ve diğer su kalite parametreleri de göz önünde bulundurulur.

F. Occurrence of Micropollutants in Surface Water Samples of the Yeşilırmak River Basin

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Nickel	Metal	0.073	345	345	100.0
Aluminum	Metal	0.512	345	345	100.0
Arsenic	Metal	0.209	345	345	100.0
Barium	Metal	0.447	345	345	100.0
Cobalt	Metal	0.026	345	345	100.0
Copper	Metal	0.263	345	345	100.0
Iron	Metal	2.172	345	345	100.0
Vanadium	Metal	0.021	345	345	100.0
Zinc	Metal	0.667	345	345	100.0
Boron	Metalloid	0.067	345	345	100.0
Silicon	Metalloid	19.7	297	297	100.0
Lead	Metal	0.066	344	345	99.7
Chromium	Metal	0.2	344	345	99.7
Silver	Metal	0.021	336	345	97.4
Antimony	Metalloid	0.12	333	345	96.5
Petroleum Hydrocarbons	Industrial Organic Compound	50	190	217	87.6
Dioxin Like Compounds	Industrial Organic Compound	0.00001	61	169	36.1
Cadmium	Metal	0.059	115	345	33.3
Bromine	Halogen	100	102	345	29.6
Beryllium	Metal	0.037	86	345	24.9
Nonylphenols (4-Nonylphenol)	Industrial Organic Compound	0.001	73	345	21.2
Titanium	Metal	7.67	63	305	20.7
Trichloromethane	Industrial Organic Compound	0.1	67	345	19.4
Anthracene	Industrial Organic Compound	0.001	65	345	18.8
Buprofezin	Insecticide	0.01	59	345	17.1
Dichlorvos	Insecticide	0.0005	56	345	16.2
Dioxin	Industrial Organic Compound	0.000005	25	169	14.8
Diethyl phthalate (DEP)	Industrial Organic Compound	0.001	47	345	13.6
Phenanthrene	Industrial Organic Compound	0.001	47	345	13.6
Di(2-ethylhexyl)-phthalate (DEHP)	Industrial Organic Compound	0.001	41	345	11.9
Bisphenol-A (BPA)	Industrial Organic Compound	0.001	38	345	11.0

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Fluorene	Industrial Organic Compound	0.001	38	345	11.0
Piperonyl butoxide	Insecticide	0.01	38	345	11.0
Benzyl Benzoate	Insecticide	0.001	37	345	10.7
Cypermethrin	Insecticide	0.005	32	305	10.5
Hexachlorocyclohexane	Insecticide	0.005	35	345	10.1
Hexachlorobenzene	Fungicide	0.001	34	345	9.9
Carbendazim	Fungicide	0.002	33	345	9.6
Acenaphthene	Industrial Organic Compound	0.005	33	345	9.6
1,1-Dichloroethane	Industrial Organic Compound	0.1	31	345	9.0
2,6 xylenol (2,6-dimethylphenol)	Industrial Organic Compound	0.001	31	345	9.0
Fluoranthene	Industrial Organic Compound	0.001	29	345	8.4
Imidacloprid	Insecticide	0.02	28	345	8.1
2-chloro-N-(ethoxymethyl)-N-(2-ethyl-6-ethylphenyl)acetamide	Herbicide	0.1	26	345	7.5
Epoxiconazole	Fungicide	0.005	25	345	7.2
Ethalfluralin	Herbicide	0.005	25	345	7.2
Dibutyl phthalate (DBP)	Pharmaceutical/PCP	0.01	24	345	7.0
Flutriafol	Fungicide	0.05	23	345	6.7
Fluroxypyr	Herbicide	0.05	22	345	6.4
PCB (Polychlorinated bipehnyls) 28	Industrial Organic Compound	0.001	22	345	6.4
Diisobutyl adipate	Pharmaceutical/PCP	0.01	22	345	6.4
Free CN	Industrial Organic Compound	1	19	304	6.3
Diflubenzuron	Insecticide	0.05	21	345	6.1
Dichloromethane (DCM)	Industrial Organic Compound	2	20	345	5.8
Diphenyl ether	Pharmaceutical/PCP	0.001	20	345	5.8
Chlorsulphuron	Insecticide	0.02	17	305	5.6
Xylene (m)	Industrial Organic Compound	0.1	19	345	5.5
Cyfluthrin; beta cyfluthrin	Insecticide	0.01	18	345	5.2
p-(1,1-dimethylpropyl) phenol (Amylphenol)	Industrial Organic Compound	0.01	17	345	4.9
1-Methylnaphthalene	Pharmaceutical/PCP	0.005	17	345	4.9
4-Chloro-3-methylphenol; Parachlorometacresol	Pharmaceutical/PCP	0.005	17	345	4.9
sulfamethoxazole	Pharmaceutical/PCP	0.1	17	345	4.9
Tridecane	Industrial Organic Compound	0.02	16	345	4.6
Prothiofos	Insecticide	0.05	16	345	4.6
Chloridazon; pirazone	Herbicide	0.05	15	345	4.3

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
2,6-di-tert-butylphenol	Industrial Organic Compound	0.001	15	345	4.3
Biphenyl	Industrial Organic Compound	0.005	15	345	4.3
Dimethoate	Insecticide	0.002	15	345	4.3
Aclonifen	Herbicide	0.005	14	345	4.1
Benzyl butyl phthalate (BBP)	Industrial Organic Compound	0.005	14	345	4.1
Mercury	Metal	0.13	10	249	4.0
Decamethylcyclopentasiloxane; Siloxane-D5	Pharmaceutical/PCP	0.001	12	305	3.9
Bifenox	Herbicide	0.005	13	345	3.8
Octylphenol ((4-(1,1' ,3,3' -tetramethylbutyl)-phenol))	Industrial Organic Compound	0.005	13	345	3.8
Atrazine-Desethyl	Herbicide	0.3	13	345	3.8
3,6-Dimethylphenanthrene	Industrial Organic Compound	0.005	12	345	3.5
Benzene	Industrial Organic Compound	0.1	11	345	3.2
Chloothalonil	Fungicide	0.01	11	345	3.2
Trinexapac-ethyl	Growth Regulator	0.01	11	345	3.2
Bis (2-ethylhexyl) terephthalate (DTOP)	Industrial Organic Compound	0.001	11	345	3.2
4-chloroaniline	Pharmaceutical/PCP	0.005	11	345	3.2
Diphenyl amine	Fungicide	0.002	10	345	2.9
Metalaxyl	Fungicide	0.005	10	345	2.9
Mesotrione	Herbicide	0.05	10	345	2.9
Benzo(e)pyrene	Industrial Organic Compound	0.001	10	345	2.9
Nitrobenzene	Industrial Organic Compound	0.2	10	345	2.9
PCB (Polychlorinated bipehnyls) 138	Industrial Organic Compound	0.001	10	345	2.9
Pyrene	Industrial Organic Compound	0.005	10	345	2.9
1,2-dichloroethane	Industrial Organic Compound	0.1	9	345	2.6
Fosetyl-Al	Fungicide	0.1	9	345	2.6
PCB (Polychlorinated bipehnyls) 52	Industrial Organic Compound	0.001	9	345	2.6
Thiacloprid	Insecticide	0.05	9	345	2.6
Propham	Herbicide	0.05	8	345	2.3
2-Mercaptobenzothiazole (MBT)	Industrial Organic Compound	0.001	8	345	2.3
N-butyltin trichloride	Industrial Organic Compound	0.003	4	186	2.2
benzo(b)fluoranthene	Industrial Organic Compound	0.001	7	345	2.0
benzo(k)fluoranthene	Industrial Organic Compound	0.001	7	345	2.0
Fenpropimorph	Fungicide	0.1	7	345	2.0
Pyrimethanil	Fungicide	0.02	7	345	2.0

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Procymidone	Herbicide	0.01	7	345	2.0
PCB (Polychlorinated bipehnyls) 153	Industrial Organic Compound	0.001	7	345	2.0
Isoproturon	Herbicide	0.05	6	345	1.7
Benzo(a)pyrene	Industrial Organic Compound	0.0001	6	345	1.7
Cyprodinil	Fungicide	0.01	6	345	1.7
Tebuconazole	Fungicide	0.02	6	345	1.7
Chrysene	Industrial Organic Compound	0.001	6	345	1.7
PCB (Polychlorinated bipehnyls) 180	Industrial Organic Compound	0.001	6	345	1.7
DDT (total)	Insecticide	0.005	6	345	1.7
Thiamethoxam	Insecticide	0.002	6	345	1.7
Tin	Metal	10	6	345	1.7
1-chloro-2,4-dinitrobenzene	Pharmaceutical/PCP	0.01	6	345	1.7
Benzo(g,h,i)perylene	Industrial Organic Compound	0.001	5	345	1.4
Indeno(1,2,3-cd)pyrene	Industrial Organic Compound	0.001	5	345	1.4
Lindane (γ-bhc, 1α,2α,3β,4α,5α,6β-hexachlorocyclohexane)	Insecticide	0.001	5	345	1.4
Cyromazine	Insecticide	0.05	5	345	1.4
Methidathion	Insecticide	0.05	5	345	1.4
Captan	Fungicide	0.002	4	345	1.2
Diflufenican	Herbicide	0.01	4	345	1.2
Lenacil	Herbicide	0.02	4	345	1.2
Metamitron	Herbicide	0.05	4	345	1.2
Picloram	Herbicide	0.05	4	345	1.2
Fenthion	Insecticide	0.05	4	345	1.2
Parathion-Methyl	Insecticide	0.01	4	345	1.2
Diclofenac	Pharmaceutical/PCP	0.1	4	345	1.2
Diuron	Herbicide	0.01	3	345	0.9
Naphthalene	Industrial Organic Compound	0.1	3	345	0.9
Penconazole	Fungicide	0.02	3	345	0.9
1,2,4-trimethylbenzene	Industrial Organic Compound	0.1	3	345	0.9
1,4-dichlorobenzene	Industrial Organic Compound	0.1	3	345	0.9
Dioctyl terephthalate (DnOP)	Industrial Organic Compound	0.01	3	345	0.9
Chlorfenapyr	Insecticide	0.005	3	345	0.9
Metam potassium	Insecticide	0.1	3	345	0.9
Metrafenone	Fungicide	0.01	2	345	0.6

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Myclobutanil	Fungicide	0.04	2	345	0.6
Propamocarb HCL	Fungicide	0.005	2	345	0.6
Clopyralid	Herbicide	0.002	2	345	0.6
Molinate	Herbicide	0.05	2	345	0.6
4,4-Dichlorodiphenyldichloroethane (DDD)	Insecticide	0.001	2	345	0.6
Chlorobenzilate	Insecticide	0.5	2	345	0.6
Clothianidin	Insecticide	0.05	2	345	0.6
4,4′-dde; 1,1-dichloro-2,2-bis(4-chlorophenyl) etin	Insecticide	0.001	2	345	0.6
Pirimicarb	Insecticide	0.05	2	345	0.6
Pyrilen	Pharmaceutical/PCP	0.01	2	345	0.6
Permethrin	Pharmaceutical/PCP	0.01	2	345	0.6
PCB (Polychlorinated bipehnyls)	Industrial Organic Compound	0.005	1	227	0.4
Hexachlorobutadiene	Industrial Organic Compound	0.1	1	345	0.3
Pentachlorobenzene	Industrial Organic Compound	0.005	1	345	0.3
Trichlorobenzenes	Industrial Organic Compound	0.1	1	345	0.3
Chlorpyrifos (Chlorpyrifos-ethyl)	Insecticide	0.01	1	345	0.3
Heptachlor and heptachlor epoxide	Insecticide	0.001	1	345	0.3
Azoxystrobin	Fungicide	0.05	1	345	0.3
Fenarimol	Fungicide	0.05	1	345	0.3
Hexaconazole	Fungicide	0.04	1	345	0.3
Trifloxystrobin	Fungicide	0.05	1	345	0.3
Mepiquat chloride	Growth Regulator	0.05	1	345	0.3
Metolachlor	Herbicide	0.05	1	345	0.3
Nicosulfuron	Herbicide	0.02	1	345	0.3
Pendimethalin	Herbicide	0.05	1	345	0.3
1,2,4,5-tetrachlorobenzene	Industrial Organic Compound	0.005	1	345	0.3
1,3-dichlorobenzene	Industrial Organic Compound	0.1	1	345	0.3
2-chloronaphthalene	Industrial Organic Compound	0.005	1	345	0.3
Ethylene Thiourea (ETU)	Industrial Organic Compound	0.2	1	345	0.3
1-chloronaphthalene	Insecticide	0.005	1	345	0.3
Azinphos-methyl	Insecticide	0.05	1	345	0.3
Diazinon	Insecticide	0.002	1	345	0.3
Endrin	Insecticide	0.005	1	345	0.3
Isodrin	Insecticide	0.001	1	345	0.3

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Cadusafos	Insecticide	0.01	1	345	0.3
Carbaryl	Insecticide	0.01	1	345	0.3
Carbofuran	Insecticide	0.1	1	345	0.3
Fenpropathrin	Insecticide	0.01	1	345	0.3
Monocrotophos	Insecticide	0.05	1	345	0.3
Quinoxyfen	Fungicide	0.1	0	345	0.0
Cybutryne	Fungicide	0.001	0	345	0.0
Alachlor	Herbicide	0.1	0	345	0.0
Atrazine	Herbicide	0.05	0	345	0.0
Simazine	Herbicide	0.05	0	345	0.0
Trifluralin	Herbicide	0.01	0	345	0.0
Terbutryn	Herbicide	0.001	0	345	0.0
Poly Aromatic Hydrocarbons (PAH)	Industrial Organic Compound	N/A	0	0	0.0
C10-13-Chloroalkanes	Industrial Organic Compound	0.05	0	186	0.0
Tributyltin compounds (Tributyltin cations)	Industrial Organic Compound	0.0005	0	186	0.0
Brominated diphenyl ethers	Industrial Organic Compound	0.004	0	345	0.0
Pentachlorophenol	Industrial Organic Compound	0.1	0	345	0.0
Perfluorooctane sulfonic acid and derivatives (PFOS)	Industrial Organic Compound	0.05	0	345	0.0
Hexabromo-cyclododecane (HBCDD)	Industrial Organic Compound	0.05	0	345	0.0
Chlorfenvinphos	Insecticide	0.005	0	345	0.0
Endosulfan	Insecticide	0.005	0	345	0.0
Dicofol	Insecticide	0.001	0	345	0.0
Imazalil	Fungicide	0.02	0	305	0.0
4,5-dichloro-2-octyl-2H-isothiazolone-3-one	Fungicide	0.05	0	345	0.0
Prochloraz; N-propyl-N-[2-(2,4,6-trichlorophenoxy)ethyl]-1H-imidazole-1-carboxamide	Fungicide	0.05	0	345	0.0
Triadimenol; α-ter-butyl-β-(4-chlorophenoxy)-1H-1,2,4-triazole-1-ethanol	Fungicide	0.1	0	345	0.0
Boscalid	Fungicide	0.04	0	345	0.0
Carboxin; vitavax	Fungicide	0.05	0	345	0.0
Diethofencarb	Fungicide	0.05	0	345	0.0
Difenoconazole	Fungicide	0.05	0	345	0.0
Dimethomorph	Fungicide	0.01	0	345	0.0
N,N-dimethyl-N'-phenylsulfamide (DMSA)	Fungicide	0.04	0	345	0.0

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Dinobuton	Fungicide	0.01	0	345	0.0
Fenhexamid	Fungicide	0.04	0	345	0.0
Fludioxonil	Fungicide	0.05	0	345	0.0
Fluopyram	Fungicide	0.01	0	345	0.0
Fluquinconazole	Fungicide	0.025	0	345	0.0
Flutolanil	Fungicide	0.05	0	345	0.0
Mandipropamid	Fungicide	0.05	0	345	0.0
Oxadixyl	Fungicide	0.05	0	345	0.0
Propiconazole	Fungicide	0.04	0	345	0.0
Pyraclostrobin	Fungicide	0.05	0	345	0.0
Spiroxamine	Fungicide	0.05	0	345	0.0
Tecnazene	Fungicide	0.01	0	345	0.0
Thiabendazol	Fungicide	0.01	0	345	0.0
Thiophanate-methyl	Fungicide	0.01	0	345	0.0
Tolclofos-methyl	Fungicide	0.5	0	345	0.0
Vinclozolin	Fungicide	0.01	0	345	0.0
Cyclanilide	Growth Regulator	0.5	0	345	0.0
Thidiazuron	Growth Regulator	0.1	0	345	0.0
2,4-D isooctyl ester	Herbicide	0	0	0	0.0
Butralin	Herbicide	0.05	0	305	0.0
Tribenuron-Methyl	Herbicide	0.04	0	305	0.0
Linuron	Herbicide	0.02	0	345	0.0
2,4,5-Trichlorophenoxyacetic (2,4,5-T)	Herbicide	0.5	0	345	0.0
2,4-d; (2,4-dichlorophenoxyacetic acid)	Herbicide	N/A	0	345	0.0
Bentazone	Herbicide	0.05	0	345	0.0
Bromoxynil	Herbicide	0.05	0	345	0.0
Dichlobenil	Herbicide	0.005	0	345	0.0
Dimethenamid	Herbicide	0.01	0	345	0.0
Ethofumesate	Herbicide	0.05	0	345	0.0
Fluazifop-p-butyl	Herbicide	0.05	0	345	0.0
Imazapyr	Herbicide	0.04	0	345	0.0
Metazachlor	Herbicide	0.05	0	345	0.0
Nitrofen	Herbicide	0.01	0	345	0.0
Oxadiazon	Herbicide	0.05	0	345	0.0
Prometryn	Herbicide	0.05	0	345	0.0

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Propazine	Herbicide	0.01	0	345	0.0
Propyzamide	Herbicide	0.05	0	345	0.0
Quizalofop-p-ethyl	Herbicide	0.05	0	345	0.0
Tebuthiuron	Herbicide	0.05	0	345	0.0
Terbuthylazine	Herbicide	0.05	0	345	0.0
Triasulfuron	Herbicide	0.01	0	345	0.0
Chloroacetic acid	Industrial Organic Compound	0	0	0	0.0
Dibutyltin oxide	Industrial Organic Compound	0.01	0	186	0.0
PCB (Polychlorinated bipehnyls) 31	Industrial Organic Compound	0.001	0	307	0.0
1,3,5-trimethylbenzene	Industrial Organic Compound	0.1	0	345	0.0
2,3,4,5,6-Pentachlorotoluene; Pentachlorotoluene	Industrial Organic Compound	0.1	0	345	0.0
2,4,6-Tri-tert-butylphenol	Industrial Organic Compound	0.001	0	345	0.0
2-amino-4-chlorophenol	Industrial Organic Compound	0.1	0	345	0.0
4,4'-Dibromodiphenyl ether	Industrial Organic Compound	0.004	0	345	0.0
4-Aminoazobenzene	Industrial Organic Compound	0.1	0	345	0.0
Benzo(a)fluorene	Industrial Organic Compound	0.001	0	345	0.0
Isopropylbenzene	Industrial Organic Compound	0.1	0	345	0.0
Carbontetrachloride (Tetrachloromethane)	Industrial Organic Compound	0.1	0	345	0.0
Xylene (o)	Industrial Organic Compound	0.1	0	345	0.0
Xylene mix	Industrial Organic Compound	0.1	0	345	0.0
n n n' n'-tetramethyl-4 4'-methylenedianiline (michler's base)	Industrial Organic Compound	0.005	0	345	0.0
PCB (Polychlorinated bipehnyls) 101	Industrial Organic Compound	0.005	0	345	0.0
Propylbenzene	Industrial Organic Compound	0.1	0	345	0.0
Styrene; Vinylbenzene	Industrial Organic Compound	0.1	0	345	0.0
Tetrabromobisphenol A (TBBP-A)	Industrial Organic Compound	0.1	0	345	0.0
Tribromo Diphenyl Ether	Industrial Organic Compound	0.004	0	345	0.0
Tributyl phosphate	Industrial Organic Compound	0.001	0	345	0.0
Trichloroethylene	Industrial Organic Compound	0.1	0	345	0.0
Tris(nonylphenyl) phosphite	Industrial Organic Compound	1.5	0	345	0.0
Propetamphos	Insecticide	0.05	0	305	0.0
Chlorantraniliprol	Insecticide	0.05	0	305	0.0
Tolfenpyrad	Insecticide	0.05	0	305	0.0
Aldrin	Insecticide	0.005	0	345	0.0

Table A 11. Total Number of Surface Water Samples Analyzed in the YRB and Frequency of Occurrence of Priority Substances and River Basin Specific Pollutants (Continued)

Pollutants*	**Group**	**LoQ**	**> LoQ**	**Total Samples Analyzed**	**Frequency of Occurrence (%)**
Demeton	Insecticide	0.01	0	345	0.0
Dieldrin	Insecticide	0.005	0	345	0.0
Fenitrothion	Insecticide	0.5	0	345	0.0
Pyriproxyfen	Insecticide	0.02	0	345	0.0
2-methyl-4,6-dinitro-phenol DNOC	Insecticide	0.05	0	345	0.0
Acetamiprid	Insecticide	0.05	0	345	0.0
Bromophos-Ethyl	Insecticide	0.001	0	345	0.0
Bromophos-Methyl	Insecticide	0.001	0	345	0.0
Bromopropylate	Insecticide	0.01	0	345	0.0
Chlordan	Insecticide	0.005	0	345	0.0
Clofentezin	Insecticide	0.01	0	345	0.0
Ethoprophos	Insecticide	0.05	0	345	0.0
Fenamiphos	Insecticide	0.01	0	345	0.0
Fenbutatin oxide	Insecticide	0.1	0	345	0.0
Fosthiazate	Insecticide	0.005	0	345	0.0
Hexythiazox	Insecticide	0.05	0	345	0.0
Malathion	Insecticide	0.1	0	345	0.0
Methamidophos	Insecticide	0.01	0	345	0.0
Methomyl	Insecticide	0.05	0	345	0.0
Methoxyfenozide	Insecticide	0.1	0	345	0.0
Omethoate	Insecticide	0.02	0	345	0.0
Phenthoate	Insecticide	0.05	0	345	0.0
Pyridaben	Insecticide	0.05	0	345	0.0
Quinalphos	Insecticide	0.05	0	345	0.0
Tefluthrin	Insecticide	0.01	0	345	0.0
Thiometon	Insecticide	0.01	0	345	0.0
Triflumuron	Insecticide	0.05	0	345	0.0
Ethylene Diamine Tetraacetic acid	Pharmaceutical/PCP	N/A	0	0	0.0
tert-butyl-4-methoxyphenol	Pharmaceutical/PCP	N/A	0	0	0.0
Triphenyltin; Fentin	Pharmaceutical/PCP	0.0005	0	186	0.0
17-alpha-ethinylestradiol	Pharmaceutical/PCP	0.1	0	345	0.0
17-beta-estradiol	Pharmaceutical/PCP	0.025	0	345	0.0
Clofibric acid	Pharmaceutical/PCP	1.5	0	345	0.0
Triclosan	Pharmaceutical/PCP	0.1	0	345	0.0

** Priority substances are given in the italic font*

G. Environmental Monitoring Data of Metals in the Literature

Table A 12. The Minimum, Maximum, and Median Environmental Monitoring Data of Metals in the Literature

Country	Stat[1]	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Ni	Pb	Zn
ARG[2]	Min.	-	-	-	-	0.5	-	3.23	99.36	9.04	-	12.70
	Med.	-	-	-	-	4.70	-	4.71	204	11.72	-	25.52
	Max.	-	-	-	-	8.89	-	6.19	308	14.39	-	38.33
BGD[3]	Min.	-	-	16.00	9.34	199	82.00	46.00	612	8.80	-	100.00
	Med.	-	-	35.00	35.00	382	114	163	4,550	39.00	-	330
	Max.	-	-	555	145	565	10,110	765	7855	560	-	1,260
BRA[3]	Min.	-	-	-	0.05	-	0.5	3.28	-	-	-	13.30
	Med.	-	-	-	4.03	-	9.25	44.14	-	-	-	219
	Max.	-	-	-	8.00	-	18.00	85.00	-	-	-	425
TCD[3]	Min.	-	-	-	10.00	-	10.00	70.00	50.00	80.00	-	60.00
	Med.	-	-	-	40.00	-	40.00	105	1,235	245	-	185
	Max.	-	-	-	1,980	-	130	190	1,990	650	-	250
CHN[4]	Min.	-	-	0.672	0.005	0.57	0.06	0.318	24.80	0.11	6.72	0.25
	Med.	-	-	2.83	0.0885	2.00	1.44	3.04	320	4.93	8.96	20.85
	Max.	-	-	50.00	95.70	60.00	352	2,470	6,680	855	11.20	38,110
ECU[3]	Min.	-	-	-	0.012	-	-	0.66	-	-	-	1.50
	Med.	-	-	-	0.585	-	-	19.00	-	-	-	26.00
	Max.	-	-	-	4.50	-	-	3,300	-	-	-	820
ETH[3]	Min.	-	-	-	-	-	-	-	630	-	-	-
	Med.	-	-	-	-	-	-	-	790	-	-	-
	Max.	-	-	-	-	-	-	-	2,180	-	-	-
EU[3]	Min.	-	-	-	-	0.06	-	0.56	-	0.34	-	3.35
	Med.	-	-	-	-	5.03	-	1.28	-	5.17	-	3.68
	Max.	-	-	-	-	10.00	-	2.00	-	10.00	-	4.00
GRC[3]	Min.	-	-	0.1	0.005	-	0.2	0.1	0.13	0.3	-	0.1
	Med.	-	-	0.7	0.2	-	1.40	2.00	42.40	1.60	-	25.25
	Max.	-	-	38.70	4.12	-	27.00	19.00	1,311	25.60	-	24,000
IND[5]	Min.	-	-	0.3	0.21	0.6	0.001	0.00067	0.001	0.001	-	0.01
	Med.	-	-	38.00	8.20	2.80	16.40	10.50	431	15.65	-	46.65
	Max.	-	-	140	84.00	193	21,800	27,400	63,500	200	-	54,000
IDN[3]	Min.	-	-	-	0.02	-	6.00	1.00	-	-	-	-
	Med.	-	-	-	0.3	-	60.50	8.75	-	-	-	-
	Max.	-	-	-	0.35	-	157	64.00	-	-	-	-

Table A 12. The Minimum, Maximum, and Median Environmental Monitoring Data of Metals in the Literature (Continued)

Country	Stat	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Ni	Pb	Zn
IRN[3]	Min.	-	-	55.35	2.65	-	91.17	10.00	30.00	22.40	-	10.00
	Med.	-	-	79.10	30.00	-	145	370	1,100	400	-	121
	Max.	-	-	103	250	-	290	3,430	22,580	830	-	2,600
IRQ[3]	Min.	-	-	-	3.01	-	-	2.35	89.45	9.51	-	6.33
	Med.	-	-	-	10.77	-	-	21.30	135	77.70	-	6.96
	Max.	-	-	-	18.52	-	-	40.25	181	146	-	7.58
CIV[3]	Min.	-	-	2.66	0.05	-	-	22.36	602	-	-	37.66
	Med.	-	-	3.09	0.345	-	-	46.64	657	-	-	62.89
	Max.	-	-	4.54	140	-	-	9,050	1,337	-	-	12,050
JPN[3]	Min.	-	-	-	0.009	0.15	-	2.40	-	-	-	-
	Med.	-	-	-	2.50	25.08	-	273	-	-	-	-
	Max.	-	-	-	5.00	50.00	-	543	-	-	-	-
KOR[3]	Min.	-	-	-	-	-	-	6.97	65.90	1.67	-	7.27
	Med.	-	-	-	-	-	-	7.72	68.55	1.83	-	9.44
	Max.	-	-	-	-	-	-	8.47	71.20	1.99	-	11.60
MYS[3]	Min.	-	-	1.00	1.00	-	3.00	1.00	-	-	-	-
	Med.	-	-	4.00	5.00	-	50.00	33.00	-	-	-	-
	Max.	-	-	7.00	43.00	-	167	58.00	-	-	-	-
MNG[3]	Min.	-	-	-	-	-	-	1.00	11.50	0.7	-	5.20
	Med.	-	-	-	-	-	-	2.60	130	9.35	-	14.10
	Max.	-	-	-	-	-	-	4.20	249	18.00	-	23.00
NGA[3]	Min.	-	-	-	7.30	630	7.70	34.10	1,000	22.00	-	84.70
	Med.	-	-	-	30.00	1,265	1,634	62.90	1,936	38.90	-	1,882
	Max.	-	-	-	13,700	1,900	8,800	4,900	9,408	4,513	-	22,230
PAK[3]	Min.	-	-	76,500	30.00	250	20.00	20.00	150	130	-	30.00
	Med.	-	-	80,200	3,165	38,165	3,640	9,215	2,900	34,000	-	1,160
	Max.	-	-	86,100	5,800	42,970	8,200	21,100	3,400	38,100	-	1,870
POL[3]	Min.	-	-	-	0.12	-	0.73	2.00	488	11.00	-	13
	Med.	-	-	-	0.74	-	0.885	5.50	528	21.50	-	458
	Max.	-	-	-	12.72	-	1.32	8.00	649	28.00	-	5,020
ZAF[3]	Min.	-	-	-	0.3	-	15.00	24.00	702	-	-	31.00
	Med.	-	-	-	1	-	270	44.65	807	-	-	83.10
	Max.	-	-	-	2	-	357	185	2,645	-	-	261
ESP[3]	Min.	-	-	0.81	0.0155	-	0.75	0.35	120	1.57	-	1.21
	Med.	-	-	4.10	0.75	-	7.04	5.52	165	5.46	-	80.60
	Max.	-	-	9.30	16.00	-	41.00	72.40	210	42.00	-	382

Table A 12. The Minimum, Maximum, and Median Environmental Monitoring Data of Metals in the Literature (Continued)

Country	Stat	Ag	Al	As	Cd	Co	Cr	Cu	Fe	Ni	Pb	Zn
TZA[3]	Min.	-	-	-	-	-	70.00	-	-	-	-	18.00
	Med.	-	-	-	-	-	178	-	-	-	-	50.00
	Max.	-	-	-	-	-	178	-	-	-	-	50.00
TUR[6]	Min.	-	-	2.35	0.0033	7.00	0.093	0.88	24.00	2.27	-	28.00
	Med.	-	-	2.35	0.589	12.57	2.19	40.00	92.50	33.50	-	115
	Max.	-	-	49.95	27.25	111	11.68	165	2,740	900	-	420
VNM[3]	Min.	-	-	3.81	-	-	3.15	4.04	-	2.95	-	11.00
	Med.	-	-	4.80	-	-	3.81	5.21	-	4.73	-	16.85
	Max.	-	-	10.30	-	-	11.2	8.38	-	7.33	-	36.10
GBR[7]	Min.	0.002	5.00	0.5	0.005	-	0.25	0.02	15.00	0.25	0.02	0.46
	Med.	0.004	34.13	0.5	0.05	-	0.25	3.18	81.10	1.69	1.00	7.75
	Max.	0.5	7,700	306	52.50	-	282	5,320	163,000	270	154	6,900
This Study	Min.	0.02	25.28	0.31	0.06	0.043	0.28	0.57	36.31	0.17	0.15	0.67
	Med.	0.11	263	3.75	0.13	0.52	2.04	17.04	394.71	4.19	1.99	12.70
	Max.	2.48	8,951	188	13.21	35.00	43.97	247	7,498	136	110	737

[1] Min: Minimum Value, Max: Maximum Value, Med: Median Value

[2] Reference: (Harguinteguy et al., 2014; Rautenberg et al., 2015)

[3] Reference: (Kumar et al., 2019)

[4] Reference: (Kumar et al., 2019; F. Liang et al., 2011; N. Liang et al., 2011)

[5] Reference: (Boarh & Misra, 2010; Kumar et al., 2019)

[6] Reference: (Cengiz et al., 2017; Kumar et al., 2019; Turgut, 2003)

[7] Reference: (Donnachie et al., 2014; Johnson et al., 2017)

H. Metal Pollution Load Heatmaps

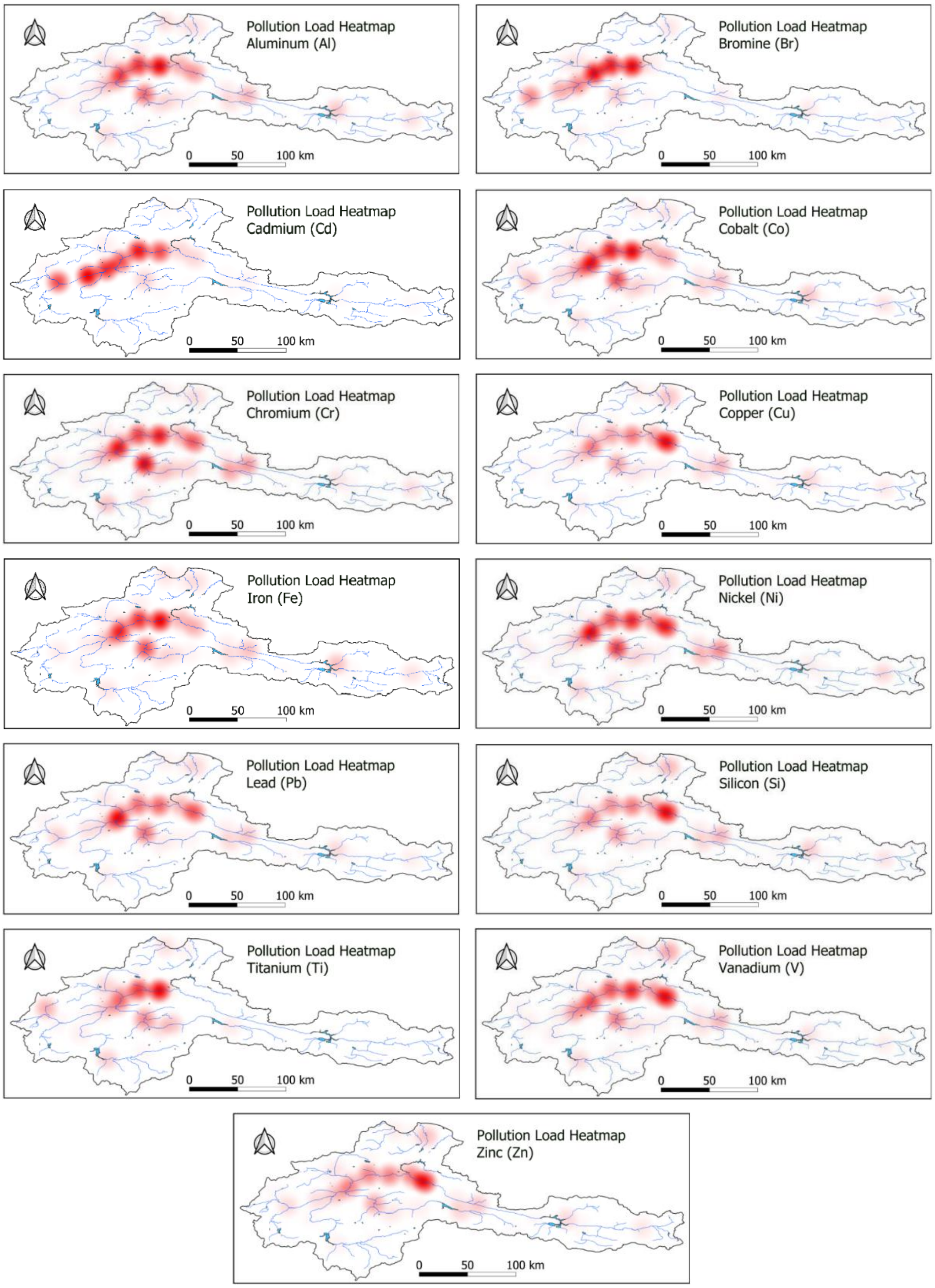
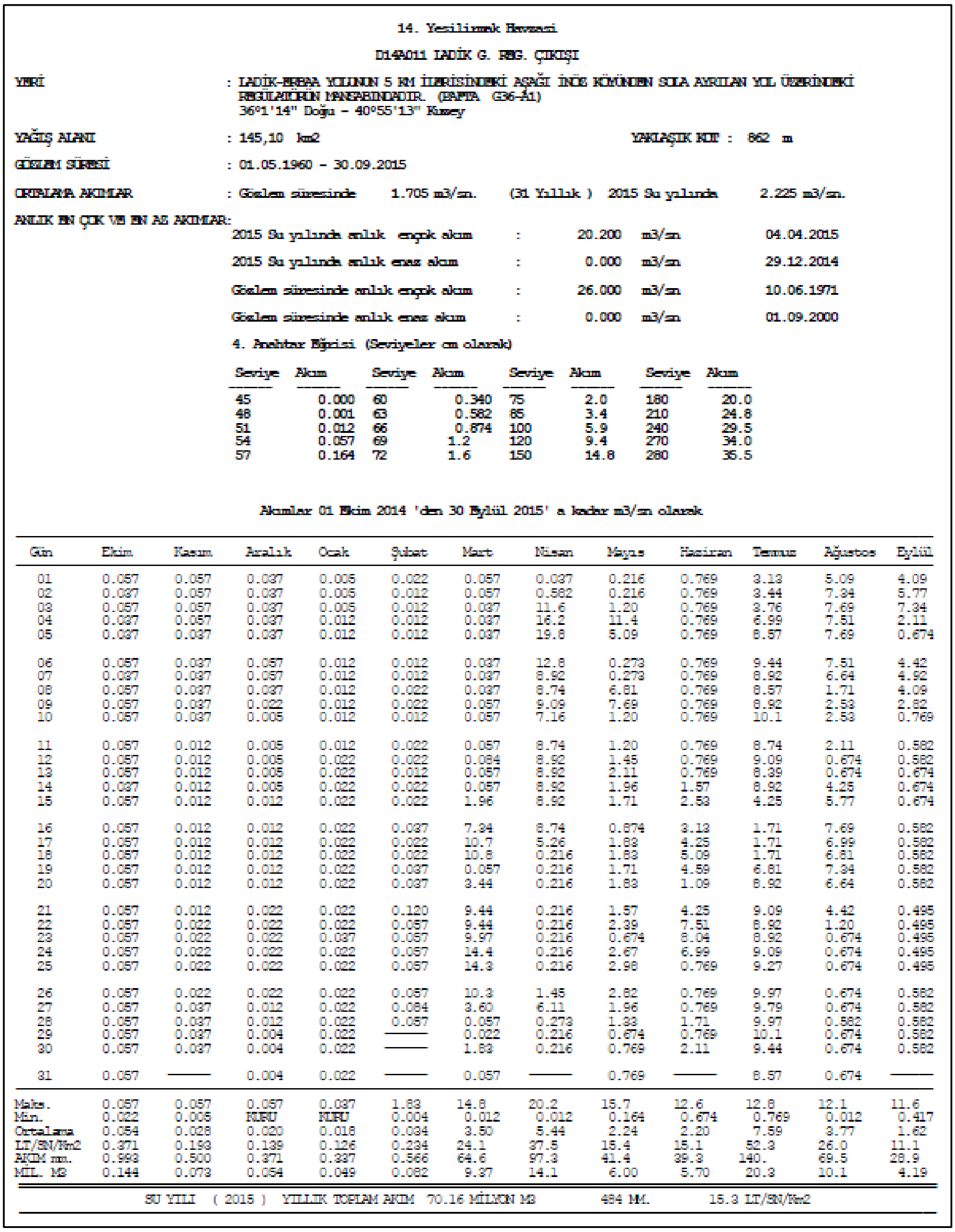


Figure A 3. Heatmap of Metal Pollution Loads in the YRB

I. Stream Gauging Station Data Format



14. Yesilirmak Havzasi

D14A011 LADİK G. REG. ÇIKIŞI

YERİ : LADİK-ERBAA YOLUNUN 5 KM İLERİSİNDEKİ AŞAĞI İNCE KÖYÜNDEN SOLA AYRILAN YOL ÜZERİNDEKİ REGÜLATÖRÜN MANSABINDADIR. (PAFTA G36-A1)
36°1'14" Doğu - 40°55'13" Kuzey

YAĞIŞ ALANI : 145,10 km2 YAKLAŞIK KOT : 862 m

GÖZLEM SÜRESİ : 01.05.1960 - 30.09.2015

ORTALAMA AKIMLAR : Gözlem süresinde 1.705 m3/sn. (31 Yıllık) 2015 Su yılında 2.225 m3/sn.

ANLIK EN ÇOK VE EN AZ AKIMLAR:

2015 Su yılında anlık ençok akım	:	20.200	m3/sn	04.04.2015
2015 Su yılında anlık enaz akım	:	0.000	m3/sn	29.12.2014
Gözlem süresinde anlık ençok akım	:	26.000	m3/sn	10.06.1971
Gözlem süresinde anlık enaz akım	:	0.000	m3/sn	01.09.2000

4. Anahtar Eğrisi (Seviyeler cm olarak)

Seviye	Akım	Seviye	Akım	Seviye	Akım	Seviye	Akım
45	0.000	60	0.340	75	2.0	180	20.0
48	0.001	63	0.582	85	3.4	210	24.8
51	0.012	66	0.874	100	5.9	240	29.5
54	0.057	69	1.2	120	9.4	270	34.0
57	0.164	72	1.6	150	14.8	280	35.5

Akımlar 01 Ekim 2014 'den 30 Eylül 2015' a kadar m3/sn olarak

Gün	Ekim	Kasım	Aralık	Ocak	Şubat	Mart	Nisan	Mayıs	Haziran	Temmuz	Ağustos	Eylül
01	0.057	0.057	0.037	0.005	0.022	0.057	0.037	0.216	0.769	3.13	5.09	4.09
02	0.037	0.057	0.037	0.005	0.012	0.057	0.582	0.216	0.769	3.44	7.34	5.77
03	0.057	0.057	0.037	0.005	0.012	0.037	11.6	1.20	0.769	3.76	7.69	7.34
04	0.037	0.057	0.037	0.012	0.012	0.037	16.2	11.4	0.769	6.99	7.51	2.11
05	0.037	0.037	0.037	0.012	0.012	0.037	19.8	5.09	0.769	8.57	7.69	0.674
06	0.057	0.037	0.057	0.012	0.012	0.037	12.8	0.273	0.769	9.44	7.51	4.42
07	0.037	0.037	0.057	0.012	0.012	0.037	8.92	0.273	0.769	8.92	6.64	4.92
08	0.057	0.037	0.037	0.012	0.022	0.037	8.74	6.81	0.769	8.57	1.71	4.09
09	0.057	0.037	0.022	0.012	0.022	0.057	9.09	7.69	0.769	8.92	2.53	2.82
10	0.057	0.037	0.005	0.012	0.012	0.057	7.16	1.20	0.769	10.1	2.53	0.769
11	0.057	0.012	0.005	0.012	0.022	0.057	8.74	1.20	0.769	8.74	2.11	0.582
12	0.057	0.012	0.005	0.022	0.022	0.084	8.92	1.45	0.769	9.09	0.674	0.582
13	0.057	0.012	0.005	0.022	0.012	0.057	8.92	2.11	0.769	8.39	0.674	0.674
14	0.037	0.012	0.005	0.022	0.022	0.057	8.92	1.96	1.57	8.92	4.25	0.674
15	0.057	0.012	0.012	0.022	0.022	1.96	8.92	1.71	2.53	4.25	5.77	0.674
16	0.057	0.012	0.012	0.022	0.037	7.34	8.74	0.874	3.13	1.71	7.69	0.582
17	0.057	0.012	0.012	0.022	0.022	10.7	5.26	1.83	4.25	1.71	6.99	0.582
18	0.057	0.012	0.012	0.022	0.022	10.8	0.216	1.83	5.09	1.71	6.81	0.582
19	0.057	0.012	0.012	0.022	0.037	0.057	0.216	1.71	4.59	6.81	7.34	0.582
20	0.057	0.012	0.012	0.022	0.037	3.44	0.216	1.83	1.09	8.92	6.64	0.582
21	0.057	0.012	0.022	0.022	0.120	9.44	0.216	1.57	4.25	9.09	4.42	0.495
22	0.057	0.022	0.022	0.022	0.057	9.44	0.216	2.39	7.51	8.92	1.20	0.495
23	0.057	0.022	0.022	0.037	0.057	9.97	0.216	0.674	8.04	8.92	0.674	0.495
24	0.057	0.022	0.022	0.022	0.057	14.4	0.216	2.67	6.99	9.09	0.674	0.495
25	0.057	0.022	0.022	0.022	0.057	14.3	0.216	2.98	0.769	9.27	0.674	0.495
26	0.057	0.022	0.022	0.022	0.057	10.3	1.45	2.82	0.769	9.97	0.674	0.582
27	0.057	0.037	0.012	0.022	0.084	3.60	6.11	1.96	0.769	9.79	0.674	0.582
28	0.057	0.037	0.012	0.022	0.057	0.057	0.273	1.33	1.71	9.97	0.582	0.582
29	0.057	0.037	0.004	0.022	—	0.022	0.216	0.674	0.769	10.1	0.674	0.582
30	0.057	0.037	0.004	0.022	—	1.83	0.216	0.769	2.11	9.44	0.674	0.582
31	0.057	—	0.004	0.022	—	0.057	—	0.769	—	8.57	0.674	—
Maks.	0.057	0.057	0.057	0.037	1.83	14.8	20.2	15.7	12.6	12.8	12.1	11.6
Min.	0.022	0.005	KURU	KURU	0.004	0.012	0.012	0.164	0.674	0.769	0.012	0.417
Ortalama	0.054	0.028	0.020	0.018	0.034	3.50	5.44	2.24	2.20	7.59	3.77	1.62
LT/SN/Km2	0.371	0.193	0.139	0.126	0.234	24.1	37.5	15.4	15.1	52.3	26.0	11.1
AKIM mm.	0.993	0.500	0.371	0.337	0.566	64.6	97.3	41.4	39.3	140.	69.5	28.9
MİL. M3	0.144	0.073	0.054	0.049	0.082	9.37	14.1	6.00	5.70	20.3	10.1	4.19

SU YILI (2015) YILLIK TOPLAM AKIM 70.16 MİLYON M3 484 MM. 15.3 LT/SN/Km2

Figure A 4. Example Stream Gauging Data Format for Station D14A011

J. Results of the Dilution Factor Calculations

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin

Sub-basin	Type¹	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF²	Local DF	Acc. DF²	Local DF	Acc. DF²	Local DF	Acc. DF²
1	UT	Gümüşhane-Köse-Köse	658	658	84.4	84.4	1.2	1.2	85.4	85.4	2.2	2.2
1	PS	Gümüşhane Köse Kentsel AAT	900	658	141.0	81.4	5.4	3.1	142.0	82.0	6.4	3.7
1	UT	Gümüşhane-Kelkit-Öbektaş	551	1,558	264.4	69.1	10.9	2.8	265.4	69.3	11.9	3.1
1	UT	Gümüşhane-Kelkit-Kaş	325	2,109	515.2	68.9	22.3	3.0	516.2	69.0	23.3	3.1
1	UT	Gümüşhane-Kelkit-Deredolu	428	0	507.8	507.8	51.4	51.4	508.8	508.8	52.4	52.4
1	UT	Gümüşhane-Kelkit-Ünlüpınar	451	0	37.0	37.0	2.0	2.0	38.0	38.0	3.0	3.0
1	PS	Gümüşhane Kelkit Kentsel AAT	10,000	3,313	50.3	37.8	2.7	2.0	51.3	38.5	3.7	2.7
1	UT	Gümüşhane-Kelkit-Gümüşgöze	423	0	10.8	10.8	0.6	0.6	11.8	11.8	1.6	1.6
2	UT	Gümüşhane-Kelkit-Söğütlü	393	13,736	1,588.3	44.2	85.1	2.4	1,589.3	44.2	86.1	2.4
2	PS	Gümüşhane Şiran Belediye Başkanlığı Kentsel AAT	2,230	0	210.8	210.8	3.4	3.4	211.8	211.8	4.4	4.4
2	UT	Gümüşhane-Şiran-Yeşilbük	334	0	275.0	275.0	4.5	4.5	276.0	276.0	5.5	5.5
2	UT	Giresun-Çamoluk-Yenice	162	16,693	6,420.0	61.8	343.9	3.3	6,421.0	61.8	344.9	3.3
2	PS	S.S Yurtbaşi-Olgunlar-Ekecik-Ulucak Köyleri Tarımsal Kalkınma	29	0	2,364.5	2,364.5	674.7	674.7	2,365.5	2,365.5	675.7	675.7
2	PS	Erzincan Refahiye Kentesel AAT	1,000	29	205.1	199.3	57.4	55.8	206.1	200.3	58.4	56.7

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m^3/day)	Cumulative Wastewater Before Discharge (m^3/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
2	UT	Sivas-Gölova-Gölova	415	0	12.3	12.3	2.6	2.6	13.3	13.3	3.6	3.6
3	UT	Giresun-Alucra-Alucra	803	0	274.1	274.1	23.8	23.8	275.1	275.1	24.8	24.8
3	PS	Şebin Süt Ürünleri Gıda Hayvancılık İnşaat Sanayi ve Ticaret	7	0	38,754.0	38,754.0	1,878.9	1,878.9	38,755.0	38,755.0	1,879.9	1,879.9
3	UT	Giresun-Şebinkarahisar-Şebinkarahisar	2,304	7	115.4	115.1	5.6	5.6	116.4	116.1	6.6	6.6
4	UT	Sivas-Suşehri-Çataloluk	169	0	387.9	387.9	3.2	3.2	388.9	388.9	4.2	4.2
4	PS	Murat Pazarlama Dağıtım Ticaret ve Sanayi	8	0	5,853.7	5,853.7	48.0	48.0	5,854.7	5,854.7	49.0	49.0
4	UT	Sivas-Akıncılar-Akıncılar	529	0	506.8	506.8	4.2	4.2	507.8	507.8	5.2	5.2
4	PS	Sivas Suşehri Kentsel AAT	10,000	0	0.8	0.8	0.0	0.0	1.8	1.8	1.0	1.0
4	UT	Sivas-Koyulhisar-Koyulhisar	782	32,119	4,140.0	98.4	100.4	2.4	4,141.0	98.4	101.4	2.4
5	UT	Tokat-Reşadiye-Kızılcaören	216	0	62.3	62.3	5.4	5.4	63.3	63.3	6.4	6.4
5	UT	Tokat-Reşadiye-Baydarlı	432	0	29.5	29.5	2.6	2.6	30.5	30.5	3.6	3.6
5	UT	Tokat-Reşadiye-Hasanşeyh	587	648	103.3	49.1	9.0	4.3	104.3	49.6	10.0	4.8
5	UT	Tokat-Reşadiye-Cimitekke	414	0	16.5	16.5	1.4	1.4	17.5	17.5	2.4	2.4
5	UT	Tokat-Reşadiye-Kuzbağı	145	1,648	688.1	55.8	60.2	4.9	689.1	55.9	61.2	5.0
5	UT	Tokat-Reşadiye-Nebişeyh	371	1,793	320.2	54.9	28.0	4.8	321.2	55.0	29.0	5.0
5	UT	Tokat-Reşadiye-Yolüstü	398	0	11.9	11.9	1.0	1.0	12.9	12.9	2.0	2.0
6	UT	Tokat-Reşadiye-Reşadiye	1,676	32,902	2,593.0	125.6	170.7	8.3	2,594.0	125.7	171.7	8.3
6	UT	Tokat-Reşadiye-Soğukpınar	212	34,577	20,647.3	126.1	1,379.0	8.4	20,648.3	126.1	1,380.0	8.4
6	PS	Fırat Elektrik Üretim ve Ticaret Anonim Şirketi	27	37,352	192,590.3	139.1	15,914.4	11.5	192,591.3	139.1	15,915.4	11.5

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
6	UT	Tokat-Reşadiye-Bozçalı	519	0	17.8	17.8	1.6	1.6	18.8	18.8	2.6	2.6
6	UT	Tokat-Başçiftlik-Başçiftlik	793	0	16.3	16.3	1.4	1.4	17.3	17.3	2.4	2.4
6	UT	Tokat-Başçiftlik-Hatipli	451	1,312	46.7	11.9	4.1	1.0	47.7	12.2	5.1	1.3
6	UT	Tokat-Reşadiye-Bereketli	436	0	56.2	56.2	4.9	4.9	57.2	57.2	5.9	5.9
6	UT	Tokat-Reşadiye-Büşürüm	366	0	21.8	21.8	1.9	1.9	22.8	22.8	2.9	2.9
6	UT	Tokat-Reşadiye-Çevrecik	406	366	26.9	14.2	2.4	1.2	27.9	14.7	3.4	1.8
6	PS	Susa İçecek Sanayi ve Ticaret	10	40,349	544,069.2	134.8	47,558.9	11.8	544,070.2	134.8	47,559.9	11.8
6	UT	Tokat-Niksar-Yazıcık	453	0	31.2	31.2	2.7	2.7	32.2	32.2	3.7	3.7
6	UT	Tokat-Niksar-Kuyucak	383	453	75.6	34.6	6.6	3.0	76.6	35.1	7.6	3.5
6	PS	Niksar Kaya Su Doğal Kaynak Suyu Üretim ve Dağıtım Sanayi ve Ticaret	10	41,196	556,534.8	135.1	52,021.9	12.6	556,535.8	135.1	52,022.9	12.6
6	UT	Tokat-Merkez-Yağmurlu	177	0	73.5	73.5	14.7	14.7	74.5	74.5	15.7	15.7
6	UT	Tokat-Niksar-Yolkonak	568	41,383	10,436.0	141.3	1,347.4	18.2	10,437.0	141.3	1,348.4	18.3
6	PS	Hamza Alaş - Öz Niksar Gıda	11.909	42,171	524,214.9	148.0	82,222.2	23.2	524,215.9	148.0	82,223.2	23.2
6	PS	Niksar Bereket Süt Ürünleri Gıda Sanayi ve Ticaret Limited Şirketi	195.995	41,987	31,852.2	148.0	4,996.0	23.2	31,853.2	148.0	4,997.0	23.2
6	PS	Olca Gıda Sanayi ve Ticaret	18.491	42,165	337,622.0	148.0	52,955.4	23.2	337,623.0	148.0	52,956.4	23.2
6	PS	Olca Gıda ve Plastik Sanayi ve Ticaret	5.667	42,177	1,101,680	148.0	172,796.7	23.2	1,101,681	148.0	172,797.7	23.2
6	UT	Tokat-Niksar-Niksar	6,181	42,183	1,019.3	130.3	164.7	21.1	1,020.3	130.4	165.7	21.2
6	UT	Tokat-Niksar-Gürçeşme	391	0	22.2	22.2	4.4	4.4	23.2	23.2	5.4	5.4
6	UT	Niksar OSB	55	48,755	121,202.7	137.0	24,253.9	27.4	121,203.7	137.0	24,254.9	27.4

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m^3/day)	Cumulative Wastewater Before Discharge (m^3/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
6	UT	Tokat-Niksar-Gökçeli	223	0	45.0	45.0	9.0	9.0	46.0	46.0	10.0	10.0
6	UT	Tokat-Niksar-Serenli	480	0	13.6	13.6	2.7	2.7	14.6	14.6	3.7	3.7
6	UT	Tokat-Niksar-Günebakan	369	0	14.9	14.9	3.0	3.0	15.9	15.9	4.0	4.0
6	UT	Tokat-Erbaa-Üzümlü	363	0	19.2	19.2	5.9	5.9	20.2	20.2	6.9	6.9
6	UT	Tokat-Erbaa-Karayaka	550	0	12.5	12.5	3.9	3.9	13.5	13.5	4.9	4.9
7	UT	Sivas-Zara-Şerefiye	379	0	322.3	322.3	28.0	28.0	323.3	323.3	29.0	29.0
7	UT	Sivas-Doğanşar-Doğanşar	268	0	302.1	302.1	59.0	59.0	303.1	303.1	60.0	60.0
7	UT	Tokat-Almus-Bağtaşı	378	0	1,589.6	1,589.6	158.0	158.0	1,590.6	1,590.6	159.0	159.0
7	UT	Tokat-Almus-Cihet	384	0	66.4	66.4	8.6	8.6	67.4	67.4	9.6	9.6
8	UT	Tokat-Almus-Dikili	277	1,410	4,964.1	814.9	644.3	105.8	4,965.1	815.1	645.3	105.9
8	UT	Tokat-Almus-Gölgeli	409	1,687	3,357.8	654.8	435.9	85.0	3,358.8	655.0	436.9	85.2
8	UT	Tokat-Almus-Akarçay	366	2,095	3,611.7	537.2	470.0	69.9	3,612.7	537.3	471.0	70.0
8	UT	Tokat-Almus-Görümlü	389	0	2.7	2.7	0.4	0.4	3.7	3.7	1.4	1.4
8	UT	Tokat-Merkez-Çat	621	0	13.7	13.7	2.1	2.1	14.7	14.7	3.1	3.1
8	UT	Tokat-Almus-Ormandibi	383	621	51.4	19.6	7.9	3.0	52.4	20.0	8.9	3.4
8	UT	Tokat-Almus-Çevreli	485	1,005	55.2	18.0	8.5	2.8	56.2	18.3	9.5	3.1
8	UT	Tokat-Almus-Kınık	308	0	24.7	24.7	3.8	3.8	25.7	25.7	4.8	4.8
8	PS	Tokat Almus Kentsel AAT	1,000	4,648	825.7	146.2	111.6	19.8	826.7	146.4	112.6	19.9
8	UT	Tokat-Almus-Ataköy	386	0	2.8	2.8	0.4	0.4	3.8	3.8	1.4	1.4
8	UT	Tokat-Merkez-Avlunlar	299	0	112.7	112.7	11.7	11.7	113.7	113.7	12.7	12.7

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
8	UT	Tokat-Merkez-Akbelen	161	0	24.2	24.2	3.7	3.7	25.2	25.2	4.7	4.7
8	PS	Doğuş YDA Adi Ortaklığı Tokat - Niksar Yolu Ana Şantiyesi	30	6,494	16,410.8	75.5	2,367.8	10.9	16,411.8	75.5	2,368.8	10.9
9	UT	Tokat-Merkez-Kemalpaşa	235	0	7.9	7.9	1.7	1.7	8.9	8.9	2.7	2.7
9	PS	Tokat Kentsel AAT	25,872	6,759	24.8	19.6	5.0	3.9	25.8	20.4	6.0	4.7
9	PS	Dimes Tokat Taşlıçiftlik	360	32,631	1,835.3	20.0	371.1	4.0	1,836.3	20.0	372.1	4.1
9	UT	Tokat-Merkez-Emirseyit	382	0	4.8	4.8	1.0	1.0	5.8	5.8	2.0	2.0
9	UT	Tokat-Merkez-Büyükyıldız	378	0	1.6	1.6	0.4	0.4	2.6	2.6	1.4	1.4
9	UT	Tokat-Merkez-Güryıldız	379	378	4.4	2.2	0.9	0.5	5.4	2.7	1.9	1.0
9	UT	Tokat-Turhal-Kat	383	34,129	2,073.0	23.0	438.5	4.9	2,074.0	23.0	439.5	4.9
9	UT	Tokat-Pazar-Pazar	941	0	4.9	4.9	1.0	1.0	5.9	5.9	2.0	2.0
9	UT	Tokat-Turhal-Şenyurt	417	0	7.8	7.8	3.3	3.3	8.8	8.8	4.3	4.3
9	UT	Tokat-Pazar-Dereköy	390	0	8.0	8.0	3.4	3.4	9.0	9.0	4.4	4.4
9	UT	Tokat-Pazar-Üzümören	762	0	4.8	4.8	2.0	2.0	5.8	5.8	3.0	3.0
9	UT	Tokat-Zile-Yıldıztepe	381	0	58.8	58.8	25.0	25.0	59.8	59.8	26.0	26.0
9	PS	Özkaleli Gıda Üretim ve Petrol Ürünleri Pazarlama Sanayi ve Ticaret	9	0	1,881.1	1,881.1	797.7	797.7	1,882.1	1,882.1	798.7	798.7
9	PS	Tokat Zile Kentsel AAT	4,100	9	9.1	9.1	3.9	3.9	10.1	10.1	4.9	4.9
9	UT	Tokat-Turhal-Ulutepe	116	0	122.4	122.4	11.0	11.0	123.4	123.4	12.0	12.0
9	PS	Türkiye Şeker Fabrikaları A.Ş. (Turhal)	4,560	41,628	39.9	3.9	16.9	1.7	40.9	4.0	17.9	1.8
9	UT	Tokat-Turhal-Yenisu	391	0	72.3	72.3	30.7	30.7	73.3	73.3	31.7	31.7

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
9	UT	Tokat-Turhal-Yazıtepe	400	391	157.3	79.5	66.7	33.7	158.3	80.0	67.7	34.2
10	PS	Bensu Kaynak Suları Eğitim Mataryelleri Hayvancılık Su Ürünleri Ticaret ve Sanayi	1	0	3,452.6	3,452.6	536.4	536.4	3,453.6	3,453.6	537.4	537.4
10	UT	Tokat-Merkez-Çamlıbel	326	0	235.4	235.4	36.6	36.6	236.4	236.4	37.6	37.6
10	UT	Tokat-Artova-Çelikli	234	0	13.4	13.4	2.1	2.1	14.4	14.4	3.1	3.1
10	PS	Mehmet Karaca: Tarım Makinaları	1	0	20,234.1	20,234.1	3,143.5	3,143.5	20,235.1	20,235.1	3,144.5	3,144.5
10	UT	Tokat-Artova-Artova	596	0	40.6	40.6	6.3	6.3	41.6	41.6	7.3	7.3
10	UT	Tokat-Yeşilyurt-Yeşilyurt	996	1,157	205.9	95.2	32.0	14.8	206.9	95.7	33.0	15.3
10	UT	Tokat-Yeşilyurt-Kuşçu	398	0	3.3	3.3	0.5	0.5	4.3	4.3	1.5	1.5
10	UT	Tokat-Yeşilyurt-Çıkrık	206	0	273.0	273.0	189.9	189.9	274.0	274.0	190.9	190.9
10	UT	Tokat-Sulusaray-Sulusaray	638	2,756	396.0	74.4	16.1	3.0	397.0	74.6	17.1	3.2
10	UT	Sivas-Yıldızeli-Yavu	211	0	168.7	168.7	17.1	17.1	169.7	169.7	18.1	18.1
10	UT	Sivas-Yıldızeli-Şeyhhalil	223	211	846.8	435.2	81.8	42.1	847.8	435.7	82.8	42.6
10	UT	Tokat-Sulusaray-Dutluca	380	0	17.0	17.0	0.7	0.7	18.0	18.0	1.7	1.7
10	UT	Yozgat-Kadışehri-Halıköy	452	0	14.9	14.9	0.6	0.6	15.9	15.9	1.6	1.6
10	UT	Yozgat-Kadışehri-Kadışehri	918	0	16.9	16.9	0.7	0.7	17.9	17.9	1.7	1.7
10	PS	Onur Sentetik Tekstil Plastik Gıda Tarım Ürünleri Petrol Sanayi ve Ticaret	8	0	889.1	889.1	36.1	36.1	890.1	890.1	37.1	37.1
10	PS	Akdağsan Gıda Tekstil Tarım Ürünleri Petrol Ticaret ve Sanayi	2	8	5,431.1	1,008.4	220.5	41.0	5,432.1	1,008.6	221.5	41.1
10	UT	Yozgat-Akdağmadeni-Akdağmadeni	4,721	10	4.2	4.2	0.2	0.2	5.2	5.2	1.2	1.2
10	UT	Yozgat-Akdağmadeni-Oluközü	314	0	12.1	12.1	0.5	0.5	13.1	13.1	1.5	1.5

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
10	UT	Yozgat-Akdağmadeni-Umutlu	392	0	7.2	7.2	0.3	0.3	8.2	8.2	1.3	1.3
10	PS	Yozgat Saraykent Kentsel AAT	1,000	0	10.9	10.9	0.6	0.6	11.9	11.9	1.6	1.6
10	UT	Yozgat-Saraykent-Çiçekli	220	0	25.6	25.6	1.0	1.0	26.6	26.6	2.0	2.0
11	UT	Yozgat-Sorgun-Ahmetfakılı	202	0	30.7	30.7	1.2	1.2	31.7	31.7	2.2	2.2
11	UT	Yozgat-Sorgun-Araplı	314	0	16.3	16.3	0.7	0.7	17.3	17.3	1.7	1.7
11	UT	Yozgat-Sorgun-Gülşehri	219	0	13.3	13.3	0.5	0.5	14.3	14.3	1.5	1.5
11	UT	Yozgat-Çekerek-Özükavak	397	0	11.8	11.8	0.5	0.5	12.8	12.8	1.5	1.5
11	UT	Yozgat-Çekerek-Bayındırhüyük	176	0	25.7	25.7	1.0	1.0	26.7	26.7	2.0	2.0
11	UT	Yozgat-Çekerek-Beyyurdu	169	0	19.7	19.7	0.8	0.8	20.7	20.7	1.8	1.8
11	UT	Yozgat-Çekerek-Çekerek	2,072	169	29.6	27.3	1.2	1.1	30.6	28.2	2.2	2.0
11	UT	Tokat-Zile-Yalınyazı	396	0	11.2	11.2	0.8	0.8	12.2	12.2	1.8	1.8
11	UT	Yozgat-Aydıncık-Baştürk	99	0	17.7	17.7	1.2	1.2	18.7	18.7	2.2	2.2
11	UT	Yozgat-Çekerek-Bazlambaç	96	0	33.9	33.9	2.3	2.3	34.9	34.9	3.3	3.3
11	UT	Yozgat-Aydıncık-Kösrelik	135	0	12.7	12.7	0.9	0.9	13.7	13.7	1.9	1.9
11	UT	Yozgat-Aydıncık-Aydıncık	471	0	7.4	7.4	0.5	0.5	8.4	8.4	1.5	1.5
11	PS	Yozgat Aydıncık Kentsel AAT	450	606	55.9	23.8	3.8	1.6	56.9	24.2	4.8	2.0
11	UT	Yozgat-Aydıncık-Baydiğin	618	0	4.2	4.2	0.3	0.3	5.2	5.2	1.3	1.3
11	UT	Yozgat-Aydıncık-Kazankaya	312	18,050	2,372.0	40.3	161.6	2.7	2,373.0	40.4	162.6	2.8
11	UT	Çorum-Ortaköy-Karahacip	361	0	8.5	8.5	0.6	0.6	9.5	9.5	1.6	1.6
11	UT	Çorum-Ortaköy-Ortaköy	438	361	22.3	12.2	1.5	0.8	23.3	12.8	2.5	1.4

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
11	UT	Çorum-Ortaköy-Aştavul	398	0	24.8	24.8	1.7	1.7	25.8	25.8	2.7	2.7
11	UT	Amasya-Göynücek-Damlaçimen	218	0	5.7	5.7	0.4	0.4	6.7	6.7	1.4	1.4
11	UT	Amasya-Göynücek-Göynücek	477	19,777	1,759.8	41.5	119.9	2.8	1,760.8	41.5	120.9	2.8
12	UT	Yozgat-Sorgun-Eymir	318	0	10.8	10.8	0.2	0.2	11.8	11.8	1.2	1.2
12	UT	Çorum-Alaca-Çopraşık	141	0	21.7	21.7	0.3	0.3	22.7	22.7	1.3	1.3
12	UT	Çorum-Alaca-Alaca	3,991	0	24.9	24.9	0.4	0.4	25.9	25.9	1.4	1.4
12	PS	Şirinler Kuruyemiş Tarım, Gıda, Hay. Yem. Tem. Hizm. İlaçlama, İnş. Petrol Tur. İth. İhr. ve Paz. San. ve Tic.	9	0	1,121.1	1,121.1	16.9	16.9	1,122.1	1,122.1	17.9	17.9
13	PS	Yuva Viyol ve Ambalaj Sanayi ve Ticaret Ltd.Şti.	389	0	20.0	20.0	0.3	0.3	21.0	21.0	1.3	1.3
13	UT	Çorum-Merkez-Seydim	163	0	7.2	7.2	0.1	0.1	8.2	8.2	1.1	1.1
13	PS	Olmuksan International Paper Ambalaj Sanayi ve Ticaret Anonim Şirketi	480	552	94.7	44.1	1.4	0.7	95.7	44.5	2.4	1.1
13	PS	Kalaycıoğlu Gıda Pazarlama Sanayi ve Ticaret	45	1,032	1,012.4	42.3	15.2	0.6	1,013.4	42.3	16.2	0.7
13	PS	Hayat Kağıt ve Enerji Sanayi Ticaret	850	1,076	54.1	23.9	0.8	0.4	55.1	24.3	1.8	0.8
13	PS	Çorum Şeker Fabrikaları A.Ş.	4,800	1,926	11.0	7.8	0.2	0.1	12.0	8.5	1.2	0.8
13	PS	Çorum Belediyesi (Merkez) AAT	60,000	6,726	0.9	0.8	0.0	0.0	1.9	1.7	1.0	0.9
13	PS	Bim Birleşik Mağazalar A.Ş.	2	0	33,677.8	33,677.8	506.9	506.9	33,678.8	33,678.8	507.9	507.9
13	PS	Saray Petrol Turizm Gıda San.Tic.Ltd Şti.	5	0	1,139.7	1,139.7	17.2	17.2	1,140.7	1,140.7	18.2	18.2
14	PS	Çorum Mecitözü Kentsel AAT	360	926	35.7	10.0	0.2	0.1	36.7	10.3	1.2	0.3
14	UT	Çorum-Mecitözü-Mecitözü	926	360	13.9	10.0	0.1	0.1	14.9	10.7	1.1	0.8

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type¹	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF²	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
14	PS	Emmioğlu Mermer Mad. İnş. Taah. İnş. Malz. Müh. Akaryakıt Pet. Ürün. Tur. İm. İth. İhr. Tic. ve San. A. Ş.	29	0	98.6	98.6	6.7	6.7	99.6	99.6	7.7	7.7
14	UT	Amasya-Göynücek-Gediksaray	151	0	10.8	10.8	0.7	0.7	11.8	11.8	1.7	1.7
14	UT	Tokat-Turhal-Turhal	12,101	46,980	99.3	20.3	42.1	8.6	100.3	20.5	43.1	8.8
14	PS	Özdemir Antimuan Madenleri A.Ş. Turhal	1,200	59,080	1,001.8	19.9	424.9	8.5	1,002.8	20.0	425.9	8.5
14	UT	Amasya-Merkez-Doğantepe	222	0	57.0	57.0	3.9	3.9	58.0	58.0	4.9	4.9
15	PS	Doğa Su Gıda Maddeleri San Tic (Akdağ Su Fabrikası)	36	0	271.5	271.5	4.3	4.3	272.5	272.5	5.3	5.3
16	PS	Ladik Akdağ Yatırım Turizm İnşaat Sanayi ve Ticaret A.Ş.	864	0	216.6	216.6	13.5	13.5	217.6	217.6	14.5	14.5
16	PS	Samsun Büyük Şehir Belediyesi Hamamayağı (Ladik) Paket AAT	100	864	1,872.1	194.2	116.6	12.1	1,873.1	194.3	117.6	12.2
16	PS	Havza Yurt Müdürlüğü Atıksu Arıtma Tesisi	150	1,000	1,398.3	182.4	124.6	16.2	1,399.3	182.5	125.6	16.4
16	PS	Aydınoğlu Un Gıda San Tıc As	120	1,150	1,755.3	165.9	158.0	14.9	1,756.3	165.9	159.0	15.0
16	PS	Otat Gıda Süt Ürünleri	1,150	1,270	183.7	87.3	16.7	7.9	184.7	87.8	17.7	8.4
16	PS	Samsun Büyük Şehir Belediyesi SASKİ Genel Müdürlüğü Havza AAT	3,555	2,420	60.8	36.2	5.8	3.5	61.8	36.8	6.8	4.1
16	PS	Nebioğulları Geri Dönüşüm Et Ürünleri Gıda Tarım Hayvancılık İnşaat Nakliye Turizm Temizlik Sanayi Ve Ticaret	4	5,975	59,032.6	38.3	6,360.5	4.1	59,033.6	38.3	6,361.5	4.1
16	PS	Gürmin Enerji Madencilik Sanayi ve Tic.	37	5,979	6,207.9	38.2	673.0	4.1	6,208.9	38.2	674.0	4.1
16	PS	Seferağa Süt Ve Gıda Mamülleri Suluova Şubesi Sanayi Ticaret	50	6,016	4,602.9	37.9	500.9	4.1	4,603.9	37.9	501.9	4.1
16	PS	Amasya Şeker Fabrikaları A.Ş.	2,600	13,401	89.0	14.5	9.8	1.6	90.0	14.6	10.8	1.8

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
16	UT	Suluova OSB	179	15,821	1,291.0	14.5	142.0	1.6	1,292.0	14.5	143.0	1.6
16	PS	Et-Bir Suluova Kesimhane	120	15,881	1,929.4	14.5	212.3	1.6	1,930.4	14.5	213.3	1.6
16	UT	Amasya-Suluova-Suluova	7,036	8,965	32.9	14.5	3.6	1.6	33.9	14.9	4.6	2.0
16	PS	Ekur Et Entegre San. ve Tic. A.Ş.	600	0	5.5	5.5	1.0	1.0	6.5	6.5	2.0	2.0
17	PS	Meray Yağ San ve Tic A.Ş.	240	0	12.7	12.7	2.3	2.3	13.7	13.7	3.3	3.3
17	UT	Amasya-Gümüşhacıköy-Gümüşhacıköy	2,729	0	1.6	1.6	0.3	0.3	2.6	2.6	1.3	1.3
18	UT	Çorum-Mecitözü-Elvançelebi	84	0	23.2	23.2	4.2	4.2	24.2	24.2	5.2	5.2
18	UT	Çorum-Merkez-Konaklı	196	84	116.9	81.8	21.1	14.7	117.9	82.5	22.1	15.4
18	UT	Çorum-Merkez-Düvenci	376	0	14.5	14.5	2.6	2.6	15.5	15.5	3.6	3.6
18	UT	Amasya-Merzifon-Kayadüzü	303	0	1.8	1.8	0.3	0.3	2.8	2.8	1.3	1.3
18	PS	5 İnci Ana Jet Üs Komutanlığı	20	0	62.9	62.9	11.3	11.3	63.9	63.9	12.3	12.3
18	PS	Devlet Hava Meydanları İşletmesi Genel Müdürlüğü	480	8,952	10.4	0.5	1.9	0.1	11.4	0.6	2.9	0.1
18	PS	Merzifon Belediyesi AAT	8,952	480	0.6	0.5	0.1	0.1	1.6	1.5	1.1	1.0
18	PS	Merzifon OSB	20	9,432	256.8	0.5	46.3	0.1	257.8	0.5	47.3	0.1
18	UT	Amasya-Suluova-Eraslan	208	0	9.7	9.7	1.7	1.7	10.7	10.7	2.7	2.7
18	PS	Tatküpü Gıda Maddeleri Pazarlama Sanayi ve Ticaret	40	0	48.9	48.9	8.8	8.8	49.9	49.9	9.8	9.8
18	PS	Beşgöz Karoser Otomotiv Sanayi ve Tic.	2	0	2,837.1	2,837.1	511.1	511.1	2,838.1	2,838.1	512.1	512.1
18	PS	Önder Aksoy Dua Et Besicilik Suluova	45	0	110.3	110.3	19.9	19.9	111.3	111.3	20.9	20.9
18	PS	Bakraç Süt Ürünleri	216	0	32.4	32.4	5.8	5.8	33.4	33.4	6.8	6.8

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m³/day)	Cumulative Wastewater Before Discharge (m³/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
19	UT	Amasya-Merkez-Aydınca	117	0	604.9	604.9	28.1	28.1	605.9	605.9	29.1	29.1
19	UT	Amasya-Merkez-Ezinepazar	322	117	240.2	176.2	16.0	11.8	241.2	176.9	17.0	12.5
19	UT	Amasya-Merkez-Uygur	180	438	522.2	152.1	55.3	16.1	523.2	152.4	56.3	16.4
19	UT	Amasya-Merkez-Yassıçal	216	0	282.8	282.8	2.5	2.5	283.8	283.8	3.5	3.5
19	UT	Amasya KSS	46	835	2,551.9	132.9	359.3	18.7	2,552.9	132.9	360.3	18.8
19	UT	Amasya OSB	104	0	665.4	665.4	27.1	27.1	666.4	666.4	28.1	28.1
19	PS	Kozlu Gıda	24	154,398	123,755.1	19.2	34,540.7	5.4	123,756.1	19.2	34,541.7	5.4
19	UT	Amasya-Merkez-Ziyaret	697	184,933	4,867.5	18.3	1,362.0	5.1	4,868.5	18.3	1,363.0	5.1
19	PS	Amasya Kentsel (Merkez) AAT	11,500	185,630	295.1	17.2	82.6	4.8	296.1	17.3	83.6	4.9
19	PS	Lesaffre Turquie Mayacılık Üretim ve Ticaret Anonim Şirketi (Özmaya)	1,080	197,130	3,143.4	17.1	879.6	4.8	3,144.4	17.1	880.6	4.8
19	UT	Amasya-Merkez-Yeşilyenice	246	198,210	13,810.5	17.2	3,864.6	4.8	13,811.5	17.2	3,865.6	4.8
19	UT	Amasya-Taşova-Özbaraklı	207	0	141.1	141.1	22.1	22.1	142.1	142.1	23.1	23.1
19	UT	Amasya-Taşova-Akınoğlu	280	207	223.7	128.6	53.2	30.6	224.7	129.2	54.2	31.2
19	UT	Amasya-Taşova-Belevi	160	0	38.4	38.4	11.9	11.9	39.4	39.4	12.9	12.9
19	UT	Amasya-Taşova-Ballıdere	193	0	56.2	56.2	17.4	17.4	57.2	57.2	18.4	18.4
19	UT	Amasya-Taşova-Boraboy	156	0	61.1	61.1	18.8	18.8	62.1	62.1	19.8	19.8
19	UT	Amasya-Taşova-Taşova	1,866	199,453	4,504.2	41.7	1,371.4	12.7	4,505.2	41.8	1,372.4	12.7
19	UT	Amasya-Taşova-Destek	217	0	162.7	162.7	50.2	50.2	163.7	163.7	51.2	51.2
19	UT	Amasya-Taşova-Alpaslan	247	217	322.2	171.6	99.4	52.9	323.2	172.1	100.4	53.5
20	UT	Tokat-Erbaa-Koçak	217	0	153.2	153.2	47.3	47.3	154.2	154.2	48.3	48.3

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	Type[1]	Facility / District	Wastewater Flow Rate (m^3/day)	Cumulative Wastewater Before Discharge (m^3/day)	Inclusive Stream Flow Rate Approach				Exclusive Stream Flow Rate Approach			
					Mean Flow		Mean Low Flow		Mean Flow		Mean Low Flow	
					Local DF	Acc. DF[2]	Local DF	Total DF	Local DF	Total DF	Local DF	Total DF
20	PS	Erbaa OSB	423	61,512	12,643.2	86.4	3,900.8	26.7	12,644.2	86.4	3,901.8	26.7
20	PS	Tokat Erbaa Kentsel AAT	10,500	51,435	509.9	86.4	157.3	26.7	510.9	86.6	158.3	26.8
20	UT	Amasya-Taşova-Esençay	380	0	10.5	10.5	3.2	3.2	11.5	11.5	4.2	4.2
20	UT	Tokat-Erbaa-Tanoba	472	0	26.3	26.3	8.1	8.1	27.3	27.3	9.1	9.1
20	UT	Tokat-Erbaa-Akça	383	1,250	73.5	17.2	22.7	5.3	74.5	17.5	23.7	5.6
20	UT	Tokat-Erbaa-Değirmenli	399	1,235	70.6	17.2	21.8	5.3	71.6	17.5	22.8	5.6
20	UT	Amasya-Taşova-Uluköy	299	0	15.8	15.8	4.9	4.9	16.8	16.8	5.9	5.9
20	UT	Tokat-Niksar-Özalan	315	0	98.6	98.6	8.1	8.1	99.6	99.6	9.1	9.1
20	UT	Ordu-Akkuş-Akkuş	1,337	0	2.0	2.0	0.5	0.5	3.0	3.0	1.5	1.5
20	UT	Ordu-Akkuş-Seferli	398	0	12.1	12.1	3.0	3.0	13.1	13.1	4.0	4.0
20	UT	Ordu-Akkuş-Salman	728	0	1.4	1.4	0.3	0.3	2.4	2.4	1.3	1.3
20	UT	Tokat-Erbaa-Gökal	571	2,778	1,424.4	242.8	92.1	15.7	1,425.4	242.9	93.1	15.9
20	PS	Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Ayvacık AAT	427	270,153	32,183.4	50.8	7,931.0	12.5	32,184.4	50.8	7,932.0	12.5
20	UT	Samsun-Ayvacık-Ayvacık	1,154	269,426	11,906.1	50.8	2,934.0	12.5	11,907.1	50.8	2,935.0	12.5
20	PS	Kardez Su Ürünleri Sanayı Tıc Ltd Stı	130	275,380	105,993.6	50.0	26,047.8	12.3	105,994.6	50.0	26,048.8	12.3
20	PS	Türkiye Şeker Fabrikaları A.Ş. (Çarşamba)	4,800	270,710	2,870.7	50.0	705.5	12.3	2,871.7	50.0	706.5	12.3
20	UT	Samsun-Çarşamba-Çarşamba	12,548	275,625	1,098.5	47.8	269.9	11.8	1,099.5	47.9	270.9	11.8
20	UT	Samsun-Çarşamba-Bafracalı	115	288,058	119,753.6	47.8	29,423.8	11.8	119,754.6	47.8	29,424.8	11.8
20	UT	Samsun-Çarşamba-Hürriyet	311	288,173	44,483.0	47.9	10,929.6	11.8	44,484.0	47.9	10,930.6	11.8
21	PS	Kavçim Çimento Sanayi ve Ticaret A.Ş.	30	0	90.7	90.7	5.4	5.4	91.7	91.7	6.4	6.4

Table A 13. The Dilution Factors Calculated for Each Point Source in the Yeşilırmak River Basin (Continued)

Sub-basin	**Type**[1]	**Facility / District**	**Wastewater Flow Rate (m^3/day)**	**Cumulative Wastewater Before Discharge (m^3/day)**	**Inclusive Stream Flow Rate Approach**				**Exclusive Stream Flow Rate Approach**			
					Mean Flow		**Mean Low Flow**		**Mean Flow**		**Mean Low Flow**	
					Local DF	**Acc. DF**[2]	**Local DF**	**Total DF**	**Local DF**	**Total DF**	**Local DF**	**Total DF**
21	PS	Kavak OSB	289	0	3.2	3.2	0.2	0.2	4.2	4.2	1.2	1.2
21	UT	Samsun-Kavak-Kavak	1,963	289	0.6	0.5	0.0	0.0	1.6	1.4	1.0	0.9
21	PS	Yemsel Tavukçuluk	36	2,252	503.7	7.9	30.2	0.5	504.7	7.9	31.2	0.5
OT	PS	Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Asarcık AAT	422	0	27.8	27.8	3.1	3.1	28.8	28.8	4.1	4.1
OT	UT	Samsun-Asarcık-Asarcık	460	0	26.1	26.1	2.9	2.9	27.1	27.1	3.9	3.9
OT	PS	Samsun Büyük Şehir Belediyesi Saski Genel Müdürlüğü Çakmak AAT	194	1,253	1,234.5	165.5	136.3	18.3	1,235.5	165.7	137.3	18.4
OT	UT	Samsun-Çarşamba-Ağcagüney	371	1,076	646.2	165.5	71.4	18.3	647.2	165.8	72.4	18.5
OT	UT	Samsun-Çarşamba-Cumhuriyet	655	0	15.8	15.8	1.7	1.7	16.8	16.8	2.7	2.7
OT	UT	Ordu-Akkuş-Akpınar	500	0	89.5	89.5	4.2	4.2	90.5	90.5	5.2	5.2
OT	UT	Samsun-Salıpazarı-Salıpazarı	1,203	0	502.9	502.9	23.7	23.7	503.9	503.9	24.7	24.7
OT	PS	Elif Fındık Sanayi ve Ticaret	27	1,730	43,633.2	676.7	2,057.1	31.9	43,634.2	676.7	2,058.1	31.9
OT	PS	Karaçuha Tarım Ürünleri İthalat-İhracat Sanayi Ve Ticaret	27	1,730	43,638.4	676.7	2,057.3	31.9	43,639.4	676.7	2,058.3	31.9
OT	PS	Güneş Fındık Tarım Ürünleri Ticaret Ve Sanayi Ltd.Şti.	27	1,757	44,116.5	673.7	2,079.9	31.8	44,117.5	673.7	2,080.9	31.8
OT	UT	Samsun-Terme-Terme	5,890	1,784	244.9	188.0	11.5	8.9	245.9	188.8	12.5	9.6

[1] PS: WWTP Point Sources; UT: Untreated Point Sources

[2] Acc. DF: Accumulative DF Scenario (DF_2)

K. Results of Total Pollution Load Assessment in the Yeşilırmak River Basin

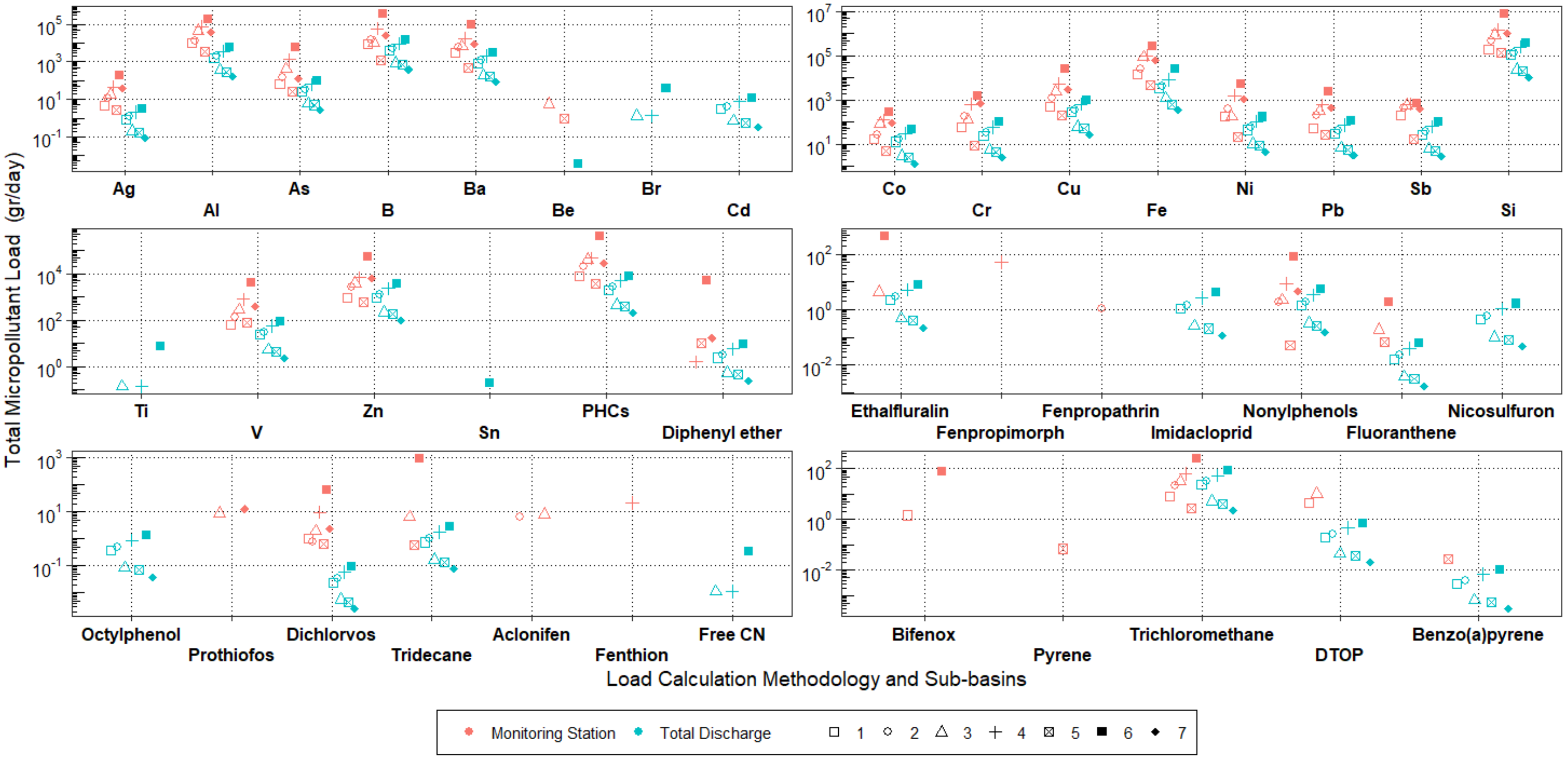


Figure A 5. Total Micropollutant Loads in Surface Water Monitoring Stations and Total Discharges from Point Sources

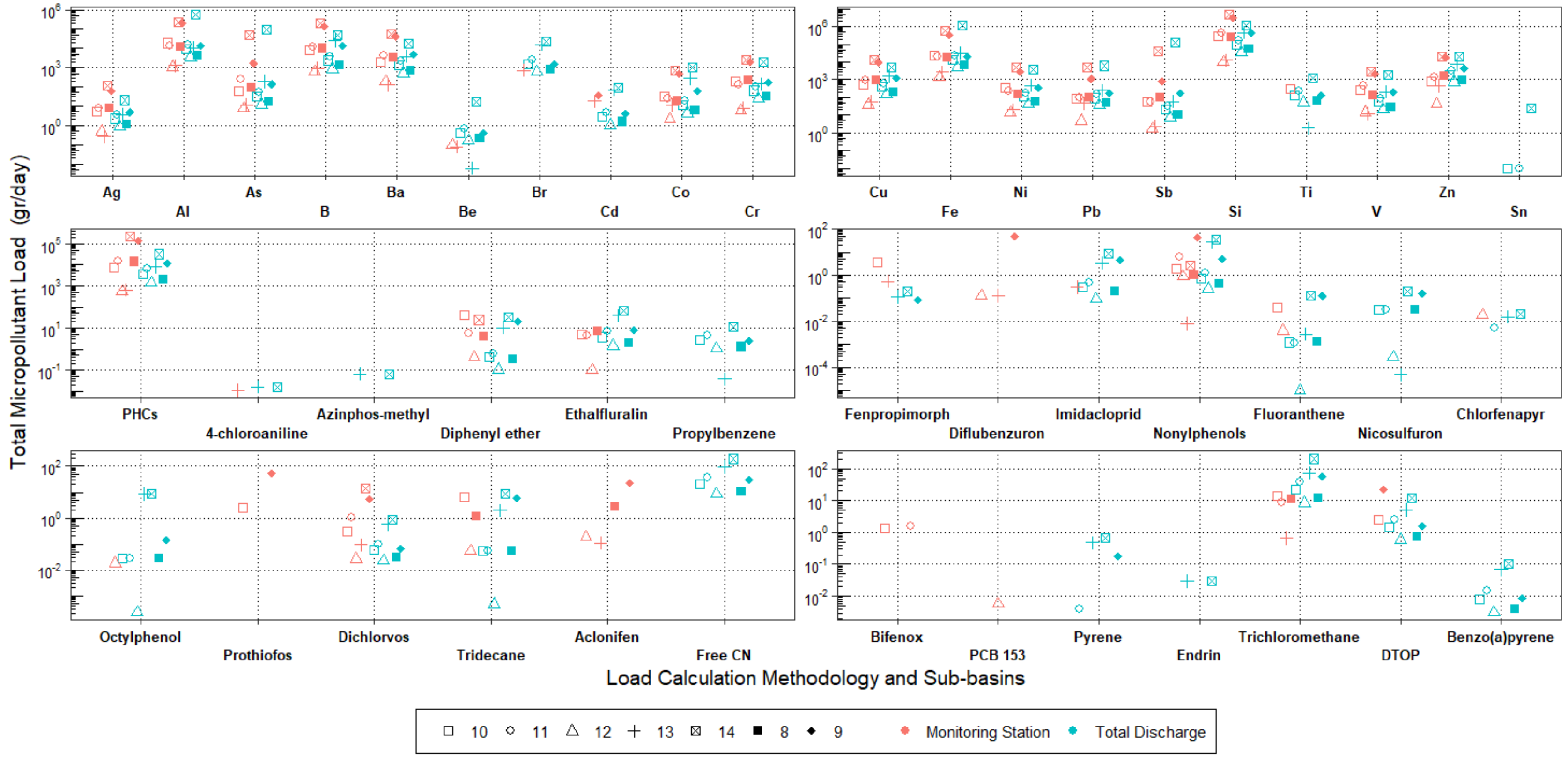


Figure A 5. Total Micropollutant Loads in Surface Water Monitoring Stations and Total Discharges from Point Sources (Continued)

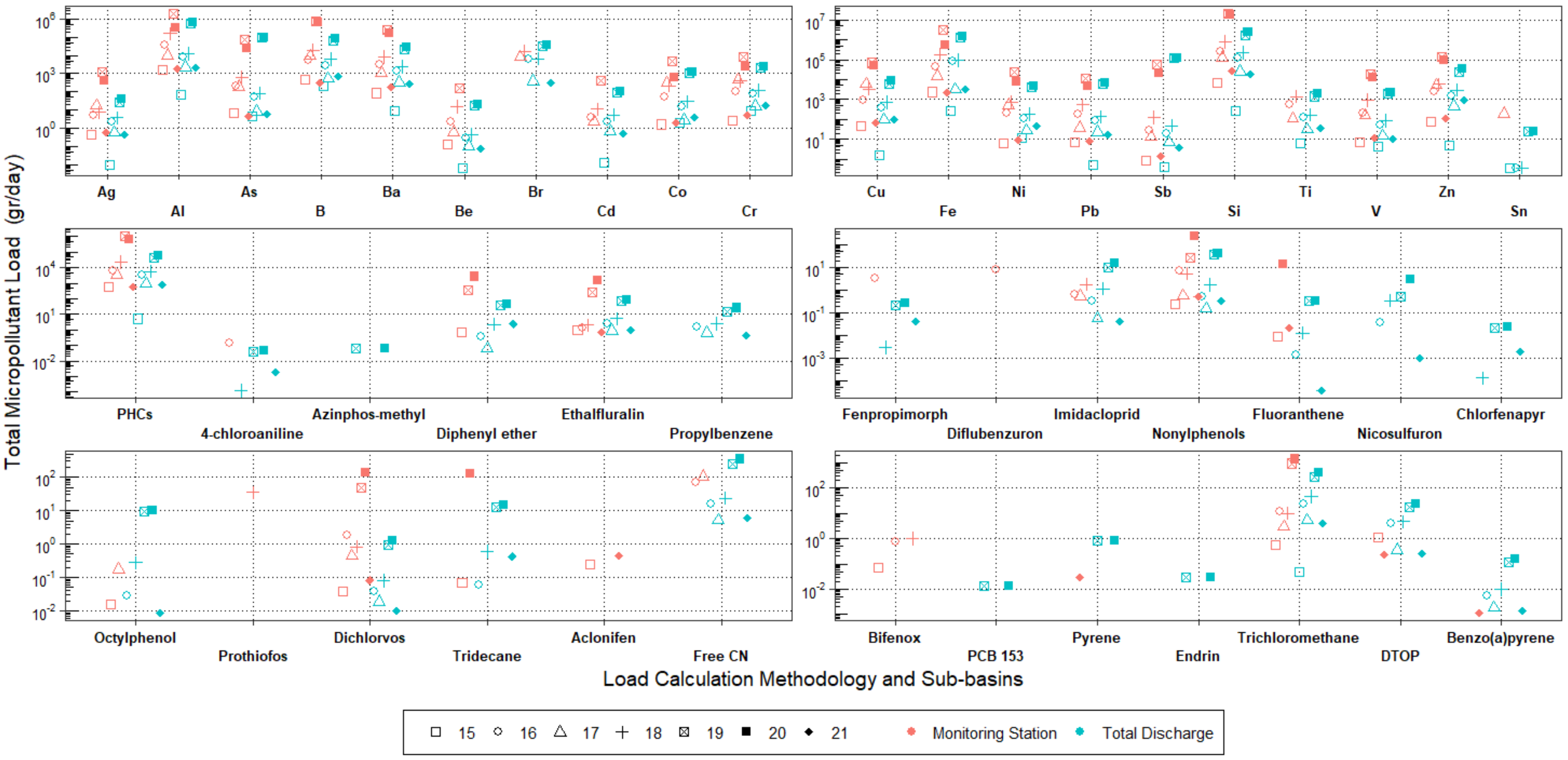


Figure A 5. Total Micropollutant Loads in Surface Water Monitoring Stations and Total Discharges from Point Sources (Continued)

L. Ecotoxicity Pathways of Cause of Concern Micropollutants

Table A 14. Known Ecotoxicity Pathways of Micropollutants That Are Cause of Concern in the YRB

Pollutant	**Pathway**	**References**
Fluoranthene	Oxidative Stress	(Magara et al., 2019; USEPA, 2012)
Nonylphenols	Estrogenicity	(Bakke, 2003; Chokwe et al., 2017)
Octylphenol	Estrogenicity	(IMAP, 2018; Lye et al., 1999)
Benzo(a)pyrene	Oxidative Stress	(Chang et al., 2019; Zena Bukowska et al., 2022)
Free CN	Oxidative Stress	(Hariharakrishnan et al., 2009; USEPA, 1980)
PHCs	Oxidative Stress Genotoxicity Endocrine Disruptor Narcosis Mutagenicity	(Dupuis & Ucan-Marin, 2015; Perhar & Arhonditsis, 2014; Reátegui-Zirena et al., 2014)
Hexachlorocyclohexane	Neurotoxicity Immunotoxicity Mutagenicity	(Ara et al., 2021)
Cypermethrin	Oxidative stress Endocrine Disruptor	(Y. Kim et al., 2007; Majumder & Kaviraj, 2017)
Dichlorvos	Endocrine Disruptor Mutagenicity Hepatotoxicity	(Deka & Mahanta, 2015; WHO, 1989)
Diflubenzuron	Oxidative Stress	(Abe et al., 2019; Pereira Maduenho & Martinez, 2008)
Ethalfluralin	No data available	-
Si	No data available	-
Br	No data available	-
Al	Oxidative Stress Genotoxicity	(Cano-Viveros et al., 2021; Galindo et al., 2010)
Co	Genotoxicity	(Turan et al., 2020)
Cu	Oxidative stress Growth Inhibition Genotoxicity	(Ajitha et al., 2021; Turan et al., 2020)
Fe	Oxidative Stress Genotoxicity	(Cano-Viveros et al., 2021; Farina et al., 2013; Turan et al., 2020)
Ni	Oxidative Stress Neurotoxicity	(Dane & Sisman, 2021; Elbeshti et al., 2018)
V	Oxidative Stress Genotoxicity	(Rojas-Lemus et al., 2020)
Zn	Oxidative Stress Growth Inhibition	(Ajitha et al., 2021; Pikula et al., 2020)
Cr	Growth Inhibition Oxidative stress Genotoxicity	(Ajitha et al., 2021; Turan et al., 2020)
Pb	Growth Inhibition Oxidative stress	(Ajitha et al., 2021)
Cd	Endocrine Disruptor Oxidative Stress Neurotoxicity Genotoxicity	(McGeer et al., 2011; Mehinto et al., 2014; Naik et al., 2020; Pikula et al., 2020)
Ti	Oxidative Stress Genotoxicity	(Faria et al., 2014; Girardello et al., 2016)
As	Oxidative Stress Genotoxicity	(J. H. Kim & Kang, 2015)

M. Plant Protection Product Usage at Provincial and Sub-basin Scales in the Yeşilırmak River Basin

Table A 15. The Annual Plant Protection Product Usage at the Provincial and Sub-basin Scale in the YRB

	Plant Protection Product Usage (kg/year or L/year)			
	Insecticide	**Fungicide**	**Herbicide**	**Other**
Provincial Scale				
Amasya	60.42	135.15	62.82	13.68
Bayburt	5.01	6.60	0.04	2.86
Çorum	2.07	12.24	25.24	13.26
Erzincan	0.67	1.45	4.19	13.39
Giresun	8.80	2.58	15.56	45.45
Gümüşhane	541.93	3.00	0.98	407.48
Ordu	5.58	4.59	1.31	2.39
Samsun	50.16	51.63	183.93	157.70
Sivas	1.04	4.73	7.76	72.43
Tokat	57.48	205.45	93.91	117.61
Yozgat	5.30	11.77	36.45	31.45
Sub-Basin Scale				
1	334.6	8.4	0.6	250.7
2	215.2	3.5	8.8	188.0
3	4.1	1.2	7.2	21.1
4	4.0	6.4	10.1	54.3
5	1.5	5.3	2.4	3.1
6	8.9	31.8	14.5	18.2
7	1.7	6.4	3.7	13.9
8	5.0	18.0	8.2	10.3
9	17.1	61.2	28.0	35.0
10	11.8	39.3	33.7	51.8
11	10.9	32.4	27.0	24.0
12	1.8	6.6	15.9	10.8
13	0.7	4.2	8.6	4.5
14	15.4	38.7	21.4	9.6
15	2.6	2.6	9.4	8.0
16	17.5	22.7	54.2	43.9
17	9.4	21.1	9.8	2.1
18	12.4	28.1	14.3	3.6
19	15.8	35.0	17.4	4.7
20	28.8	46.7	66.9	60.2
21	19.1	19.6	69.9	60.0

N. Results of the Risk Assessment

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB

Sub-basin	Pollutant	MEC	PNEC	f	RQ_f
1	Al	1.646E+03	4.807E+01	0.75	25.68
1	Br	3.240E+01	3.100E+01	0.13	0.13
1	Cd	1.281E-01	8.000E-02	0.13	0.20
1	Co	2.948E+00	3.000E-01	0.25	2.46
1	Cr	7.495E+00	1.600E+00	0.25	1.17
1	Cu	1.850E+01	1.299E+01	0.88	1.25
1	Cypermethrin	6.352E-02	8.000E-05	0.13	99.24
1	Dichlorvos	2.042E-01	6.000E-04	0.25	85.08
1	Fe	2.497E+03	9.522E+01	0.50	13.11
1	Ni	2.441E+01	4.000E+00	0.25	1.53
1	Pb	3.936E+00	1.200E+00	0.38	1.23
1	PHCs	4.960E+02	9.600E+01	0.50	2.58
1	Si	7.552E+03	1.830E+03	0.88	3.61
1	V	6.243E+00	1.600E+00	0.25	0.98
1	Zn	1.748E+02	5.900E+00	0.63	18.52
2	Al	4.567E+02	4.807E+01	0.75	7.13
2	Cd	8.876E-02	8.000E-02	0.13	0.14
2	Co	7.403E-01	3.000E-01	0.25	0.62
2	Cr	3.508E+00	1.600E+00	0.63	1.37
2	Cu	1.841E+01	1.299E+01	0.63	0.89
2	Cypermethrin	8.978E-02	8.000E-05	0.13	140.28
2	Dichlorvos	6.843E-02	6.000E-04	0.13	14.26
2	Fe	7.777E+02	9.522E+01	0.75	6.13
2	Ni	8.120E+00	4.000E+00	0.50	1.02
2	Pb	6.944E+00	1.200E+00	0.50	2.89
2	PHCs	5.810E+02	9.600E+01	0.50	3.03
2	Si	5.845E+03	1.830E+03	0.88	2.79
2	V	2.416E+00	1.600E+00	0.50	0.75
2	Zn	1.828E+02	5.900E+00	0.75	23.24
3	Al	1.083E+03	4.807E+01	1.00	22.53
3	Br	6.150E+01	3.100E+01	0.13	0.25
3	Cd	1.306E-01	8.000E-02	0.13	0.20
3	Co	2.429E+00	3.000E-01	0.63	5.06
3	Cr	1.716E+00	1.600E+00	0.13	0.13
3	Cu	2.666E+01	1.299E+01	0.75	1.54
3	Dichlorvos	1.131E-01	6.000E-04	0.13	23.56
3	Diflubenzuron	1.820E-01	1.300E-01	0.13	0.17
3	Fe	1.834E+03	9.522E+01	1.00	19.26
3	Hexachlorocyclohexane	4.771E-02	2.000E-02	0.25	0.60
3	Pb	6.737E+00	1.200E+00	0.75	4.21
3	PHCs	5.000E+02	9.600E+01	0.50	2.60
3	Si	7.348E+03	1.830E+03	0.88	3.51
3	V	3.352E+00	1.600E+00	0.63	1.31

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	Pollutant	MEC	PNEC	f	RQ$_f$
3	Zn	1.721E+02	5.900E+00	0.75	21.88
4	Al	9.495E+02	4.807E+01	0.88	17.28
4	Cd	1.184E-01	8.000E-02	0.13	0.18
4	Co	1.495E+00	3.000E-01	0.38	1.87
4	Cr	8.172E+00	1.600E+00	0.25	1.28
4	Cu	3.944E+01	1.299E+01	0.63	1.90
4	Cypermethrin	5.143E-02	8.000E-05	0.13	80.36
4	Dichlorvos	1.428E-01	6.000E-04	0.25	59.49
4	Fe	1.288E+03	9.522E+01	0.75	10.15
4	Ni	1.233E+01	4.000E+00	0.50	1.54
4	Pb	7.067E+00	1.200E+00	0.38	2.21
4	PHCs	4.200E+02	9.600E+01	0.38	1.64
4	Si	8.238E+03	1.830E+03	0.88	3.94
4	V	4.520E+00	1.600E+00	1.00	2.83
4	Zn	1.338E+02	5.900E+00	0.63	14.17
5	Al	5.133E+02	4.807E+01	1.00	10.68
5	Benzo(a)pyrene	1.435E-02	1.700E-04	0.14	12.06
5	Br	3.950E+01	3.100E+01	0.14	0.18
5	Cd	1.072E-01	8.000E-02	0.14	0.19
5	Co	6.849E-01	3.000E-01	0.71	1.63
5	Cu	2.000E+01	1.299E+01	1.00	1.54
5	Cypermethrin	2.648E-01	8.000E-05	0.14	472.93
5	Dichlorvos	2.949E-01	6.000E-04	0.29	140.41
5	Fe	6.106E+02	9.522E+01	1.00	6.41
5	Fluoranthene	3.090E-02	6.300E-03	0.14	0.70
5	Pb	4.635E+00	1.200E+00	0.71	2.76
5	PHCs	4.790E+02	9.600E+01	0.57	2.85
5	Si	1.175E+04	1.830E+03	0.86	5.50
5	V	7.832E+00	1.600E+00	1.00	4.89
5	Zn	2.716E+02	5.900E+00	0.86	39.46
6	Al	1.976E+02	4.807E+01	1.00	4.11
6	Cd	1.018E-01	8.000E-02	0.13	0.16
6	Cu	1.821E+01	1.299E+01	0.75	1.05
6	Cypermethrin	4.014E-02	8.000E-05	0.13	62.72
6	Dichlorvos	2.181E-01	6.000E-04	0.38	136.29
6	Ethalfluralin	2.128E+00	3.000E-01	0.13	0.89
6	Fe	2.476E+02	9.522E+01	0.75	1.95
6	Ni	7.236E+00	4.000E+00	0.25	0.45
6	Nonylphenols	3.638E-01	3.000E-01	0.13	0.15
6	Pb	2.753E+00	1.200E+00	0.38	0.86
6	PHCs	5.950E+02	9.600E+01	0.50	3.10
6	Si	6.467E+03	1.830E+03	0.75	2.65
6	V	3.203E+00	1.600E+00	1.00	2.00
6	Zn	1.464E+02	5.900E+00	1.00	24.81
7	Al	1.165E+03	4.807E+01	0.75	18.18
7	Cd	8.478E-02	8.000E-02	0.13	0.13
7	Co	2.572E+00	3.000E-01	0.25	2.14
7	Cr	1.062E+01	1.600E+00	1.00	6.64

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	Pollutant	MEC	PNEC	f	RQ_f
7	Cu	1.975E+01	1.299E+01	0.88	1.33
7	Cypermethrin	3.200E-01	8.000E-05	0.13	500.00
7	Dichlorvos	9.781E-02	6.000E-04	0.13	20.38
7	Fe	1.943E+03	9.522E+01	0.50	10.20
7	Hexachlorocyclohexane	2.718E-02	2.000E-02	0.13	0.17
7	Ni	2.684E+01	4.000E+00	0.25	1.68
7	Pb	6.511E+00	1.200E+00	0.63	3.39
7	PHCs	4.570E+02	9.600E+01	0.38	1.79
7	Si	6.424E+03	1.830E+03	0.88	3.07
7	V	4.525E+00	1.600E+00	0.63	1.77
7	Zn	1.193E+02	5.900E+00	0.63	12.63
8	Al	3.004E+02	4.807E+01	1.00	6.25
8	Cd	8.794E-02	8.000E-02	0.13	0.14
8	Co	6.281E-01	3.000E-01	0.63	1.31
8	Cr	9.903E+00	1.600E+00	0.75	4.64
8	Cu	2.084E+01	1.299E+01	0.75	1.20
8	Ethalfluralin	1.029E+00	3.000E-01	0.13	0.43
8	Fe	4.709E+02	9.522E+01	1.00	4.95
8	Pb	4.465E+00	1.200E+00	0.38	1.40
8	PHCs	3.870E+02	9.600E+01	0.63	2.52
8	Si	7.093E+03	1.830E+03	0.88	3.39
8	V	3.028E+00	1.600E+00	1.00	1.89
8	Zn	1.974E+02	5.900E+00	0.50	16.73
9	Al	9.065E+02	4.807E+01	1.00	18.86
9	Br	3.360E+01	3.100E+01	0.13	0.14
9	Cd	2.816E-01	8.000E-02	0.25	0.88
9	Co	1.751E+00	3.000E-01	1.00	5.84
9	Cr	6.289E+00	1.600E+00	1.00	3.93
9	Cu	2.811E+01	1.299E+01	1.00	2.16
9	Cypermethrin	5.641E-02	8.000E-05	0.13	88.13
9	Dichlorvos	7.992E-02	6.000E-04	0.13	16.65
9	Diflubenzuron	5.667E-01	1.300E-01	0.13	0.54
9	Fe	1.423E+03	9.522E+01	1.00	14.94
9	Hexachlorocyclohexane	4.832E-02	2.000E-02	0.13	0.30
9	Ni	9.479E+00	4.000E+00	0.75	1.78
9	Nonylphenols	6.490E-01	3.000E-01	0.13	0.27
9	Pb	5.359E+00	1.200E+00	0.75	3.35
9	PHCs	6.870E+02	9.600E+01	0.38	2.68
9	Si	7.958E+03	1.830E+03	0.88	3.81
9	V	5.433E+00	1.600E+00	1.00	3.40
9	Zn	1.529E+02	5.900E+00	1.00	25.92
10	Al	1.522E+03	4.807E+01	1.00	31.67
10	Br	1.097E+02	3.100E+01	0.13	0.44
10	Cd	9.568E-02	8.000E-02	0.13	0.15
10	Co	2.534E+00	3.000E-01	0.88	7.39
10	Cr	9.397E+00	1.600E+00	1.00	5.87
10	Cu	1.838E+01	1.299E+01	1.00	1.41
10	Dichlorvos	6.749E-02	6.000E-04	0.13	14.06

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**f**	**RQ_f**
10	Diflubenzuron	1.953E-01	1.300E-01	0.13	0.19
10	Ethalfluralin	1.066E+00	3.000E-01	0.13	0.44
10	Fe	1.973E+03	9.522E+01	1.00	20.72
10	Ni	2.447E+01	4.000E+00	0.88	5.35
10	Nonylphenols	4.425E-01	3.000E-01	0.13	0.18
10	Pb	4.817E+00	1.200E+00	0.75	3.01
10	PHCs	5.280E+02	9.600E+01	0.50	2.75
10	Si	1.031E+04	1.830E+03	0.88	4.93
10	V	9.891E+00	1.600E+00	1.00	6.18
10	Zn	7.854E+01	5.900E+00	0.75	9.98
11	Al	4.444E+02	4.807E+01	0.88	8.09
11	Br	5.640E+01	3.100E+01	0.50	0.91
11	Cd	1.148E-01	8.000E-02	0.13	0.18
11	Co	9.095E-01	3.000E-01	0.75	2.27
11	Cr	3.003E+00	1.600E+00	0.88	1.64
11	Cu	1.838E+01	1.299E+01	1.00	1.42
11	Cypermethrin	8.376E-02	8.000E-05	0.13	130.87
11	Dichlorvos	1.365E-01	6.000E-04	0.13	28.43
11	Ethalfluralin	6.149E-01	3.000E-01	0.13	0.26
11	Fe	6.325E+02	9.522E+01	1.00	6.64
11	Ni	6.063E+00	4.000E+00	0.50	0.76
11	Nonylphenols	4.519E-01	3.000E-01	0.25	0.38
11	Pb	3.202E+00	1.200E+00	0.38	1.00
11	PHCs	6.000E+02	9.600E+01	0.38	2.34
11	Si	9.939E+03	1.830E+03	0.75	4.07
11	V	1.178E+01	1.600E+00	1.00	7.36
11	Zn	1.047E+02	5.900E+00	0.75	13.31
12	Al	1.075E+03	4.807E+01	1.00	22.37
12	Br	8.720E+01	3.100E+01	0.63	1.76
12	Co	2.001E+00	3.000E-01	0.88	5.84
12	Cr	5.062E+00	1.600E+00	0.75	2.37
12	Cu	2.146E+01	1.299E+01	1.00	1.65
12	Dichlorvos	8.556E-02	6.000E-04	0.13	17.83
12	Diflubenzuron	2.538E-01	1.300E-01	0.13	0.24
12	Ethalfluralin	3.158E-01	3.000E-01	0.13	0.13
12	Fe	1.381E+03	9.522E+01	1.00	14.50
12	Fluoranthene	7.000E-03	6.300E-03	0.13	0.14
12	Hexachlorocyclohexane	7.220E-02	2.000E-02	0.13	0.45
12	Ni	1.211E+01	4.000E+00	0.50	1.51
12	Nonylphenols	2.775E+00	3.000E-01	0.13	1.16
12	Pb	3.683E+00	1.200E+00	0.88	2.69
12	PHCs	4.200E+02	9.600E+01	0.38	1.64
12	Si	5.690E+03	1.830E+03	0.75	2.33
12	V	1.050E+01	1.600E+00	1.00	6.56
12	Zn	7.035E+01	5.900E+00	0.88	10.43
13	Al	2.316E+03	4.807E+01	1.00	48.17
13	Br	7.065E+02	3.100E+01	1.00	22.79
13	Cd	4.559E+01	8.000E-02	1.00	569.89

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**f**	**RQ_f**
13	Co	3.503E+01	3.000E-01	1.00	116.76
13	Cr	1.078E+01	1.600E+00	1.00	6.74
13	Cu	4.905E+01	1.299E+01	1.00	3.78
13	Cypermethrin	6.502E-02	8.000E-05	0.13	101.60
13	Dichlorvos	2.564E-01	6.000E-04	0.25	106.82
13	Diflubenzuron	3.463E-01	1.300E-01	0.13	0.33
13	Fe	3.427E+03	9.522E+01	1.00	35.99
13	Free CN	1.630E+00	1.200E+00	0.13	0.17
13	Ni	2.107E+01	4.000E+00	1.00	5.27
13	Pb	9.563E+01	1.200E+00	1.00	79.69
13	PHCs	4.830E+02	9.600E+01	0.63	3.14
13	Si	8.645E+03	1.830E+03	0.63	2.95
13	V	1.298E+01	1.600E+00	1.00	8.11
13	Zn	4.235E+02	5.900E+00	1.00	71.79
14	Al	5.304E+02	4.807E+01	1.00	11.03
14	As	7.412E+01	5.300E+01	0.63	0.87
14	Co	1.198E+00	3.000E-01	1.00	3.99
14	Cr	4.512E+00	1.600E+00	1.00	2.82
14	Cu	2.144E+01	1.299E+01	0.88	1.44
14	Cypermethrin	8.186E-02	8.000E-05	0.13	127.90
14	Dichlorvos	1.325E-01	6.000E-04	0.13	27.61
14	Diflubenzuron	1.805E-01	1.300E-01	0.13	0.17
14	Fe	1.185E+03	9.522E+01	1.00	12.45
14	Hexachlorocyclohexane	1.200E-01	2.000E-02	0.13	0.75
14	Ni	8.146E+00	4.000E+00	1.00	2.04
14	Pb	9.470E+00	1.200E+00	1.00	7.89
14	PHCs	6.630E+02	9.600E+01	0.50	3.45
14	Si	7.483E+03	1.830E+03	0.88	3.58
14	V	4.820E+00	1.600E+00	1.00	3.01
14	Zn	1.092E+02	5.900E+00	1.00	18.50
15	Al	1.345E+03	4.807E+01	1.00	27.98
15	Cd	9.995E-02	8.000E-02	0.13	0.16
15	Co	1.181E+00	3.000E-01	1.00	3.94
15	Cr	2.123E+00	1.600E+00	0.13	0.17
15	Cu	2.433E+01	1.299E+01	1.00	1.87
15	Cypermethrin	1.060E-01	8.000E-05	0.13	165.67
15	Dichlorvos	1.305E-01	6.000E-04	0.13	27.20
15	Ethalfluralin	3.279E+00	3.000E-01	0.13	1.37
15	Fe	2.007E+03	9.522E+01	1.00	21.08
15	Fluoranthene	2.618E-02	6.300E-03	0.13	0.52
15	Hexachlorocyclohexane	9.076E-02	2.000E-02	0.13	0.57
15	Nonylphenols	5.848E-01	3.000E-01	0.13	0.24
15	Pb	4.698E+00	1.200E+00	1.00	3.91
15	PHCs	4.670E+02	9.600E+01	0.50	2.43
15	Si	4.579E+03	1.830E+03	0.75	1.88
15	V	4.110E+00	1.600E+00	1.00	2.57
15	Zn	9.496E+01	5.900E+00	1.00	16.09
16	Al	6.689E+03	4.807E+01	1.00	139.16

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**f**	**RQ_f**
16	Br	1.648E+02	3.100E+01	0.63	3.32
16	Cd	5.030E-01	8.000E-02	0.75	4.72
16	Co	6.112E+00	3.000E-01	1.00	20.37
16	Cr	1.691E+01	1.600E+00	0.63	6.60
16	Cu	8.367E+01	1.299E+01	1.00	6.44
16	Cypermethrin	2.200E-01	8.000E-05	0.13	343.75
16	Dichlorvos	4.271E-01	6.000E-04	0.25	177.94
16	Diflubenzuron	2.432E+00	1.300E-01	0.13	2.34
16	Ethalfluralin	4.210E-01	3.000E-01	0.13	0.18
16	Fe	7.498E+03	9.522E+01	1.00	78.75
16	Free CN	1.595E+01	1.200E+00	0.13	1.66
16	Ni	2.762E+01	4.000E+00	0.63	4.32
16	Nonylphenols	1.692E+00	3.000E-01	0.25	1.41
16	Pb	2.871E+01	1.200E+00	1.00	23.92
16	PHCs	5.150E+02	9.600E+01	0.50	2.68
16	Si	2.166E+04	1.830E+03	0.88	10.36
16	Ti	9.670E+01	2.600E+01	0.13	0.46
16	V	2.434E+01	1.600E+00	1.00	15.21
16	Zn	2.512E+02	5.900E+00	1.00	42.58
17	Al	2.767E+03	4.807E+01	1.00	57.56
17	Br	8.046E+02	3.100E+01	1.00	25.95
17	Cd	4.883E-01	8.000E-02	0.75	4.58
17	Co	6.550E+01	3.000E-01	1.00	218.34
17	Cr	1.022E+02	1.600E+00	1.00	63.89
17	Cu	6.773E+02	1.299E+01	1.00	52.14
17	Cypermethrin	8.655E-02	8.000E-05	0.13	135.23
17	Dichlorvos	2.518E-01	6.000E-04	0.13	52.46
17	Fe	3.145E+03	9.522E+01	1.00	33.03
17	Free CN	3.820E+01	1.200E+00	0.25	7.96
17	Hexachlorocyclohexane	2.437E-02	2.000E-02	0.13	0.15
17	Ni	1.143E+02	4.000E+00	1.00	28.58
17	Nonylphenols	3.150E-01	3.000E-01	0.13	0.13
17	Pb	7.245E+00	1.200E+00	1.00	6.04
17	PHCs	5.030E+02	9.600E+01	0.38	1.96
17	Si	1.243E+04	1.830E+03	0.88	5.94
17	Ti	2.725E+01	2.600E+01	0.13	0.13
17	V	2.348E+01	1.600E+00	1.00	14.67
17	Zn	7.371E+02	5.900E+00	1.00	124.94
18	Al	6.196E+03	4.807E+01	1.00	128.90
18	Br	3.816E+02	3.100E+01	1.00	12.31
18	Cd	3.203E-01	8.000E-02	0.75	3.00
18	Co	8.534E+00	3.000E-01	1.00	28.45
18	Cr	1.673E+01	1.600E+00	1.00	10.45
18	Cu	1.646E+02	1.299E+01	1.00	12.67
18	Cypermethrin	1.200E-01	8.000E-05	0.13	187.50
18	Dichlorvos	7.511E-02	6.000E-04	0.25	31.30
18	Fe	7.133E+03	9.522E+01	1.00	74.91
18	Free CN	3.660E+00	1.200E+00	0.13	0.38

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	Pollutant	MEC	PNEC	f	RQ_f
18	Ni	2.344E+01	4.000E+00	1.00	5.86
18	Nonylphenols	5.022E-01	3.000E-01	0.13	0.21
18	Pb	2.232E+01	1.200E+00	1.00	18.60
18	PHCs	9.970E+02	9.600E+01	0.38	3.89
18	Si	2.083E+04	1.830E+03	0.88	9.96
18	Ti	8.460E+01	2.600E+01	0.25	0.81
18	V	3.152E+01	1.600E+00	1.00	19.70
18	Zn	2.104E+02	5.900E+00	1.00	35.66
19	Al	1.386E+03	4.807E+01	1.00	28.83
19	Br	1.100E+02	3.100E+01	0.75	2.66
19	Cd	3.153E-01	8.000E-02	0.50	1.97
19	Co	3.323E+00	3.000E-01	1.00	11.08
19	Cr	4.090E+00	1.600E+00	0.88	2.24
19	Cu	4.896E+01	1.299E+01	1.00	3.77
19	Cypermethrin	3.870E-02	8.000E-05	0.13	60.46
19	Dichlorvos	1.264E-01	6.000E-04	0.13	26.34
19	Ethalfluralin	6.806E-01	3.000E-01	0.13	0.28
19	Fe	2.392E+03	9.522E+01	1.00	25.12
19	Ni	1.831E+01	4.000E+00	0.88	4.01
19	Pb	5.592E+00	1.200E+00	1.00	4.66
19	PHCs	6.240E+02	9.600E+01	0.63	4.06
19	Si	8.048E+03	1.830E+03	0.88	3.85
19	V	7.673E+00	1.600E+00	1.00	4.80
19	Zn	2.132E+02	5.900E+00	1.00	36.13
20	Al	1.523E+02	4.807E+01	1.00	3.17
20	Br	4.100E+01	3.100E+01	0.13	0.17
20	Cu	1.764E+01	1.299E+01	0.75	1.02
20	Dichlorvos	3.085E-01	6.000E-04	0.13	64.27
20	Ethalfluralin	3.404E+00	3.000E-01	0.13	1.42
20	Fe	5.489E+02	9.522E+01	0.75	4.32
20	Fluoranthene	2.785E-02	6.300E-03	0.13	0.55
20	Free CN	1.240E+00	1.200E+00	0.13	0.13
20	Nonylphenols	5.233E-01	3.000E-01	0.13	0.22
20	Pb	2.676E+00	1.200E+00	0.38	0.84
20	PHCs	5.460E+02	9.600E+01	0.38	2.13
20	Si	5.864E+03	1.830E+03	0.88	2.80
20	V	4.273E+00	1.600E+00	1.00	2.67
20	Zn	7.976E+01	5.900E+00	0.88	11.83
21	Al	1.263E+03	4.807E+01	1.00	26.27
21	Benzo(a)pyrene	2.101E-03	1.700E-04	0.13	1.54
21	Cd	1.093E-01	8.000E-02	0.13	0.17
21	Co	1.344E+00	3.000E-01	0.50	2.24
21	Cr	2.534E+00	1.600E+00	0.38	0.59
21	Cu	2.211E+01	1.299E+01	1.00	1.70
21	Cypermethrin	1.400E-01	8.000E-05	0.13	218.75
21	Dichlorvos	1.792E-01	6.000E-04	0.13	37.33
21	Diflubenzuron	1.567E-01	1.300E-01	0.13	0.15
21	Ethalfluralin	1.453E+00	3.000E-01	0.13	0.61

Table A 16. Weighed Risk Quotients of Micropollutants Detected in the Surface Water Samples of the YRB (Continued)

Sub-basin	Pollutant	MEC	PNEC	f	RQ_f
21	Fe	1.519E+03	9.522E+01	1.00	15.95
21	Fluoranthene	4.007E-02	6.300E-03	0.13	0.80
21	Ni	6.036E+00	4.000E+00	0.13	0.19
21	Nonylphenols	7.160E-01	3.000E-01	0.25	0.60
21	Pb	3.809E+00	1.200E+00	0.88	2.78
21	PHCs	3.670E+02	9.600E+01	0.38	1.43
21	Si	8.129E+03	1.830E+03	0.75	3.33
21	V	5.096E+00	1.600E+00	1.00	3.19
21	Zn	1.224E+02	5.900E+00	0.88	18.15

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents

Sub-basin	Pollutant	MEC	PNEC	RQ_f
1	Al	3.425E+01	4.807E+01	0.71
1	Benzo(a)pyrene	2.746E-05	1.700E-04	0.16
1	Br	1.938E+01	3.100E+01	0.63
1	Cd	9.837E-02	8.000E-02	1.23
1	Co	4.011E-01	3.000E-01	1.34
1	Cr	2.264E-01	1.600E+00	0.14
1	Cu	1.785E+00	1.299E+01	0.14
1	Cypermethrin	1.396E-03	8.000E-05	17.46
1	Dichlorvos	2.264E-04	6.000E-04	0.38
1	Ethalfluralin	1.678E-02	3.000E-01	0.06
1	Fe	6.423E+01	9.522E+01	0.67
1	Fluoranthene	7.300E-05	6.300E-03	0.01
1	Free CN	4.967E-02	1.200E+00	0.04
1	Ni	3.511E-01	4.000E+00	0.09
1	Nonylphenols	8.567E-03	3.000E-01	0.03
1	Octylphenol	2.504E-03	1.000E-01	0.03
1	Pb	4.309E-01	1.200E+00	0.36
1	PHCs	9.395E+00	9.600E+01	0.10
1	Si	2.394E+02	1.830E+03	0.13
1	Ti	1.118E-01	2.600E+01	0.00
1	V	1.582E-01	1.600E+00	0.10
1	Zn	7.507E+00	5.900E+00	1.27
2	Al	1.783E+01	4.807E+01	0.37
2	Benzo(a)pyrene	1.352E-05	1.700E-04	0.08
2	Br	9.511E+00	3.100E+01	0.31
2	Cd	4.690E-02	8.000E-02	0.59
2	Co	1.908E-01	3.000E-01	0.64
2	Cr	1.150E-01	1.600E+00	0.07
2	Cu	8.689E-01	1.299E+01	0.07
2	Cypermethrin	6.803E-04	8.000E-05	8.50

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**RQ_f**
2	Dichlorvos	1.103E-04	6.000E-04	0.18
2	Ethalfluralin	8.185E-03	3.000E-01	0.03
2	Fe	3.238E+01	9.522E+01	0.34
2	Fluoranthene	3.438E-05	6.300E-03	0.01
2	Free CN	2.417E-02	1.200E+00	0.02
2	Ni	1.791E-01	4.000E+00	0.04
2	Nonylphenols	4.069E-03	3.000E-01	0.01
2	Octylphenol	1.180E-03	1.000E-01	0.01
2	Pb	2.211E-01	1.200E+00	0.18
2	PHCs	4.667E+00	9.600E+01	0.05
2	Si	1.165E+02	1.830E+03	0.06
2	Ti	5.919E-02	2.600E+01	0.00
2	V	8.100E-02	1.600E+00	0.05
2	Zn	3.746E+00	5.900E+00	0.63
3	Al	7.046E+00	4.807E+01	0.15
3	Benzo(a)pyrene	2.457E-06	1.700E-04	0.01
3	Br	1.588E+00	3.100E+01	0.05
3	Cd	2.370E-03	8.000E-02	0.03
3	Co	8.031E-03	3.000E-01	0.03
3	Cr	3.507E-02	1.600E+00	0.02
3	Cu	1.178E-01	1.299E+01	0.01
3	Cypermethrin	9.382E-05	8.000E-05	1.17
3	Dichlorvos	1.513E-05	6.000E-04	0.03
3	Ethalfluralin	1.173E-03	3.000E-01	0.00
3	Fe	9.221E+00	9.522E+01	0.10
3	Free CN	3.219E-03	1.200E+00	0.00
3	Ni	5.685E-02	4.000E+00	0.01
3	Nonylphenols	1.425E-04	3.000E-01	0.00
3	Pb	7.543E-02	1.200E+00	0.06
3	PHCs	1.007E+00	9.600E+01	0.01
3	Si	1.540E+01	1.830E+03	0.01
3	Ti	2.717E-02	2.600E+01	0.00
3	V	2.701E-02	1.600E+00	0.02
3	Zn	8.750E-01	5.900E+00	0.15
4	Al	1.410E+01	4.807E+01	0.29
4	Benzo(a)pyrene	9.724E-06	1.700E-04	0.06
4	Br	6.791E+00	3.100E+01	0.22
4	Cd	3.165E-02	8.000E-02	0.40
4	Co	1.282E-01	3.000E-01	0.43
4	Cr	8.752E-02	1.600E+00	0.05
4	Cu	6.113E-01	1.299E+01	0.05
4	Cypermethrin	4.791E-04	8.000E-05	5.99
4	Dichlorvos	7.763E-05	6.000E-04	0.13
4	Ethalfluralin	5.779E-03	3.000E-01	0.02
4	Fe	2.452E+01	9.522E+01	0.26
4	Fluoranthene	2.261E-05	6.300E-03	0.00
4	Free CN	1.698E-02	1.200E+00	0.01
4	Ni	1.370E-01	4.000E+00	0.03

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	Pollutant	MEC	PNEC	RQ_f
4	Nonylphenols	2.724E-03	3.000E-01	0.01
4	Octylphenol	7.758E-04	1.000E-01	0.01
4	Pb	1.709E-01	1.200E+00	0.14
4	PHCs	3.409E+00	9.600E+01	0.04
4	Si	8.180E+01	1.830E+03	0.04
4	Ti	4.811E-02	2.600E+01	0.00
4	V	6.239E-02	1.600E+00	0.04
4	Zn	2.759E+00	5.900E+00	0.47
5	Al	1.104E+02	4.807E+01	2.30
5	Benzo(a)pyrene	3.852E-05	1.700E-04	0.23
5	Br	2.488E+01	3.100E+01	0.80
5	Cd	3.716E-02	8.000E-02	0.46
5	Co	1.257E-01	3.000E-01	0.42
5	Cr	5.486E-01	1.600E+00	0.34
5	Cu	1.846E+00	1.299E+01	0.14
5	Cypermethrin	1.471E-03	8.000E-05	18.38
5	Dichlorvos	2.371E-04	6.000E-04	0.40
5	Ethalfluralin	1.839E-02	3.000E-01	0.06
5	Fe	1.384E+02	9.522E+01	1.45
5	Free CN	5.041E-02	1.200E+00	0.04
5	Ni	8.907E-01	4.000E+00	0.22
5	Nonylphenols	2.234E-03	3.000E-01	0.01
5	Pb	1.182E+00	1.200E+00	0.99
5	PHCs	1.578E+01	9.600E+01	0.16
5	Si	2.411E+02	1.830E+03	0.13
5	Ti	4.255E-01	2.600E+01	0.02
5	V	4.233E-01	1.600E+00	0.26
5	Zn	1.371E+01	5.900E+00	2.32
6	Al	3.221E+01	4.807E+01	0.67
6	As	4.513E-04	5.300E+01	0.00
6	Benzo(a)pyrene	1.514E-05	1.700E-04	0.09
6	Br	1.021E+01	3.100E+01	0.33
6	Cd	3.283E-02	8.000E-02	0.41
6	Co	1.289E-01	3.000E-01	0.43
6	Cr	1.759E-01	1.600E+00	0.11
6	Cu	8.458E-01	1.299E+01	0.07
6	Cypermethrin	6.662E-04	8.000E-05	8.33
6	Dichlorvos	1.077E-04	6.000E-04	0.18
6	Ethalfluralin	8.157E-03	3.000E-01	0.03
6	Fe	5.173E+01	9.522E+01	0.54
6	Fluoranthene	1.851E-05	6.300E-03	0.00
6	Free CN	2.334E-02	1.200E+00	0.02
6	Ni	2.796E-01	4.000E+00	0.07
6	Nonylphenols	2.646E-03	3.000E-01	0.01
6	Octylphenol	6.349E-04	1.000E-01	0.01
6	Pb	3.604E-01	1.200E+00	0.30
6	PHCs	5.733E+00	9.600E+01	0.06
6	Si	1.123E+02	1.830E+03	0.06

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**RQ_f**
6	Ti	1.204E-01	2.600E+01	0.00
6	V	1.309E-01	1.600E+00	0.08
6	Zn	4.818E+00	5.900E+00	0.82
7	Al	6.019E+00	4.807E+01	0.13
7	Benzo(a)pyrene	2.101E-06	1.700E-04	0.01
7	Br	1.357E+00	3.100E+01	0.04
7	Cd	2.026E-03	8.000E-02	0.03
7	Co	6.857E-03	3.000E-01	0.02
7	Cr	2.992E-02	1.600E+00	0.02
7	Cu	1.006E-01	1.299E+01	0.01
7	Cypermethrin	8.020E-05	8.000E-05	1.00
7	Dichlorvos	1.293E-05	6.000E-04	0.02
7	Ethalfluralin	1.003E-03	3.000E-01	0.00
7	Fe	7.546E+00	9.522E+01	0.08
7	Free CN	2.749E-03	1.200E+00	0.00
7	Ni	4.858E-02	4.000E+00	0.01
7	Nonylphenols	1.219E-04	3.000E-01	0.00
7	Pb	6.448E-02	1.200E+00	0.05
7	PHCs	8.604E-01	9.600E+01	0.01
7	Si	1.315E+01	1.830E+03	0.01
7	Ti	2.320E-02	2.600E+01	0.00
7	V	2.309E-02	1.600E+00	0.01
7	Zn	7.478E-01	5.900E+00	0.13
8	Al	9.877E+01	4.807E+01	2.05
8	Benzo(a)pyrene	3.702E-05	1.700E-04	0.22
8	Br	2.419E+01	3.100E+01	0.78
8	Cd	4.756E-02	8.000E-02	0.59
8	Co	1.722E-01	3.000E-01	0.57
8	Cr	5.002E-01	1.600E+00	0.31
8	Cu	1.851E+00	1.299E+01	0.14
8	Cypermethrin	1.471E-03	8.000E-05	18.39
8	Dichlorvos	2.373E-04	6.000E-04	0.40
8	Ethalfluralin	1.828E-02	3.000E-01	0.06
8	Fe	1.273E+02	9.522E+01	1.34
8	Fluoranthene	1.202E-05	6.300E-03	0.00
8	Free CN	5.072E-02	1.200E+00	0.04
8	Ni	8.095E-01	4.000E+00	0.20
8	Nonylphenols	3.296E-03	3.000E-01	0.01
8	Octylphenol	4.124E-04	1.000E-01	0.00
8	Pb	1.069E+00	1.200E+00	0.89
8	PHCs	1.486E+01	9.600E+01	0.15
8	Si	2.429E+02	1.830E+03	0.13
8	Ti	3.774E-01	2.600E+01	0.01
8	V	3.833E-01	1.600E+00	0.24
8	Zn	1.281E+01	5.900E+00	2.17
9	Al	6.532E+01	4.807E+01	1.36
9	Benzo(a)pyrene	2.423E-05	1.700E-04	0.14
9	Br	1.663E+01	3.100E+01	0.54

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	Pollutant	MEC	PNEC	RQ_f
9	Cd	4.133E-02	8.000E-02	0.52
9	Co	1.951E-01	3.000E-01	0.65
9	Cr	4.261E-01	1.600E+00	0.27
9	Cu	2.663E+00	1.299E+01	0.20
9	Cypermethrin	1.022E-03	8.000E-05	12.78
9	Dichlorvos	1.629E-04	6.000E-04	0.27
9	Ethalfluralin	1.544E-02	3.000E-01	0.05
9	Fe	8.511E+01	9.522E+01	0.89
9	Fluoranthene	1.057E-04	6.300E-03	0.02
9	Free CN	4.130E-02	1.200E+00	0.03
9	Ni	6.829E-01	4.000E+00	0.17
9	Nonylphenols	6.491E-03	3.000E-01	0.02
9	Octylphenol	6.000E-04	1.000E-01	0.01
9	Pb	7.789E-01	1.200E+00	0.65
9	PHCs	1.496E+01	9.600E+01	0.16
9	Si	4.216E+02	1.830E+03	0.23
9	Ti	2.217E-01	2.600E+01	0.01
9	V	3.792E-01	1.600E+00	0.24
9	Zn	1.261E+01	5.900E+00	2.14
10	Al	8.129E+01	4.807E+01	1.69
10	As	1.393E-04	5.300E+01	0.00
10	Benzo(a)pyrene	2.937E-05	1.700E-04	0.17
10	Br	1.908E+01	3.100E+01	0.62
10	Cd	3.299E-02	8.000E-02	0.41
10	Co	1.162E-01	3.000E-01	0.39
10	Cr	4.080E-01	1.600E+00	0.26
10	Cu	1.438E+00	1.299E+01	0.11
10	Cypermethrin	1.144E-03	8.000E-05	14.30
10	Dichlorvos	1.845E-04	6.000E-04	0.31
10	Ethalfluralin	1.426E-02	3.000E-01	0.05
10	Fe	1.033E+02	9.522E+01	1.08
10	Fluoranthene	4.723E-06	6.300E-03	0.00
10	Free CN	3.934E-02	1.200E+00	0.03
10	Ni	6.613E-01	4.000E+00	0.17
10	Nonylphenols	2.155E-03	3.000E-01	0.01
10	Octylphenol	1.620E-04	1.000E-01	0.00
10	Pb	8.750E-01	1.200E+00	0.73
10	PHCs	1.191E+01	9.600E+01	0.12
10	Si	1.882E+02	1.830E+03	0.10
10	Ti	3.125E-01	2.600E+01	0.01
10	V	3.138E-01	1.600E+00	0.20
10	Zn	1.031E+01	5.900E+00	1.75
11	Al	1.359E+02	4.807E+01	2.83
11	As	1.392E-04	5.300E+01	0.00
11	Benzo(a)pyrene	5.010E-05	1.700E-04	0.29
11	Br	3.137E+01	3.100E+01	1.01
11	Cd	5.134E-02	8.000E-02	0.64
11	Co	1.783E-01	3.000E-01	0.59

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	Pollutant	MEC	PNEC	RQ_f
11	Cr	6.790E-01	1.600E+00	0.42
11	Cu	2.354E+00	1.299E+01	0.18
11	Cypermethrin	1.935E-03	8.000E-05	24.19
11	Dichlorvos	3.016E-04	6.000E-04	0.50
11	Ethalfluralin	2.416E-02	3.000E-01	0.08
11	Fe	1.717E+02	9.522E+01	1.80
11	Fluoranthene	4.720E-06	6.300E-03	0.00
11	Free CN	6.423E-02	1.200E+00	0.05
11	Ni	1.101E+00	4.000E+00	0.28
11	Nonylphenols	3.357E-03	3.000E-01	0.01
11	Octylphenol	1.619E-04	1.000E-01	0.00
11	Pb	1.459E+00	1.200E+00	1.22
11	PHCs	1.979E+01	9.600E+01	0.21
11	Si	3.102E+02	1.830E+03	0.17
11	Ti	5.226E-01	2.600E+01	0.02
11	V	5.229E-01	1.600E+00	0.33
11	Zn	1.710E+01	5.900E+00	2.90
12	Al	1.745E+02	4.807E+01	3.63
12	Benzo(a)pyrene	6.093E-05	1.700E-04	0.36
12	Br	3.936E+01	3.100E+01	1.27
12	Cd	5.899E-02	8.000E-02	0.74
12	Co	1.998E-01	3.000E-01	0.67
12	Cr	8.673E-01	1.600E+00	0.54
12	Cu	2.921E+00	1.299E+01	0.22
12	Cypermethrin	2.328E-03	8.000E-05	29.09
12	Dichlorvos	3.752E-04	6.000E-04	0.63
12	Ethalfluralin	2.910E-02	3.000E-01	0.10
12	Fe	2.188E+02	9.522E+01	2.30
12	Fluoranthene	2.184E-07	6.300E-03	0.00
12	Free CN	7.979E-02	1.200E+00	0.07
12	Ni	1.408E+00	4.000E+00	0.35
12	Nonylphenols	3.556E-03	3.000E-01	0.01
12	Octylphenol	7.492E-06	1.000E-01	0.00
12	Pb	1.869E+00	1.200E+00	1.56
12	PHCs	2.495E+01	9.600E+01	0.26
12	Si	3.816E+02	1.830E+03	0.21
12	Ti	6.725E-01	2.600E+01	0.03
12	V	6.693E-01	1.600E+00	0.42
12	Zn	2.169E+01	5.900E+00	3.68
13	Al	1.443E+02	4.807E+01	3.00
13	Benzo(a)pyrene	4.883E-04	1.700E-04	2.87
13	Br	3.302E+02	3.100E+01	10.65
13	Cd	2.233E+00	8.000E-02	27.91
13	Co	9.589E+00	3.000E-01	31.96
13	Cr	1.258E+00	1.600E+00	0.79
13	Cu	1.683E+01	1.299E+01	1.30
13	Cypermethrin	2.615E-02	8.000E-05	326.82
13	Dichlorvos	4.191E-03	6.000E-04	6.99

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**RQ$_f$**
13	Ethalfluralin	3.010E-01	3.000E-01	1.00
13	Fe	7.382E+02	9.522E+01	7.75
13	Fluoranthene	1.941E-05	6.300E-03	0.00
13	Free CN	5.230E-01	1.200E+00	0.44
13	Ni	4.266E+00	4.000E+00	1.07
13	Nonylphenols	2.012E-01	3.000E-01	0.67
13	Octylphenol	6.284E-02	1.000E-01	0.63
13	Pb	3.269E+00	1.200E+00	2.72
13	PHCs	5.360E+01	9.600E+01	0.56
13	Si	3.598E+03	1.830E+03	1.97
13	Ti	2.928E-02	2.600E+01	0.00
13	V	1.715E+00	1.600E+00	1.07
13	Zn	1.019E+02	5.900E+00	17.27
14	Al	1.198E+03	4.807E+01	24.92
14	As	2.010E+02	5.300E+01	3.79
14	Benzo(a)pyrene	6.164E-05	1.700E-04	0.36
14	Br	4.064E+01	3.100E+01	1.31
14	Cd	1.511E-01	8.000E-02	1.89
14	Co	1.958E+00	3.000E-01	6.53
14	Cr	2.190E+00	1.600E+00	1.37
14	Cu	4.667E+00	1.299E+01	0.36
14	Cypermethrin	2.765E-03	8.000E-05	34.57
14	Dichlorvos	4.385E-04	6.000E-04	0.73
14	Ethalfluralin	3.539E-02	3.000E-01	0.12
14	Fe	2.580E+03	9.522E+01	27.10
14	Fluoranthene	4.658E-05	6.300E-03	0.01
14	Free CN	7.895E-02	1.200E+00	0.07
14	Ni	6.635E+00	4.000E+00	1.66
14	Nonylphenols	1.397E-02	3.000E-01	0.05
14	Octylphenol	3.236E-03	1.000E-01	0.03
14	Pb	1.259E+01	1.200E+00	10.49
14	PHCs	2.041E+01	9.600E+01	0.21
14	Si	5.960E+02	1.830E+03	0.33
14	Ti	6.252E-01	2.600E+01	0.02
14	V	1.781E+00	1.600E+00	1.11
14	Zn	2.276E+01	5.900E+00	3.86
15	Al	7.292E-01	4.807E+01	0.02
15	As	2.998E-02	5.300E+01	0.00
15	Br	5.635E-03	3.100E+01	0.00
15	Cd	8.761E-05	8.000E-02	0.00
15	Co	2.674E-02	3.000E-01	0.09
15	Cr	6.333E-02	1.600E+00	0.04
15	Cu	1.820E-02	1.299E+01	0.00
15	Fe	3.390E+00	9.522E+01	0.04
15	Ni	7.741E-02	4.000E+00	0.02
15	Pb	3.397E-03	1.200E+00	0.00
15	PHCs	4.469E-02	9.600E+01	0.00
15	Si	1.990E+00	1.830E+03	0.00

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**RQ_f**
15	Ti	8.208E-02	2.600E+01	0.00
15	V	5.851E-02	1.600E+00	0.04
15	Zn	6.790E-02	5.900E+00	0.01
16	Al	2.119E+02	4.807E+01	4.41
16	As	1.869E-02	5.300E+01	0.00
16	Benzo(a)pyrene	7.233E-05	1.700E-04	0.43
16	Br	1.329E+02	3.100E+01	4.29
16	Cd	8.920E-02	8.000E-02	1.11
16	Co	3.642E-01	3.000E-01	1.21
16	Cr	1.184E+00	1.600E+00	0.74
16	Cu	4.087E+00	1.299E+01	0.31
16	Cypermethrin	2.855E-03	8.000E-05	35.69
16	Dichlorvos	4.606E-04	6.000E-04	0.77
16	Ethalfluralin	3.552E-02	3.000E-01	0.12
16	Fe	1.079E+03	9.522E+01	11.33
16	Fluoranthene	1.961E-05	6.300E-03	0.00
16	Free CN	1.065E-01	1.200E+00	0.09
16	Ni	1.702E+00	4.000E+00	0.43
16	Nonylphenols	6.069E-03	3.000E-01	0.02
16	Octylphenol	6.727E-04	1.000E-01	0.01
16	Pb	2.189E+00	1.200E+00	1.82
16	PHCs	3.019E+01	9.600E+01	0.31
16	Si	7.088E+02	1.830E+03	0.39
16	Ti	8.618E-01	2.600E+01	0.03
16	V	8.056E-01	1.600E+00	0.50
16	Zn	2.624E+01	5.900E+00	4.45
17	Al	2.152E+02	4.807E+01	4.48
17	Benzo(a)pyrene	7.477E-05	1.700E-04	0.44
17	Br	4.835E+01	3.100E+01	1.56
17	Cd	7.221E-02	8.000E-02	0.90
17	Co	2.462E-01	3.000E-01	0.82
17	Cr	1.082E+00	1.600E+00	0.68
17	Cu	3.647E+00	1.299E+01	0.28
17	Cypermethrin	2.855E-03	8.000E-05	35.69
17	Dichlorvos	5.219E-04	6.000E-04	0.87
17	Ethalfluralin	3.570E-02	3.000E-01	0.12
17	Fe	2.701E+02	9.522E+01	2.84
17	Free CN	9.916E-02	1.200E+00	0.08
17	Ni	1.779E+00	4.000E+00	0.44
17	Nonylphenols	4.338E-03	3.000E-01	0.01
17	Pb	2.303E+00	1.200E+00	1.92
17	PHCs	3.075E+01	9.600E+01	0.32
17	Si	5.143E+02	1.830E+03	0.28
17	Ti	8.260E-01	2.600E+01	0.03
17	V	8.771E-01	1.600E+00	0.55
17	Zn	2.716E+01	5.900E+00	4.60
18	Al	2.159E+02	4.807E+01	4.49
18	As	1.225E-02	5.300E+01	0.00

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**RQ_f**
18	Benzo(a)pyrene	9.725E-05	1.700E-04	0.57
18	Br	1.220E+02	3.100E+01	3.94
18	Cd	2.138E-01	8.000E-02	2.67
18	Co	8.713E-01	3.000E-01	2.90
18	Cr	1.247E+00	1.600E+00	0.78
18	Cu	5.804E+00	1.299E+01	0.45
18	Cypermethrin	4.294E-03	8.000E-05	53.68
18	Dichlorvos	7.080E-04	6.000E-04	1.18
18	Ethalfluralin	5.260E-02	3.000E-01	0.18
18	Fe	8.376E+02	9.522E+01	8.80
18	Fluoranthene	1.217E-04	6.300E-03	0.02
18	Free CN	1.562E-01	1.200E+00	0.13
18	Ni	1.887E+00	4.000E+00	0.47
18	Nonylphenols	1.731E-02	3.000E-01	0.06
18	Octylphenol	4.177E-03	1.000E-01	0.04
18	Pb	2.354E+00	1.200E+00	1.96
18	PHCs	3.748E+01	9.600E+01	0.39
18	Si	8.913E+02	1.830E+03	0.49
18	Ti	8.327E-01	2.600E+01	0.03
18	V	8.746E-01	1.600E+00	0.55
18	Zn	3.239E+01	5.900E+00	5.49
19	Al	3.547E+02	4.807E+01	7.38
19	As	5.768E+01	5.300E+01	1.09
19	Benzo(a)pyrene	2.228E-05	1.700E-04	0.13
19	Br	1.684E+01	3.100E+01	0.54
19	Cd	5.205E-02	8.000E-02	0.65
19	Co	5.969E-01	3.000E-01	1.99
19	Cr	6.911E-01	1.600E+00	0.43
19	Cu	1.629E+00	1.299E+01	0.13
19	Cypermethrin	1.054E-03	8.000E-05	13.17
19	Dichlorvos	1.579E-04	6.000E-04	0.26
19	Ethalfluralin	1.257E-02	3.000E-01	0.04
19	Fe	7.747E+02	9.522E+01	8.14
19	Fluoranthene	3.509E-05	6.300E-03	0.01
19	Free CN	3.154E-02	1.200E+00	0.03
19	Ni	1.997E+00	4.000E+00	0.50
19	Nonylphenols	4.853E-03	3.000E-01	0.02
19	Octylphenol	1.083E-03	1.000E-01	0.01
19	Pb	3.735E+00	1.200E+00	3.11
19	PHCs	7.735E+00	9.600E+01	0.08
19	Si	2.212E+02	1.830E+03	0.12
19	Ti	2.215E-01	2.600E+01	0.01
19	V	5.563E-01	1.600E+00	0.35
19	Zn	8.316E+00	5.900E+00	1.41
20	Al	3.484E+02	4.807E+01	7.25
20	As	5.225E+01	5.300E+01	0.99
20	Benzo(a)pyrene	3.143E-05	1.700E-04	0.18
20	Br	2.275E+01	3.100E+01	0.73

Table A 17. Weighed, Estimated Surface Water Risk Quotients of Micropollutants from Point Source Effluents (Continued)

Sub-basin	**Pollutant**	**MEC**	**PNEC**	**RQ_f**
20	Cd	6.705E-02	8.000E-02	0.84
20	Co	6.215E-01	3.000E-01	2.07
20	Cr	7.731E-01	1.600E+00	0.48
20	Cu	2.105E+00	1.299E+01	0.16
20	Cypermethrin	1.428E-03	8.000E-05	17.85
20	Dichlorvos	2.195E-04	6.000E-04	0.37
20	Ethalfluralin	1.737E-02	3.000E-01	0.06
20	Fe	7.418E+02	9.522E+01	7.79
20	Fluoranthene	4.091E-05	6.300E-03	0.01
20	Free CN	4.601E-02	1.200E+00	0.04
20	Ni	2.057E+00	4.000E+00	0.51
20	Nonylphenols	5.949E-03	3.000E-01	0.02
20	Octylphenol	1.295E-03	1.000E-01	0.01
20	Pb	3.682E+00	1.200E+00	3.07
20	PHCs	1.170E+01	9.600E+01	0.12
20	Si	2.955E+02	1.830E+03	0.16
20	Ti	3.038E-01	2.600E+01	0.01
20	V	6.267E-01	1.600E+00	0.39
20	Zn	1.152E+01	5.900E+00	1.95
21	Al	2.192E+02	4.807E+01	4.56
21	Benzo(a)pyrene	7.029E-05	1.700E-04	0.41
21	Br	4.588E+01	3.100E+01	1.48
21	Cd	7.088E-02	8.000E-02	0.89
21	Co	2.857E-01	3.000E-01	0.95
21	Cr	1.161E+00	1.600E+00	0.73
21	Cu	4.256E+00	1.299E+01	0.33
21	Cypermethrin	2.762E-03	8.000E-05	34.53
21	Dichlorvos	4.305E-04	6.000E-04	0.72
21	Ethalfluralin	3.848E-02	3.000E-01	0.13
21	Fe	2.727E+02	9.522E+01	2.86
21	Fluoranthene	1.985E-06	6.300E-03	0.00
21	Free CN	1.272E-01	1.200E+00	0.11
21	Ni	2.460E+00	4.000E+00	0.61
21	Nonylphenols	7.786E-03	3.000E-01	0.03
21	Octylphenol	1.850E-04	1.000E-01	0.00
21	Pb	2.191E+00	1.200E+00	1.83
21	PHCs	3.026E+01	9.600E+01	0.32
21	Si	4.993E+02	1.830E+03	0.27
21	Ti	1.014E+00	2.600E+01	0.04
21	V	7.884E-01	1.600E+00	0.49
21	Zn	4.322E+01	5.900E+00	7.33

O. Results of the Correlation Analysis

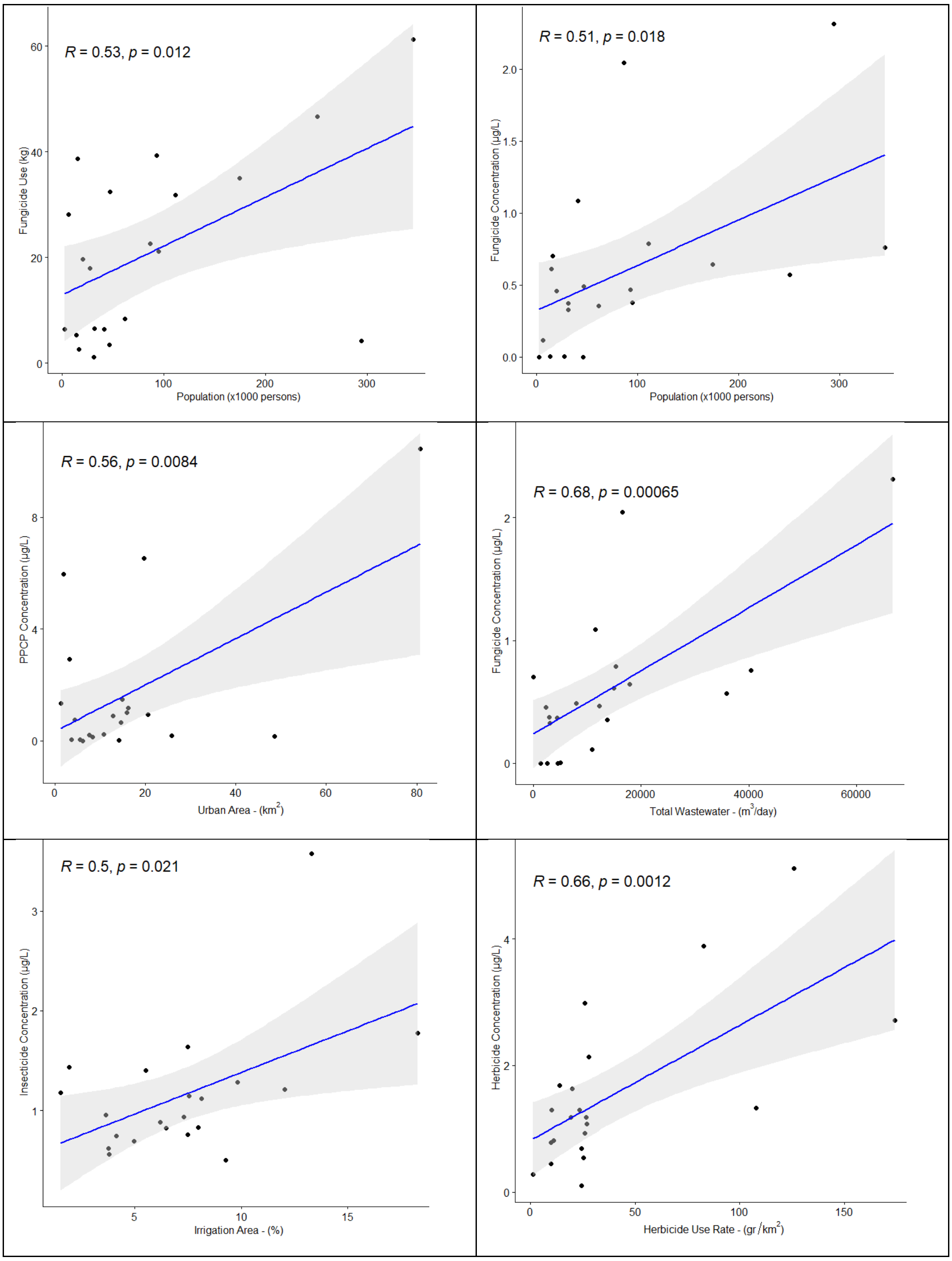


Figure A 6. Results of the Correlation Analysis

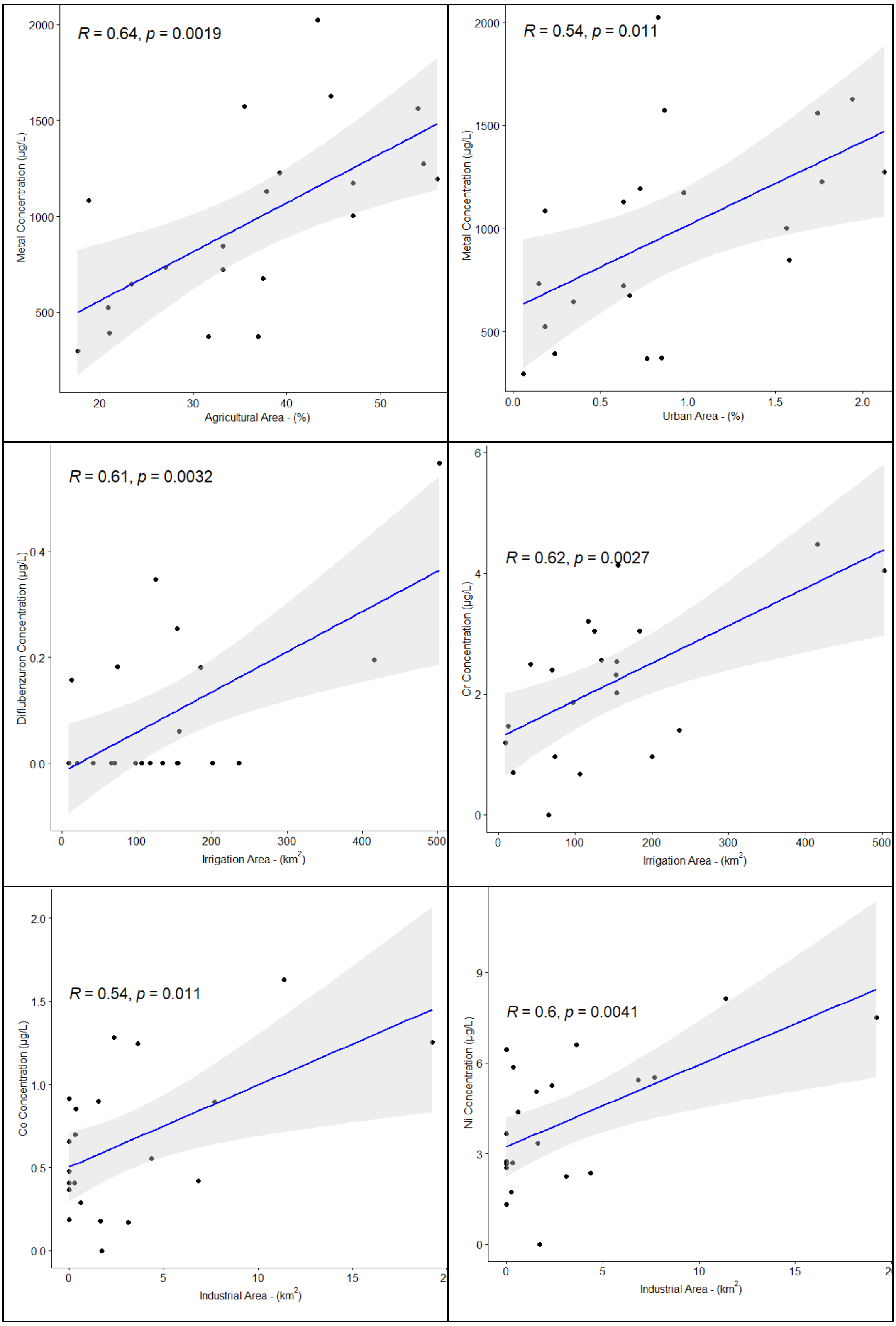


Figure A 6. Results of the Correlation Analysis (Continued)

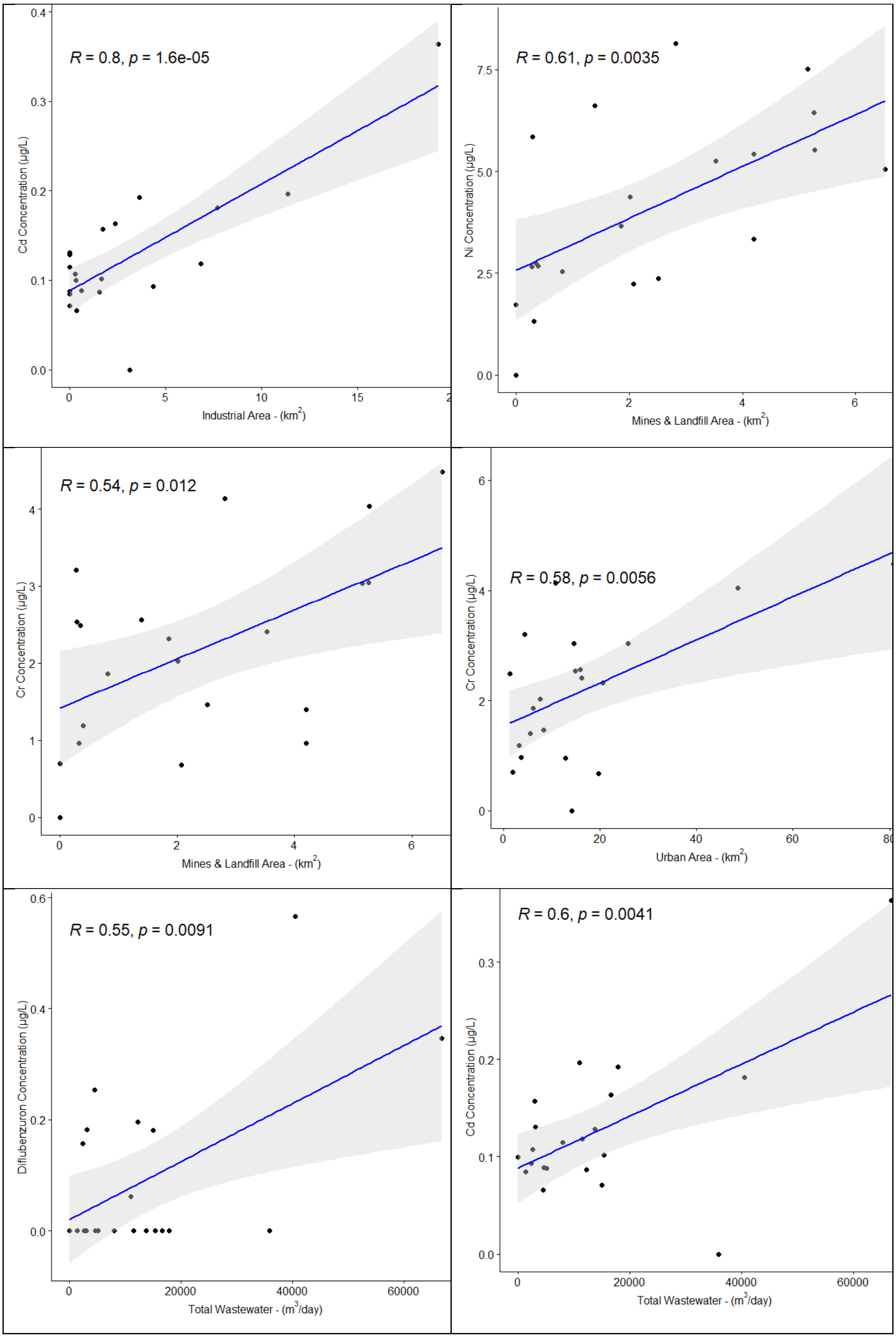


Figure A 6. Results of the Correlation Analysis (Continued)

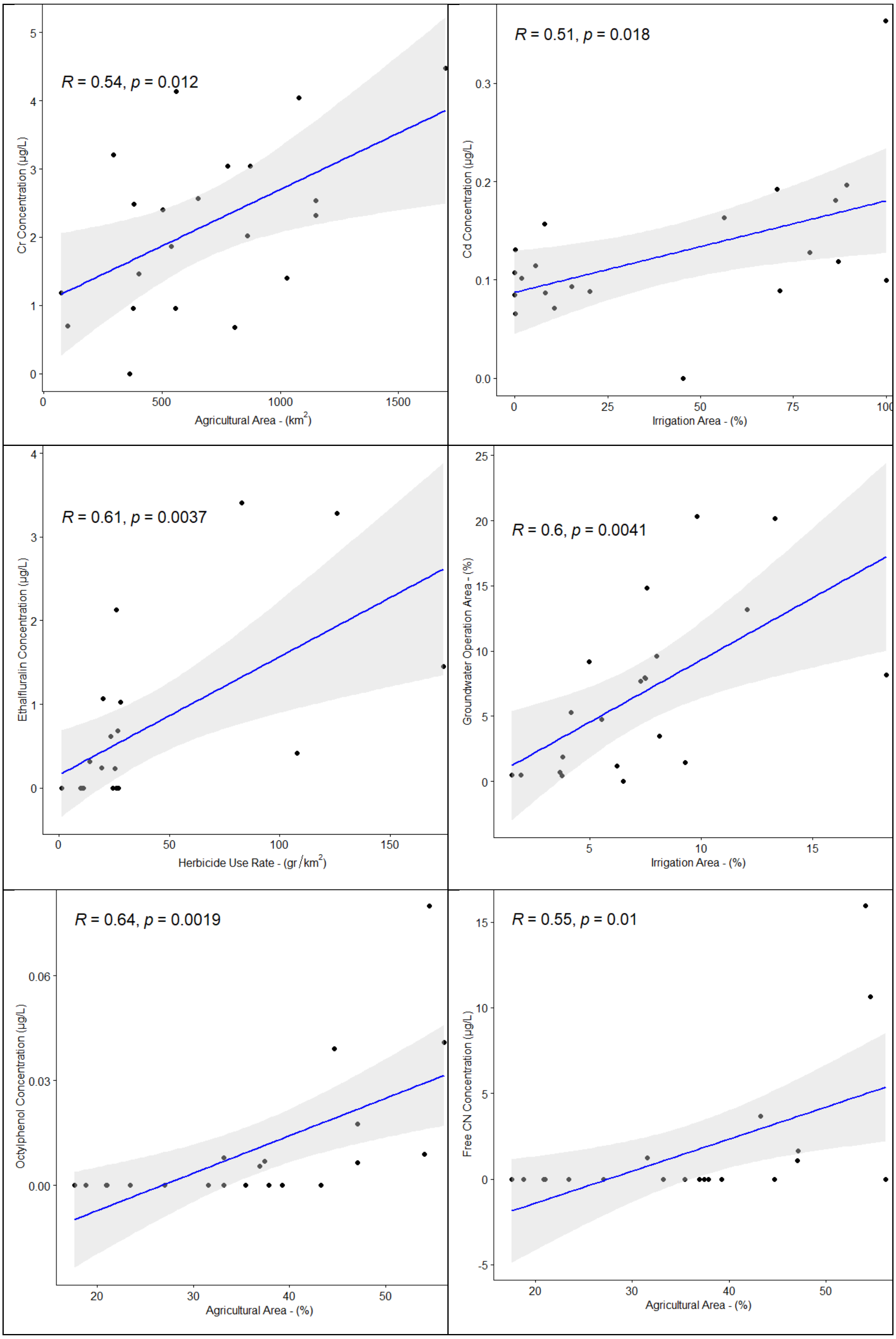


Figure A 6. Results of the Correlation Analysis (Continued)

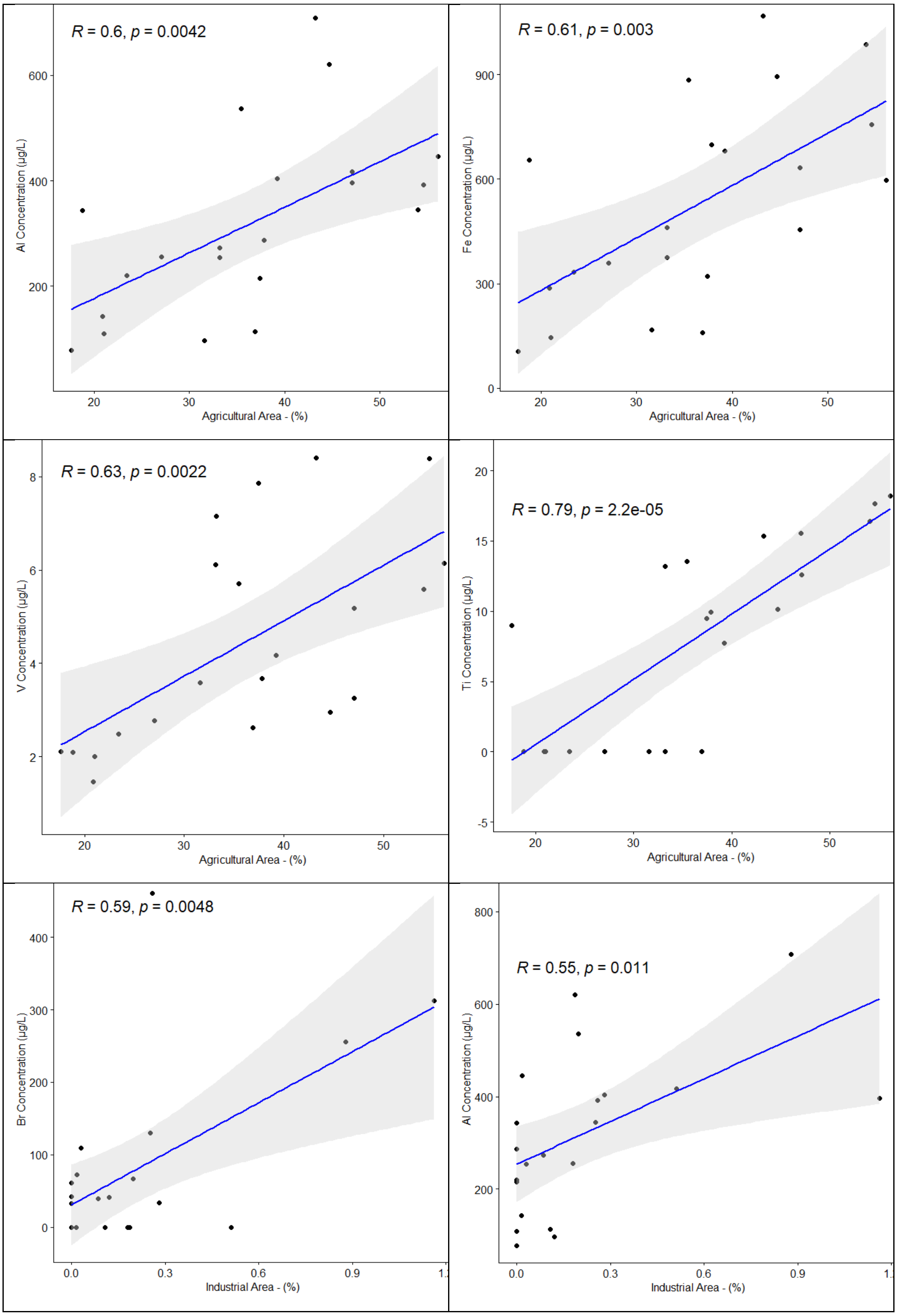


Figure A 6. Results of the Correlation Analysis (Continued)

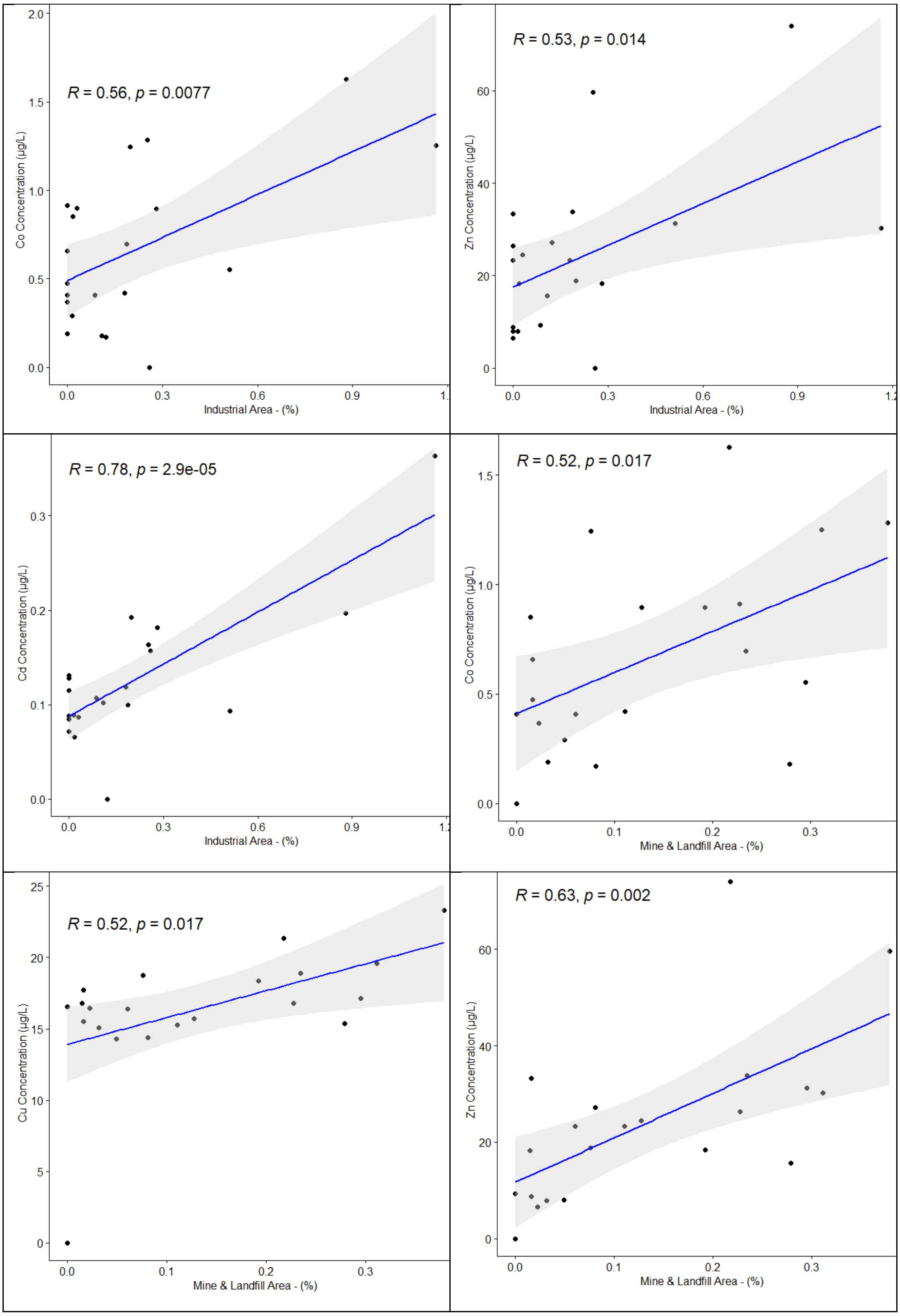


Figure A 6. Results of the Correlation Analysis (Continued)

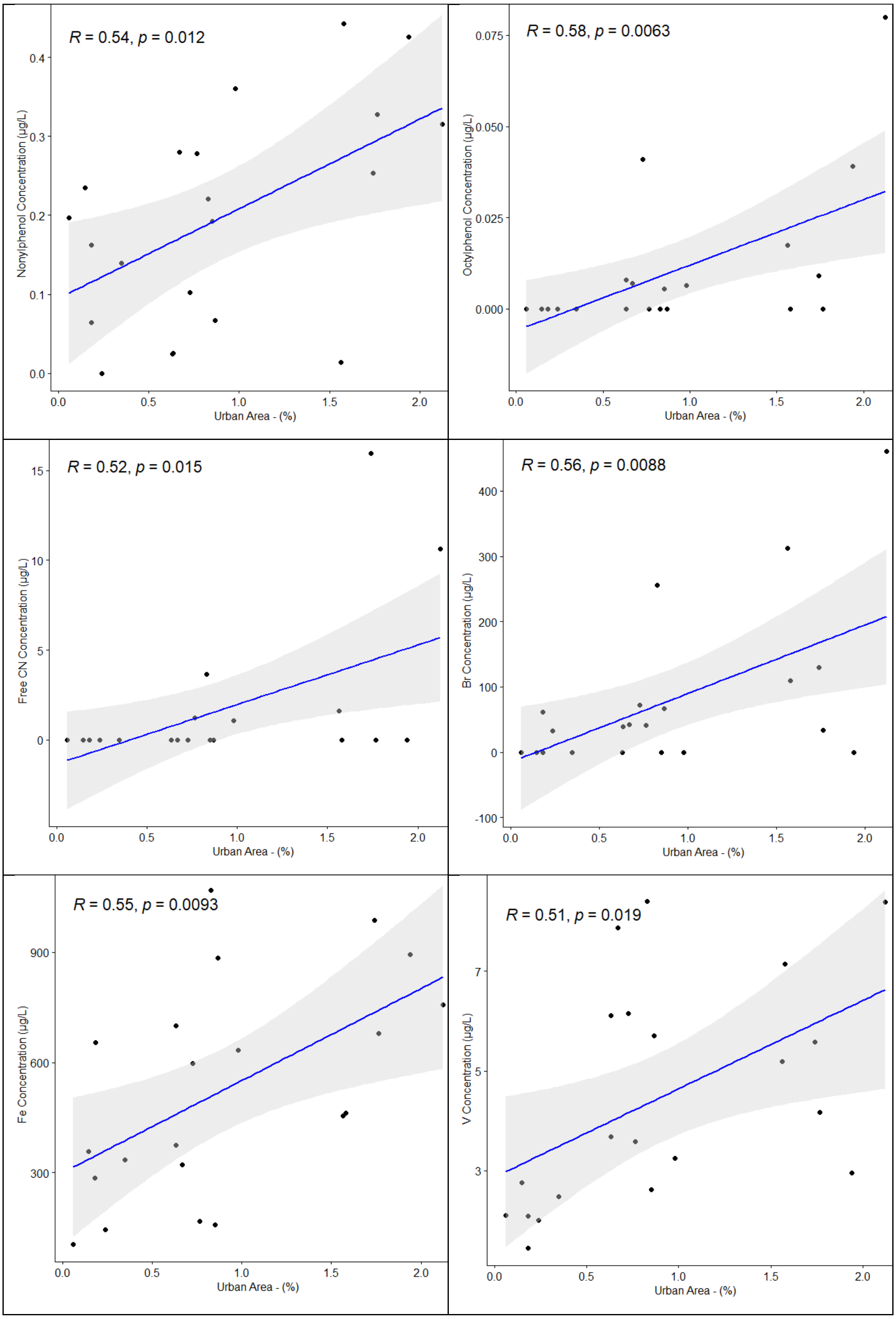


Figure A 6. Results of the Correlation Analysis (Continued)

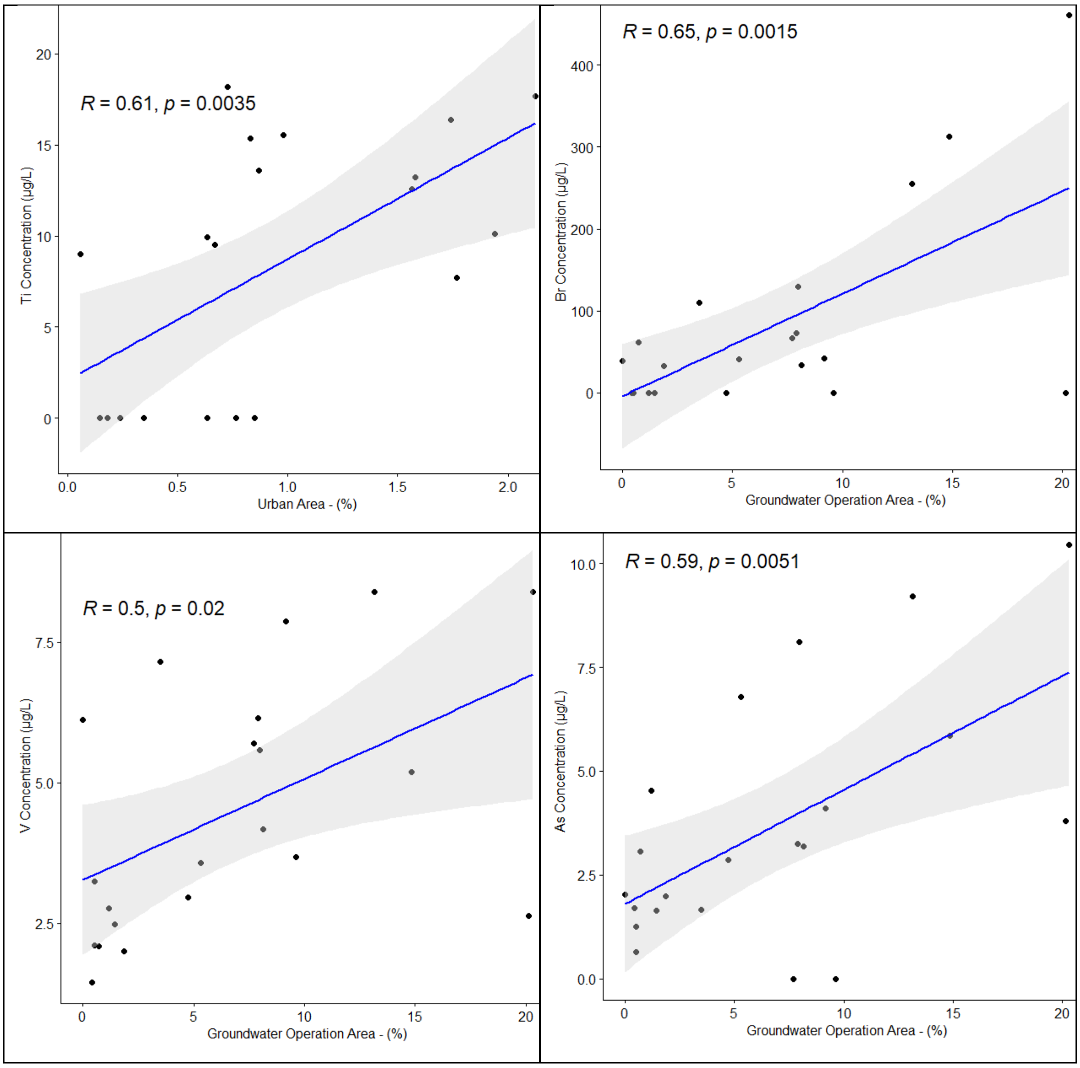


Figure A 6. Results of the Correlation Analysis (Continued)

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EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	METU Environmental Engineering	2013
BS	METU Environmental Engineering	2008

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2018-Present	Ankara University Water Management Institute	Lecturer
2014-2018	METU Environmental Engineering	Teaching Assistant
2011-2013	Vadi Mühendislik	EIA Expert

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PROJECTS

1. Researcher, the Ministry of Environment and Urbanization, Evaluation of Waste Processing Facilities, Investigation of Compliance Status and Development of Compliance Requirements Models within the Scope of Integrated Pollution Prevention and Control, 2021-

2. Researcher, the Ministry of Agriculture and Forestry, Blue Peace in the Middle East Project - Preparation Agricultural Water Efficiency Report, 2019-2021

3. Researcher, the Ministry of Environment and Urbanization, Providing Audit Capability to Waste Declaration System and Improving Waste Management System, 2019-2020

4. Expert, World Bank, Preparation of Water Sector Engagement Report for Turkey, 2019

5. Researcher, the Ministry of Environment and Urbanization, Application of Cleaner Production in Specific Industries, 2019

6. Support Staff, Central Finance and Contracts Unit, Building capacity on Vulnerabilities of the Agricultural Sector to Climate Change in Turkey, 2018-2021

7. Researcher, the Ministry of Environment and Urbanization, Determination of Environmental Quality Standards (EQS) Based Discharge Limits and Development of Implementation Strategies, 2016-2018

8. Researcher, TÜBİTAK 1003, Management of Point And Diffuse Pollutant Sources in Yeşilırmak River Basin (Project Code: 115Y013), 2015-2020

9. Researcher, Ministry of Environment and Urbanization, Technical Support Project for Strengthening the Capacity of the Ministry of Environment and Urbanization in the Field of Environmental Impact Assessment, 2017

10. Researcher, the Ministry of Forestry and Water Affairs, Technical Support Projects Regarding the Implementation of Total Maximum Daily Load (TMDL) Approach in Gediz River Basin, 2014-2017

11. Researcher, the Ministry of Environment and Urbanization, Determination of Waste Generation Factors and Preparation of Sector Guidelines for Sectoral Management of Industrial Wastes, 2016

12. Researcher, ÇAYDAG 108Y116, Evaluation of the Distribution of Nitrogenous Compounds Produced by Microbiological Activity in Different Mediums (Air, Water, Sediment) in a Eutrophic Lake and Determination of Fluxes Between These Mediums Project, 2009-2013