STORMWATER QUALITY AND POLLUTANTS LOADING FROM CATCHMENTS AT SUNGAI JOHOR

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Science
Universiti Teknologi Malaysia

MAY 2017

This is especially dedicated to me and my supervisors

ACKNOWLEDGEMENTS

Praise to Allah S.W.T for the blessing and strength to finish this research. May Allah bless the Prophet Muhammad S.A.W and his family. The research would not be completed without the cooperation and guidance around me specially my lecturers, family and friends. First, I would like to express my deepest gratitude to my supervisor, Prof Madya Dr. Razali bin Ismail, Department of Chemistry, Faculty of Science, UTM for his guidance, assistance, sacrifice and advice during the all the stage of this research. I also wish to thank Prof. Dr. Zulkifli Yusop, Department of Hydraulics and Hydrology, Faculty of Civil Engineering, UTM for all the guidance and advice throughout this research. My sincere appreciation also goes to my parents and siblings, for their pray, their endless supports and motivations to keep me stay positive.

To the laboratory staffs in Universiti Teknologi Malaysia (UTM), I would like to acknowledge your assistance during my laboratory analysis. Particularly, I wish to thank Mr Yassin, Mrs Mariam, Zulaikha, Mrs Zubaidah and Miss Aini for their guidance in laboratory works and handling the instrumentations for the analysis. My sincere appreciation also extends to my sampling team, to my bestfriend as well as my laboratory partners, Ain Syuhada and Kamilah, with whom I started this study, thank you for all the helps, moral supports and the good times we had together. I am also very thankful for the quick response and informations given from Badan Kawal Selia Air Johor (BAKAJ), Department of Irrigation and Drainage (DID) and Malaysian Meterological Department (MMD). Lastly, my sincere thanks goes to my bestfriends, Jash, Lina, Izzah, Dhea, Nuor, Fika and Teha, thanks for always being there for me, through thick and thin.

ABSTRACT

Sungai Johor is an important water resource in terms of aquaculture, agriculture and source of drinking water for the entire Kota Tinggi, Skudai, and Iskandar Puteri districts as well as Singapore. However, a tropical downpour may increase pollutants loading in the river which in turn may affect its beneficial uses. The purpose of this study is to investigate the concentrations and loading of pollutants in stormflow. Comparisons were made against baseflow for two different landuses, agricultural and suburban catchment areas. Three sampling stations namely Sungai Sebol (A1), Sungai Penggeli (A2) and Rantau Panjang (A3) were chosen to represent agricultural landuse, while Sungai Kemang (U1), Sungai Kampung Kelantan (U2) and Sungai Pemandi (U3) as the suburban. Parameters studied include water quality (DO, BOD, COD, TSS, pH and NH_3), nutrients (NO_3^-, NO_2^-, TN, PO_4^{3-} and TP), metals (As, Cd, Cr, Cu, Mn, Ni, Hg, Zn, Al, Fe and Pb) and organophosphorus pesticides (malathion and chlorpyrifos). Comparison were made based on concentration, pollutant loading, pollutograph and first flush to evaluate the effect of storm event on the water quality of the studied tributaries. The study shows in general, during baseflow, most parameters were within the Class II and Class III of NWQS. However, stormflow increases the concentration and loading of pollutants, in particular for BOD, COD, TSS, NO_3^-, TP, Hg and Fe. The use of pollutants load, rather than concentration, is a better representative for river quality because the amount of rainfall, water discharge and catchment size do affect the measured water quality of river during a storm. Parameters in agricultural catchment were dominantly classified in Type 1 while most of the parameters in suburban followed the Type 2 classification of pollutograph. Most of the pollutants in A1 and A2 catchments did not exhibit any first flush phenomenon while the pollutants in suburban catchments only show moderate first flush. Therefore, based on the positive and strong correlation between pollutants and amount of rainfall, it can be concluded that rainfall does influence the mobilization of pollutants into surface water during storm events. The study suggests that stormflow does have a great effect in increasing pollutant concentration and loading, which then may affect the existing beneficial uses of the river.

ABSTRAK

Sungai Johor adalah sumber air yang penting dari segi akuakultur, pertanian dan sumber air minuman untuk seluruh daerah-daerah Kota Tinggi, Skudai, dan Iskandar Puteri serta Singapura. Walau bagaimanapun, hujan lebat tropika boleh meningkatkan beban pencemar di dalam sungai yang seterusnya boleh menjejaskan penggunaan bermanfaat airnya. Tujuan kajian ini ialah untuk menyiasat kepekatan dan beban pencemaran di dalam air larian ribut. Perbandingan dibuat terhadap aliran dasar untuk dua gunatanah berbeza iaitu kawasan tadahan pertanian dan kawasan pinggir bandar. Tiga stesen persampelan iaitu Sungai Sebol (A1), Sungai Penggeli (A2) dan Rantau Panjang (A3) telah dipilih untuk mewakili gunatanah pertanian manakala Sungai Kemang (U1), Sungai Kampung Kelantan (U2) dan Sungai Pemandi (U3) mewakili kawasan pinggir bandar. Parameter yang dikaji termasuklah kualiti air (DO, BOD, COD, TSS, pH dan NH_3), nutrien (NO_3^-, NO_2^-, TN, PO_4^{3-} dan TP), logam (As, Cd, Cr, Cu, Mn, Ni, Hg, Zn, Al, Fe dan Pb) dan racun perosak organofosforus (malation dan klorpirifos). Perbandingan telah dibuat berdasarkan kepekatan, beban pencemar, polutograf dan curahan pertama untuk menilai kesan hujan ribut kepada kualiti air sungai yang dikaji. Hasil kajian menunjukkan secara amnya, semasa aliran dasar kebanyakkan parameter berada dalam Kelas II dan Kelas III NWQS. Walau bagaimanapun, air larian ribut meningkatkan kepekatan dan beban pencemar khususnya bagi BOD, COD, TSS, NO_3^-, TP, Hg dan Fe. Penggunaan beban pencemar, dan bukannya kepekatan, adalah lebih baik untuk mewakili kualiti sungai kerana jumlah taburan hujan, pelepasan air dan saiz kawasan tadahan sungai akan menjejaskan kualiti air yang diukur semasa ribut. Kebanyakan parameter dalam kawasan tadahan pertanian mendominasi kelas Jenis 1 manakala kebanyakan parameter di kawasan pinggir bandar dikelaskan dalam Jenis 2 polutograf. Kebanyakan bahan pencemar dalam kawasan tadahan A1 dan A2 tidak menunjukan sebarang fenomena curahan pertama manakala bahan pencemar di kawasan pinggir bandar hanya menunjukan curahan pertama yang sederhana. Oleh itu, berdasarkan korelasi positif dan kuat antara pencemar dan jumlah hujan, boleh disimpulkan bahwa taburan hujan dapat mempengaruhi pergerakan bahan pencemar ke dalam air permukaan semasa peristiwa ribut. Kajian ini mencadangkan bahawa air larian ribut memberikan kesan yang besar dalam meningkatkan kepekatan pencemar dan beban pencemar, yang seterusnya boleh mempengaruhi penggunaan bermanfaat sedia ada sungai tersebut.

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LIST OF ABBREVIATIONS

Al	–	Aluminium
As	–	Arsenic
ASMA	–	Alam Sekitar Malaysia Sdn Bhd
BAKAJ	–	Badan Kawal Selia Air Johor
BOD	–	Biochemical Oxygen Demand
Cd	–	Cadmium
COD	–	Chemical Oxygen Demand
C-Q	–	Concentration-Discharge
Cr	–	Chromium
Cu	–	Copper
DID	–	Department of Irrigation and Drainage
DO	–	Dissolved Oxygen
DOC	–	Dissolved Organic Carbon
DOE	–	Department of Environment
EMC	–	Event Mean Concentration
FAAS	–	Flame Atomic Absorption Spectroscopy
Fe	–	Iron
FF	–	First Flush
GC-ECD	–	Gas Chromatography Electron Capture Detector
GF-AAS	–	Graphite Furnace- Atomic Absorption Spectroscopy
Hg	–	Mercury
HNO_3	–	Nitric Acid
H_2SO_4	–	Sulphuric Acid
KHP	–	Potassium Hydrogen Phthalate
$KMnO_4$	–	Potassium Permanganate
LLE	–	Liquid-Liquid Extraction

LOD	–	Limit of detection
LOQ	–	Limit of quantitation
MGD	–	Million gallon per day
MLD	–	Million litre per day
Mn	–	Manganese
MMD	–	Malaysian Meteorological Department
MV	–	Pollution load curve
N	–	Nitrogen
N_2	–	Nitrogen gas
NH_3	–	Ammonia
NH_4	–	Ammonium
NH_4Cl	–	Ammonium chloride
Ni	–	Nickel
NO_2^-	–	Nitrite
NO_3^-	–	Nitrate
NPS	–	Non-point sources pollution
NTU	–	Nephelometric Turbidity Unit
NWQS	–	National Water Quality Standard
P	–	Phosphorus
Pb	–	Lead
PO_4^{3-}	–	Phosphate
PS	–	Point source pollution
SAJH	–	Syarikat Air Johor Holding
SD	–	Standard deviation
TN	–	Total nitrogen
TSS	–	Total suspended solids
TP	–	Total phosphorus
WTP	–	Water treatment plant
Zn	–	Zinc

LIST OF SYMBOLS

b	–	First flush coefficient
^{0}C	–	Degree Celsius
F	–	Dimensionless cumulative runoff flow rate
FF	–	First flush
g	–	gram
L	–	Litre
M		Total Mass
µg/L	–	microgram per litre
mg/L	–	milligram per litre
min	–	minutes
mL	–	millilitre
mm/hr	–	millimeter per hour
m^3/s	–	cubic metre per second
ppm	–	Part per million
ppb	–	Part per billion
Q	–	Discharge
v	–	Velocity
V	–	Total volume

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

River water is a very important resource to our country due to its usage for domestic needs, agriculture, industrial and urbanization as well as recreational use. Deterioration of water quality in the river has often been discussed due to the dependence of human beings for drinking water and routine daily activities (Maarof and Hua, 2015). Sediment runoff, industrial waste, livestock, agriculture and heavy metals are liable in reducing the level of water quality in Malaysia. A study conducted at Sungai Perlis showed polluted status, where water sample was collected at two stations, near residential area and wet market. It falls into class IV in Water Quality Index from National Water Quality Standards in Malaysia (Amneera *et al.*, 2013). Water pollution mostly occurs in areas with highly concentrated dwellings that released their effluent directly to water bodies.

Water pollutants in rivers can be contributed by point source (PS) and non-point source (NPS). PS pollution may include industrial waste that discharges to rivers and the sea through a pipe or drain. NPS pollution originates from diffuse contamination that accumulated from a large area (Amneera *et al.*, 2013). It is difficult to identify and control NPS pollution compared to PS pollution. NPS pollution can enter the river by leaching the pollutant through rainfall. Landuse and rainfall are two frequent factors that affect river runoff and erosion process near the river and can lead to water pollution (Fang *et al.*, 2012). Heavy rainfall can cause stormwater, which is the quick response of a stream to a precipitation event.

During stormflow, the water level of river increases and contains higher loads of pollutants. Previous study indicated that the pesticides concentration increased during stormflow and a massive mobilization of pesticides was observed during floods (Rabiet *et al.*, 2010). The use of pesticides is causing a threat to the water quality in agricultural areas because the pesticides may pass through the soil and flow into the surface water and groundwater (Ormad *et al.*,2008). The concentration of heavy metals during stormflow also showed significant increase in both dissolved and particulate associated phases which controlled by antecedent hydrological conditions, mobilization and sediment dynamics of the system (Blake *et al.*, 2003). Stormwater runoff can be the main contributor to river pollution and degradation of water quality.

The fast development of agricultural, activities in particular palm oil, and modern farming were implemented to satisfy the economic demand and to generate considerable income to the country. The Government also focused on urbanization to reflect the growth and success of the country (Charlie, 2008). As a result of increased development of agricultural and urbanization, the country in general is facing a higher level of the pollution threat.

The increased population in this country will increase the needs for new residential areas and in turn caused an increase in water demand. Sungai Johor is the major source for water supply in Johor which is about 55% of total state needs. The treatment plants in Sungai Johor supply treated water to fast growing Iskandar Malaysia with capacity 227 MGD and water treatment plants (WTP) operated by PUB with capacity 250 MGD to supply treated water to Singapore (IRDA, 2008). Currently, the deficit yield from Sungai Johor becomes a major problem due to sharing abstraction between two countries which is Johor and Singapore. The shortage of water resource for Johor Bahru, Kulaijaya and Kota Tinggi required new source and new water treatment plant. High demand of water and the agricultural development and urbanization near Sungai Johor definitely give an adverse impact to quality of Sungai Johor basin in particular. Therefore, the concentration of stormwater runoff at Sungai Johor, the pollutants loading and their correlation with other related factors such as rainfall intensity, landuse and discharge are carried out in this study.

1.2 Problem Statement

Considering the role of Sungai Johor as a vital source of water to the consumer, the river condition during storm must be taken into account. NPS pollution, in particular, pollution from storm water and runoff is difficult to be identified specifically and control, because it came from various sources and covers a large area. The Department of Environment (DOE) Malaysia implemented Monthly Discharge Monitoring Report for PS pollution; however, there are no standard or controlling techniques for NPS pollution. In order to maintain the river basin according to the current designated use, the sources of pollutant discharge from the land use activities along the Sungai Johor basin must be identified and controlled. The NPS management plays an important role in water pollution control and can increase the understanding of pollutant occurrence in the environment and its related public health risk.

Heavy rainfall can generate higher water level, flow rate, volume and pollutants loading in rivers. The water quality during baseflow is completely different from during stormflow. The extensive use of fertilizer and pesticides can be a major contributor to surface and groundwater pollution, especially during a storm event. The existing heavy metals that tend to be in particulate form were also affected with the solids transport to the surface water (Herngren *et al.*, 2005). The pollutants such as pesticides and metals cannot be treated by conventional treatment water (Abdollah, 2010). The possibility of excess ammonia runoff from palm oil mill as occurred recently (Hammim, 2016.; Othman, 2016.; Rasid, 2016) remains the omnipresent danger of pollutants to the WTP. The present conventional water treatment plants also do not have the ability to treat ammonia (Omran, 2011). The overdose chlorine usage to treat ammonia more than 5 mg/L may cause hazardous by-product of carcinogenic chloramines in treated water (Hankin, 2001). The affected water from the river can create problems in water resource which is to provide clean and safe water for the domestic demands and also the aquaculture farming carried out at the Sungai Johor estuary.

In addition, a large number of research works have been reported to measure water quality during rainfall which is based on concentration, (Blake *et al.*, 2003; Gasim *et al.*, 2007; Jusoh, 2011) however, few reports had been carried out based on loading. It is expected that loading is more representative than concentration during a storm event, due to the relationship of runoff volume with pollutant build-up and antecedent dry period before the storm event.

1.3 Objective of Study

i. To assess the water quality during baseflow and stormflow at agricultural and suburban catchments based on the WQI parameters, nutrients, heavy metals and pesticides.
ii. To estimate the pollutant loading during stormflow and baseflow at the selected sampling points and to compare the pollutants loading between agricultural and suburban catchment area,
iii. To comprehend the significant difference and correlation between pollutant values recorded during stormflow with other pollutants and hydrological condition.

1.4 Scope of Study

This present research involved water samples during baseflow and stormflow at sampling location includes agricultural area and suburban area. Six sampling points were selected; Sungai Sebol (A1), Sungai Penggeli (A2), Rantau Panjang (A3), Sungai Kemang (U1), Sungai Kampung Kelantan (U2) and Sungai Pemandi (U3). The scope of study includes measurement of the discharge at all sampling points for water sampling during baseflow and stormflow conditions, *in-situ* and laboratory analysis analysis of water samples and making comparison of pollutant loading during baseflow and stormflow.

The laboratory analysis includes determination of Biochemical Oxygen Demand (BOD), Total Suspended Solid (TSS), using HACH DR/ 4000 Spectrometer to analyse Chemical Oxygen Demand (COD) and nutrients (nitrate, nitrite, total nitrogen, ammonia, orthophosphate and total phosphorus), extraction of water sample to determined pesticides and using nitric acid open digestion to determine heavy metals. The identification and quantification of heavy metals were done using Flame Atomic Absorption Spectrometer (FAAS), Graphite Furnace Atomic Absorption Spectrometer (GFAAS), and Mercury Hydride Generation (FIMS-100). The identification of pesticides was carried out using Gas Chromatography Electron Capture Detector (GC-ECD).

Water quality parameter values were compared with the National Water Quality Standards for Malaysia (NWQS). The comparison of data between baseflow and stormflow, agricultural and urban were plotted using Box and Whisker Plot. The data analysis also includes pollutograph and hysteresis loop. The pollutant loading was calculated by multiplying the discharge with Event Mean Concentration (EMC). The reliability of the difference was tested by using *t*-test statistical analysis and the correlation analysis was obtained by Pearson correlation analysis.

1.5 Limitation of Study

The methodology of the study had been set up to achieve the above objectives, however, there were some unavoidable limitations. The limitation of this study is only the single sampling had been conducted. More frequent sampling will give more representative data for pollutant load in storm event. This problem is due to the large distance between UTM and sampling sites which is 55 km and at least one hour of travelling time. In addition, the storm information is based on weather forecast and information given by locals. However, sometimes the rain does not occur as predicted in the weather forecast while at other times, the rainfall had receded or stopped upon arrival at the sampling locations.

1.6 Significance of Study

This study is important since Sungai Johor is the major water supply in Johor, and agricultural activities cover a large area in Kota Tinggi. NPS pollution can degrade water quality of rivers and in the long term the condition of river will become worse (Penev *et al.*, 2014).

It is also important to know the existence of pesticides and heavy metals because of their harmful effect on the river, aquatic life, environment and human. This study includes heavy metals and pesticides and their loading in the river. These pollutants have possibility to degrade the water quality of raw water that involve to be treat by WTP; Bandar Tenggara Water Treatment Plant, Semangar Water Treatment Plant and Sungai Johor Water Treatment Plant. Bandar Tenggara Water Treatment Plant treats water from Sungai Penggeli, though no specific water treatment plant is assigned for water treatment process of Sungai Sebol. However, water from that river will flow into Sungai Johor that supply raw water to Semangar Water Treatment Plant and Sungai Johor Water Treatment Plant. It is significant to ensure clean water supply to the people around the area and also the aquaculture activities (mussels, pond culture of tiger prawn and banana prawn, cage culture of sea bass and red snapper and cockle culture) at the downstream area that includes Tanjung Buai, Teluk Sengat and Pulau Nanas, Pasir Gudang.

The study intends to study the extent of stormwater on water quality degradation. Further actions can then be taken the relevant authorities to reduce the sources of pollution to the already polluted river. Hopefully, steps will be taken to introduce suitable treatment, cost and management of stormwater runoff, which is one of the sources of NPS pollution.

Based on the literature review, only a few pollutant loading studies had been carried out in Sungai Johor tributaries but no published study had been found to correlate concentration and pollutant loadings in Sungai Johor. Other studies had observed that large pollutant load were detected during a storm event, therefore it is important to study the pollutant load in Sungai Johor tributaries since it will affect the beneficial uses as stated above (water treatment plant and aquaculture).

1.7 Flowchart of the Whole Work Plan

The whole of work plan is shown in Figure 1.1 below.

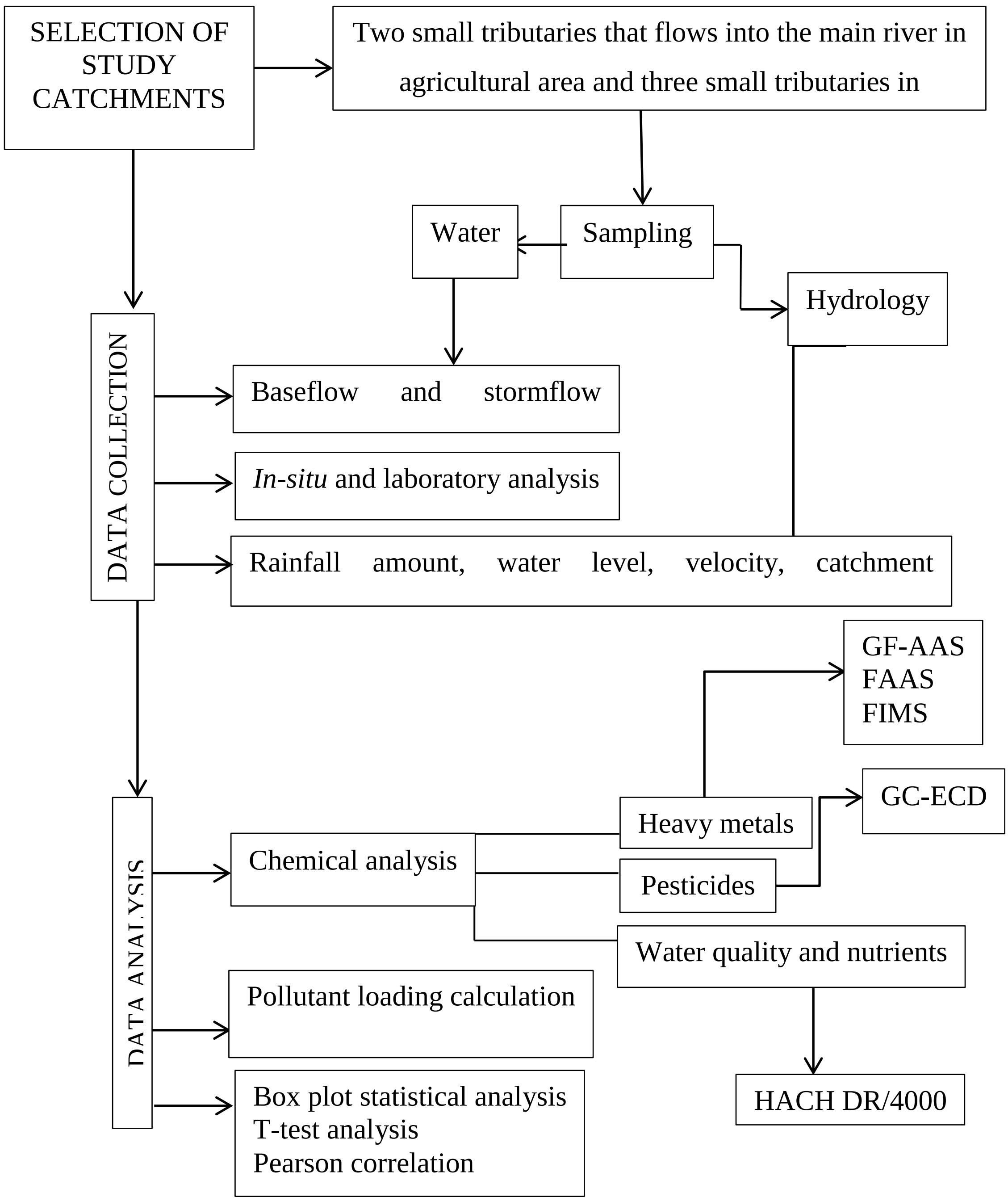

Figure 1.1 The flowchart for whole planned work

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APPENDIX A

Table A1: Condition of F-AAS, GF-AAS and FI-MHS

Parameters	Conditions		
	F-AAS	GF-AAS	FI-MHS
Flame	Air-Acetylene	-	–
Air Flow (L/min)	10	-	–
Acetylene Flow (L/min)	4.0	-	–
Argon Flow (mL/min)	–	0.3	90
Integration Time (second)	–	5	20
Wavelength (nm)	Al (309.27), Fe (248.33), Zn (213.86), Pb (283.30), Cu (324.80)	Cd (228.80), Cr (357.90), Ni (232.00), Mn (279.48)	Hg (253.70)
Slit Width (nm)	0.7	0.7	0.7

Table A2: LOD and LOQ obtained from the calibration curves for all studied metal

Heavy Metals	Coefficient of Determination (R^2)	LOD (ppb)	LOQ (ppb)
As	0.9995	0.000740	0.002260
Al	0.9949	0.000074	0.000224
Cd	0.9994	0.000006	0.000020
Cu	0.9997	0.000018	0.000053
Cr	0.9988	0.000011	0.000032
Fe	0.9980	0.000710	0.002152
Hg	0.9959	0.170910	0.517910
Mn	0.9985	0.000003	0.000010
Ni	0.9986	0.000008	0.000026
Pb	0.9969	0.000029	0.000089
Zn	0.9961	0.000022	0.000068

Table A3: The repeatability and recovery of method (heavy metals)

Heavy Metals	River water sample (n=3)	
	Repeatability (%)	Recovery (%)
As		117.92
Al	0.4-11.0	93.12
Cd	0.5-8.3	124.12
Cu	0.1-5.7	105.58
Cr	0.5-9.5	133.04
Fe	1.0-12.5	92.56
Hg	0.07-6.92	78.12
Mn	0.4-8.7	132.72
Ni	0.4-9.8	128.28
Pb	1.4-11.5	120.08
Zn	1.5-11.6	78.20

Table A4:LOD and LOQ obtained from the calibration curves for pesticides

Pesticides	Range (ppm)	Coefficient of Determination (R^2)	LOD (ppm)	LOQ (ppm)
Malathion	0.075 - 0.9	0.998	0.04	0.001
Chlorpyrifos	0.005 – 0.060	0.999	0.14	0.004

Table A5: The repeatability and recovery of method (pesticides)

Pesticides	Spiking Level (µg/L)	River water sample (n=3)	
		Repeatability (%)	Recovery (%)
Malathion	5	15.0	98.2
	10	21.6	59.8
	100	35.0	117.0
Chlorpyrifos	5	16.8	66.0
	10	15.3	68.7
	100	18.3	83.9

Table A6: List of factories nearby agricultural sampling sites

Industrial factory and source of pollution	Location	
	Longitude	Latitude
Bandar Tenggara Landfill	1°51’25”	103°38’20”
Oxidation pond (Bandar Tenggara)	1°51’38”	103°37’57”
Halex Industries (M) Sdn Bhd	1°52’39”	103°36’44”
Build Green Technology Sdn Bhd	1°51’44”	103°36’42”
CAA Technologist (M) Sdn Bhd	1°52’48”	103°36’53”
Hokuden (M) Sdn Bhd	1°52’46”	103°36’0”
GN Packaging Sdn Bhd	1°52’32”	103°37’13”
Seiwa Podoyo Sdn Bhd	1°52’32”	103°37’13”
Sunnydale Sdn Bhd	1°52’30”	103°37’44”
Jamaree Enterprise Sdn Bhd	1°52’38”	103°37’39”
Concept Betoflor Sdn Bhd	1°52’41”	103°37’36”
Piala Rinting Sdn Bhd	1°52’41”	103°37’36”
Wibawa Urus Sdn Bhd	1°52’42”	103°37’35”
Siri Belukar Sdn Bhd	1°52’58”	103°37’14”
Ayamas Corporation Bhd	1°53’24”	103°36’41”

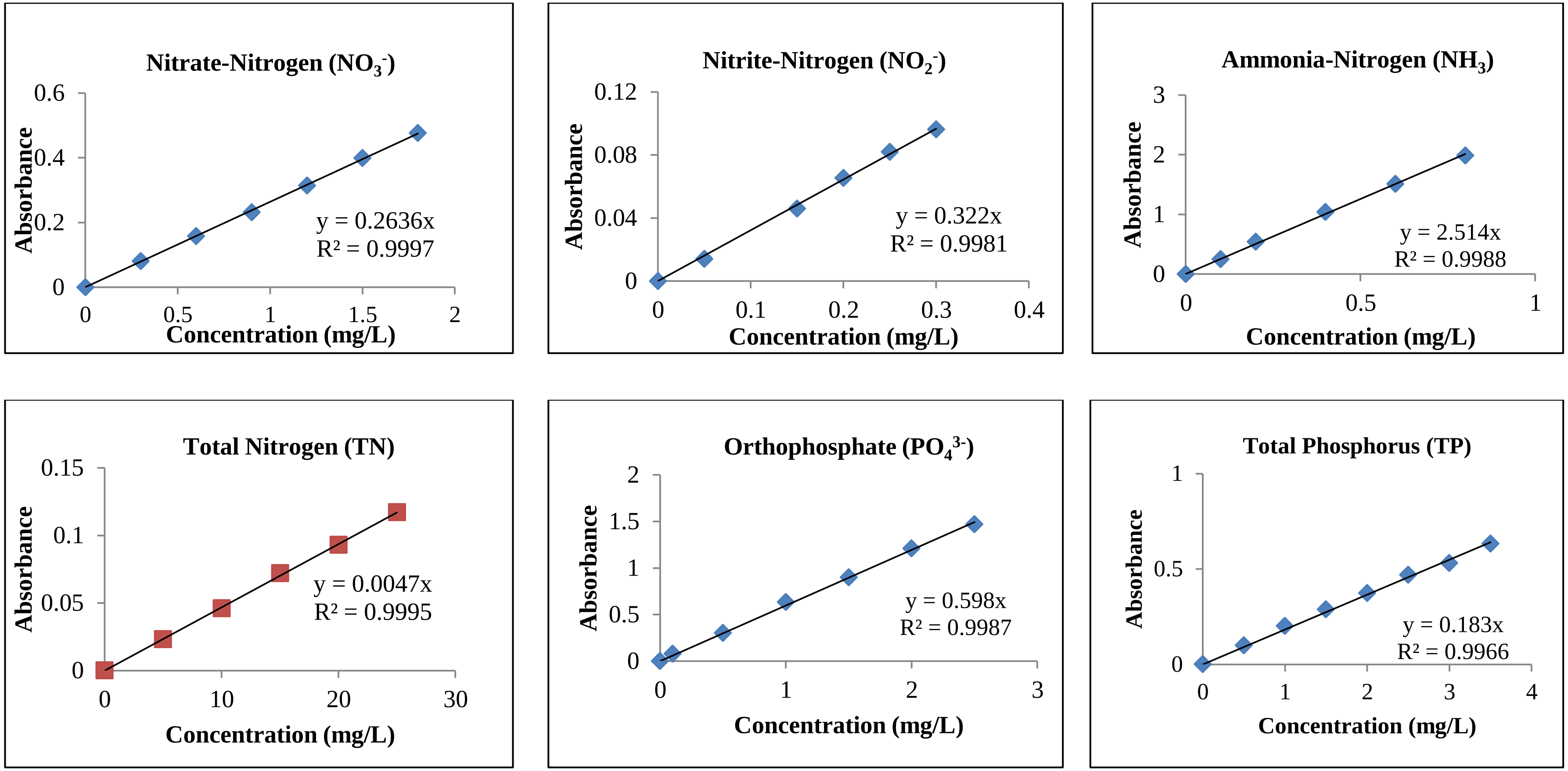


Figure A1 Calibration curves of NO_3^-, NO_2^-, NH_3, TN, PO_4^{3-} and TP

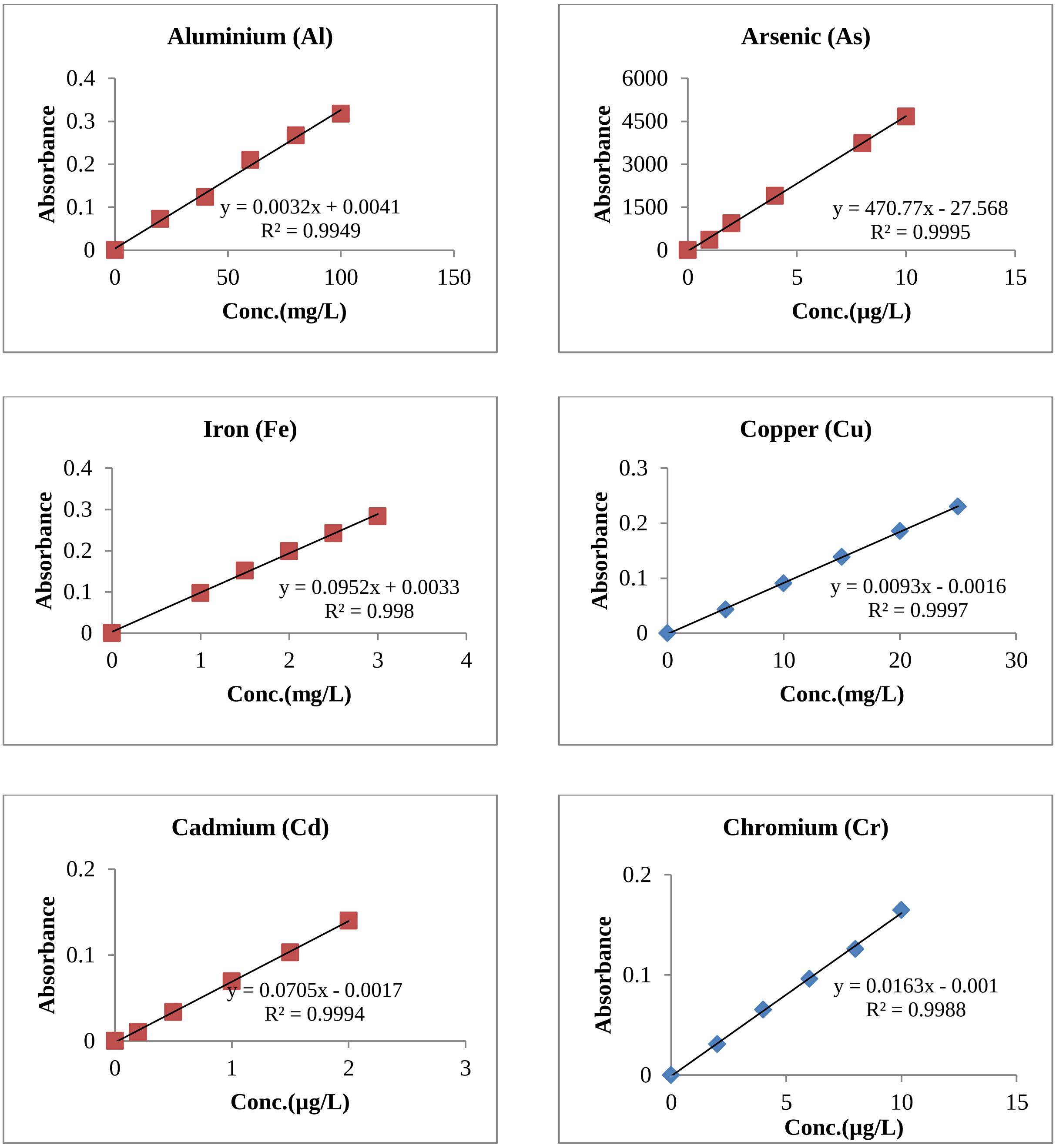


Figure A2 Calibration curves of studied heavy metals

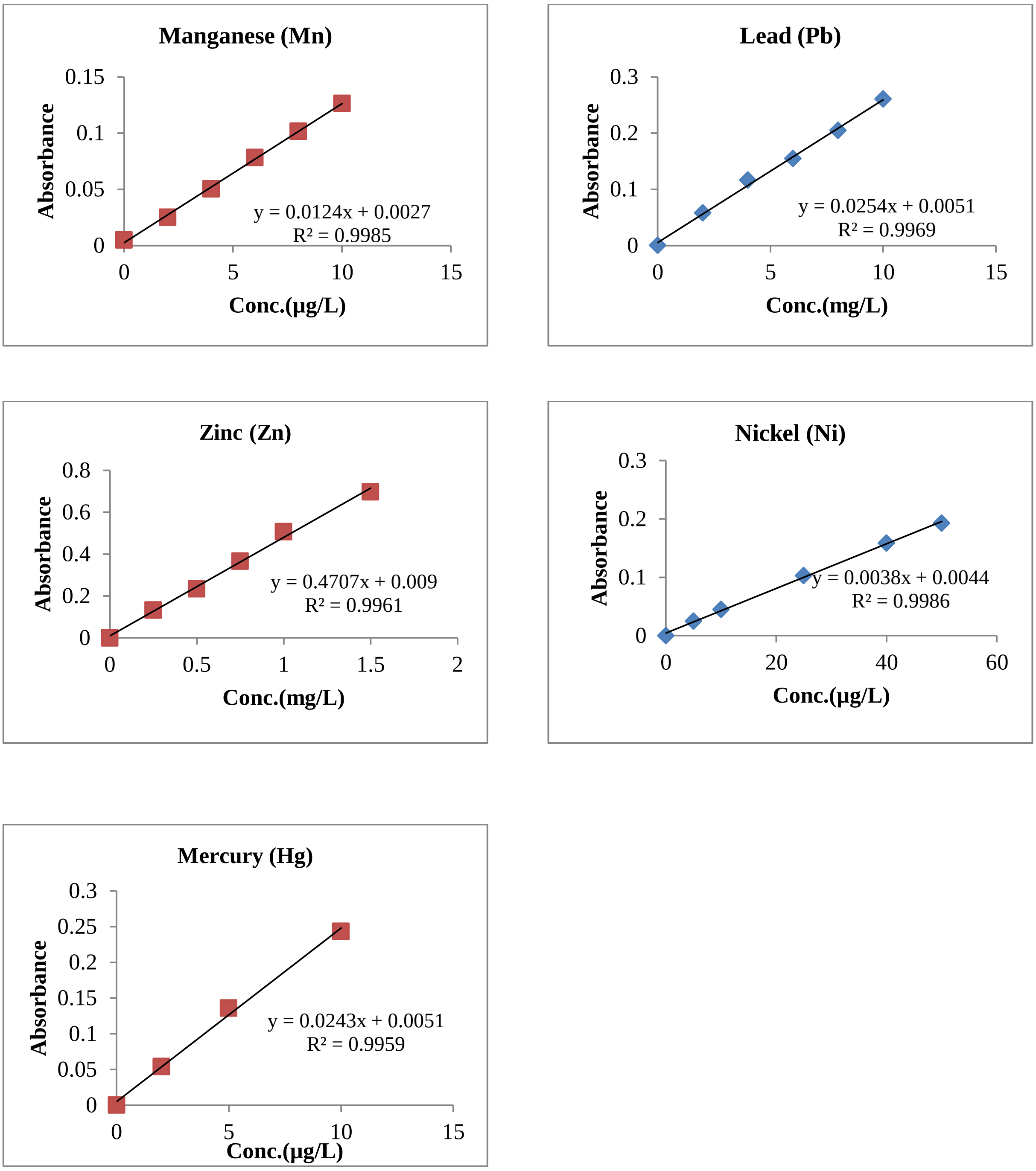


Figure A2 Calibration curves of studied heavy metals

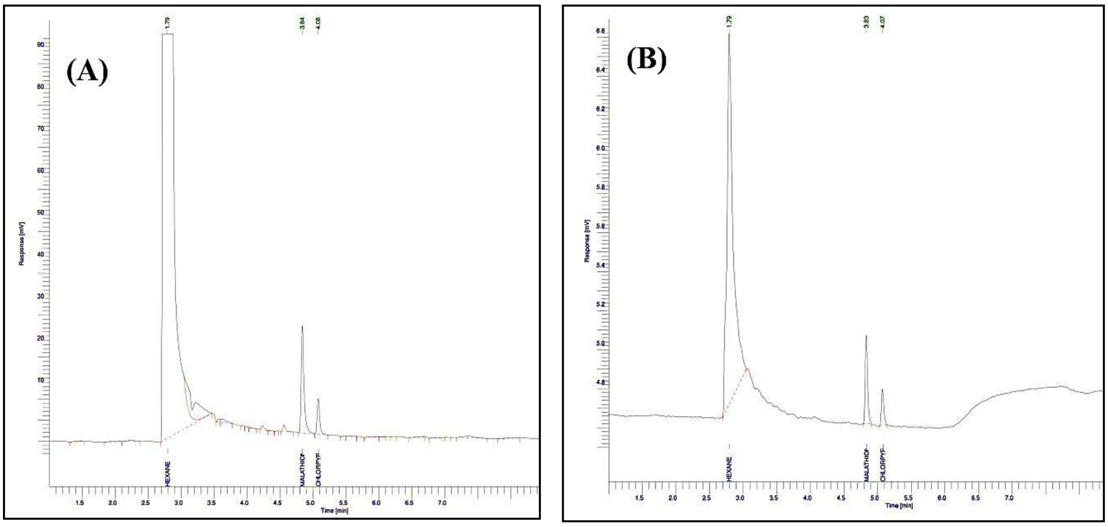


Figure A3 Chromatogram (GC-ECD) for (A) spiked standard solution of 5 µg/L chlorpyrifos (3.8 min) and 75 µg/L malathion (4.0 min) in blank as well as in (B) river water

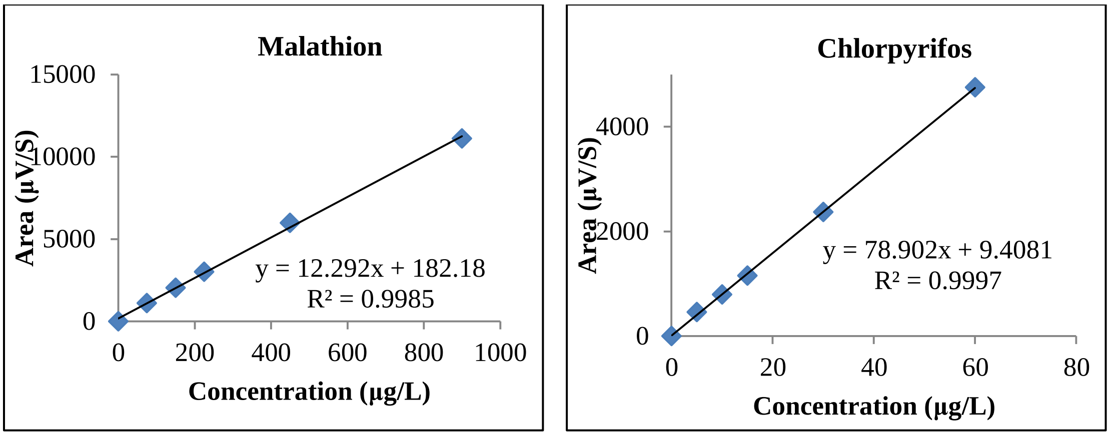
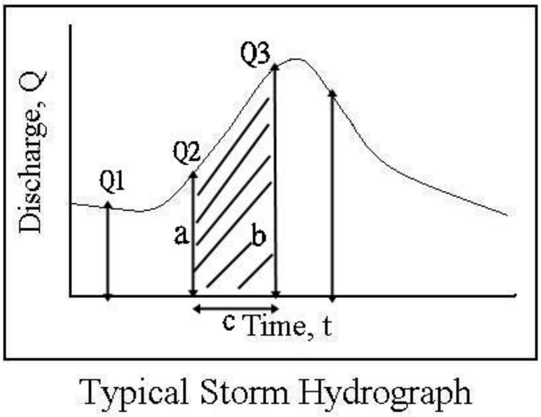


Figure A4 Calibration curves of chlorpyrifos and malathion pesticides



Calculation of volume for shaded area

Volume (m^3) = $\frac{1}{2}$ (c) ($\frac{a+b}{2}$)
c (s) = time duration from Q2 to Q3
a (m^3/s) = river discharge at second point
b (m^3/s) = river discharge at third point

Figure A5 Calculation of volume of river

APPENDIX B

Table B1: Rainfall data (mm) at A1 (Sg. Sebol Rainfall Station)

JABATAN METEOROLOGI MALAYSIA
HOURLY RAINFALL DURATION AND AMOUNT

Station: FELDA SG. SIBOL
Date: 01-04-2015

Hour	Duration [minute]	Amount [millimetre]
0 :00 - 1 :00	00	0.0
1 :00 - 2 :00	00	0.0
2 :00 - 3 :00	00	0.0
3 :00 - 4 :00	00	0.0
4 :00 - 5 :00	00	0.0
5 :00 - 6 :00	00	0.0
6 :00 - 7 :00	00	0.0
7 :00 - 8 :00	00	0.0
8 :00 - 9 :00	00	0.0
9 :00 - 10 :00	00	0.0
10 :00 - 11 :00	00	0.0
11 :00 - 12 :00	00	0.0
12 :00 - 13 :00	00	0.0
13 :00 - 14 :00	00	0.0
14 :00 - 15 :00	00	0.0
15 :00 - 16 :00	21	0.9
16 :00 - 17 :00	42	4.8
17 :00 - 18 :00	55	42.5
18 :00 - 19 :00	00	0.0
19 :00 - 20 :00	00	0.0
20 :00 - 21 :00	00	0.0
21 :00 - 22 :00	00	0.0
22 :00 - 23 :00	00	0.0
23 :00 - 24 :00	00	0.0

Total Rainfall (midnight to midnight) mm : 48.2

Definiton: Trace - Rainfall amount less than 0.1 mm
Def. - Defective Value
N.A. - Not Available

Table B2: Rainfall data (mm) at A2 (Sg. Sebol Rainfall Station)

JABATAN METEOROLOGI MALAYSIA
HOURLY RAINFALL DURATION AND AMOUNT

Station: FELDA SG. SIBOL
Date: 19-04-2015

Hour	Duration [minute]	Amount [millimetre]
0 :00 - 1 :00	00	0.0
1 :00 - 2 :00	00	0.0
2 :00 - 3 :00	00	0.0
3 :00 - 4 :00	00	0.0
4 :00 - 5 :00	00	0.0
5 :00 - 6 :00	00	0.0
6 :00 - 7 :00	00	0.0
7 :00 - 8 :00	00	0.0
8 :00 - 9 :00	00	0.0
9 :00 - 10 :00	00	0.0
10 :00 - 11 :00	00	0.0
11 :00 - 12 :00	00	0.0
12 :00 - 13 :00	00	0.0
13 :00 - 14 :00	00	0.0
14 :00 - 15 :00	20	0.3
15 :00 - 16 :00	23	0.4
16 :00 - 17 :00	24	8.5
17 :00 - 18 :00	00	0.0
18 :00 - 19 :00	00	0.0
19 :00 - 20 :00	00	0.0
20 :00 - 21 :00	00	0.0
21 :00 - 22 :00	00	0.0
22 :00 - 23 :00	00	0.0
23 :00 - 24 :00	00	0.0

Total Rainfall (midnight to midnight) mm : **9.2**

Definition: Trace - Rainfall amount less than 0.1 mm
Def. - Defective Value
N.A. - Not Available

Table B3: Rainfall data (mm) at U1 (Ladang Getah Malaya Rainfall Station)

SPRHiN 2015
Jabatan Pengairan dan Saliran Malaysia
1738131 Ldg. Getah Malaya di Kota Tinggi

Date	Hour	Amount [milimitre]
10/12/2015	1:00:00	0
10/12/2015	2:00:00	0
10/12/2015	3:00:00	0
10/12/2015	4:00:00	0
10/12/2015	5:00:00	0
10/12/2015	6:00:00	0
10/12/2015	7:00:00	0
10/12/2015	8:00:00	0
10/12/2015	9:00:00	0
10/12/2015	10:00:00	0
10/12/2015	11:00:00	0.1
10/12/2015	12:00:00	0.5
10/12/2015	13:00:00	5
10/12/2015	14:00:00	6.5
10/12/2015	15:00:00	10.5
10/12/2015	16:00:00	9.5
10/12/2015	17:00:00	0
10/12/2015	18:00:00	0
10/12/2015	19:00:00	0
10/12/2015	20:00:00	0
10/12/2015	21:00:00	0
10/12/2015	22:00:00	0
10/12/2015	23:00:00	0
10/12/2015	24:00:00	0

Total Rainfall (midnight to midnight) mm : 32.1

Definition: Trace- Rainfall amount less than 0.1 mm
Def.- Defective Value
N.A. - Not available

Table B4: Rainfall data (mm) at U2 (Ladang Permatang Rainfall Station)

SPRHiN
2015
Jabatan Pengairan dan Saliran Malaysia
1739002 Ldg. Permatang di Kota Tinggi
Station : Rainfall

Date	Hour	Rainfall amount [milimitre]
23/12/2015	2:00:00	0
23/12/2015	3:00:00	0
23/12/2015	4:00:00	0
23/12/2015	5:00:00	0
23/12/2015	6:00:00	0
23/12/2015	7:00:00	0
23/12/2015	8:00:00	0
23/12/2015	9:00:00	0.1
23/12/2015	10:00:00	0.1
23/12/2015	11:00:00	0.1
23/12/2015	12:00:00	0.1
23/12/2015	13:00:00	0.1
23/12/2015	14:00:00	0.5
23/12/2015	15:00:00	2
23/12/2015	16:00:00	10
23/12/2015	17:00:00	15
23/12/2015	18:00:00	2.5
23/12/2015	19:00:00	0
23/12/2015	20:00:00	0
23/12/2015	21:00:00	0
23/12/2015	22:00:00	0
23/12/2015	23:00:00	0
23/12/2015	24:00:00	0

Total Rainfall (midnight to midnight) mm : 30.5

Definition: Trace- Rainfall amount less than 0.1 mm
Def.- Defective Value
N.A. - Not available

Table B5: Rainfall data (mm) at U3 (Ladang Getah Malaya Rainfall Station)

SPRHiN 2016
Jabatan Pengairan dan Saliran Malaysia
1738131 Ldg. Getah Malaya di Kota Tinggi

Date	Hour	Amount [milimitre]
1/2/2016	1:00:00	0
1/2/2016	2:00:00	0
1/2/2016	3:00:00	0
1/2/2016	4:00:00	0
1/2/2016	5:00:00	0
1/2/2016	6:00:00	0
1/2/2016	7:00:00	0
1/2/2016	8:00:00	0
1/2/2016	9:00:00	0
1/2/2016	10:00:00	2.7
1/2/2016	11:00:00	0.7
1/2/2016	12:00:00	5.6
1/2/2016	13:00:00	7.2
1/2/2016	14:00:00	3.4
1/2/2016	15:00:00	0.2
1/2/2016	16:00:00	0
1/2/2016	17:00:00	0
1/2/2016	18:00:00	0
1/2/2016	19:00:00	0
1/2/2016	20:00:00	0
1/2/2016	21:00:00	0
1/2/2016	22:00:00	0
1/2/2016	23:00:00	0
1/2/2016	24:00:00	0

Total Rainfall (midnight to midnight) mm : 19.8

Definition: Trace- Rainfall amount less than 0.1 mm
Def.- Defective Value
N.A. - Not available

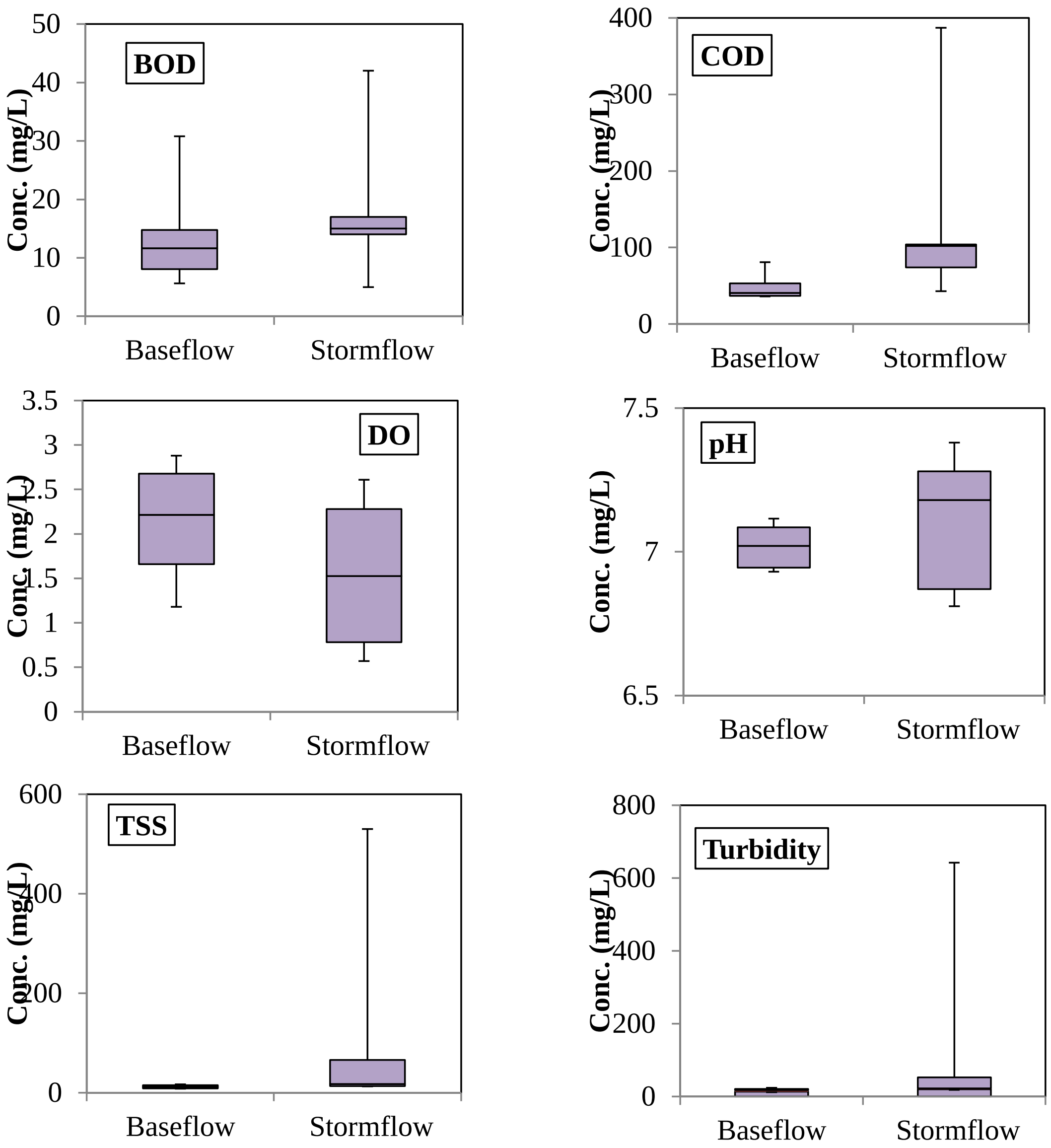


Figure B1 Box plot comparison of water quality parameter (BOD, COD, TSS, DO, pH and turbidity) concentration against event flow at A1

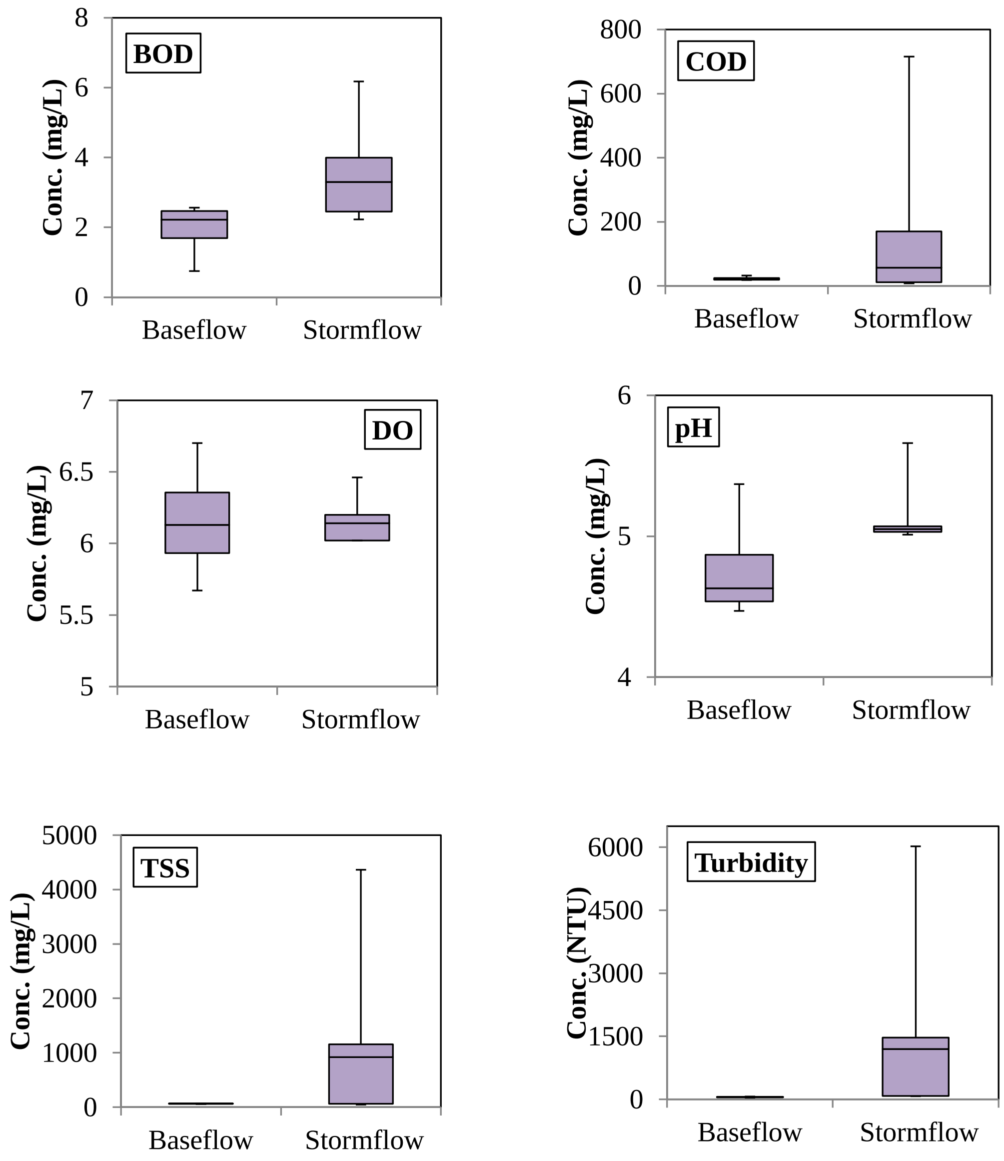


Figure B2 Box plot comparison of water quality parameter (BOD, COD, TSS, DO, pH and turbidity) concentration against event flow at A2

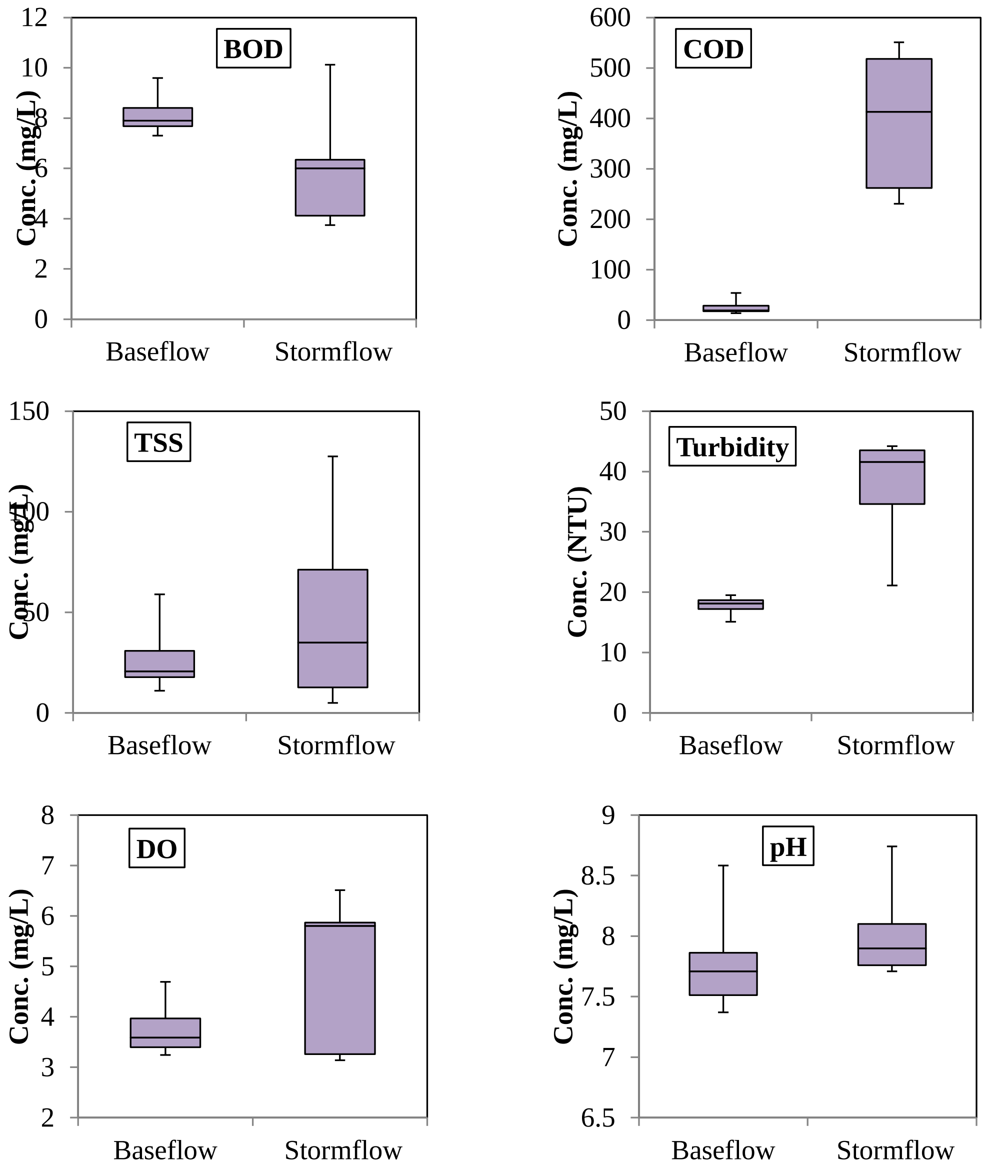


Figure B3 Box plot comparison of BOD, COD, TSS, turbidity, DO and pH concentration against event flow at U1

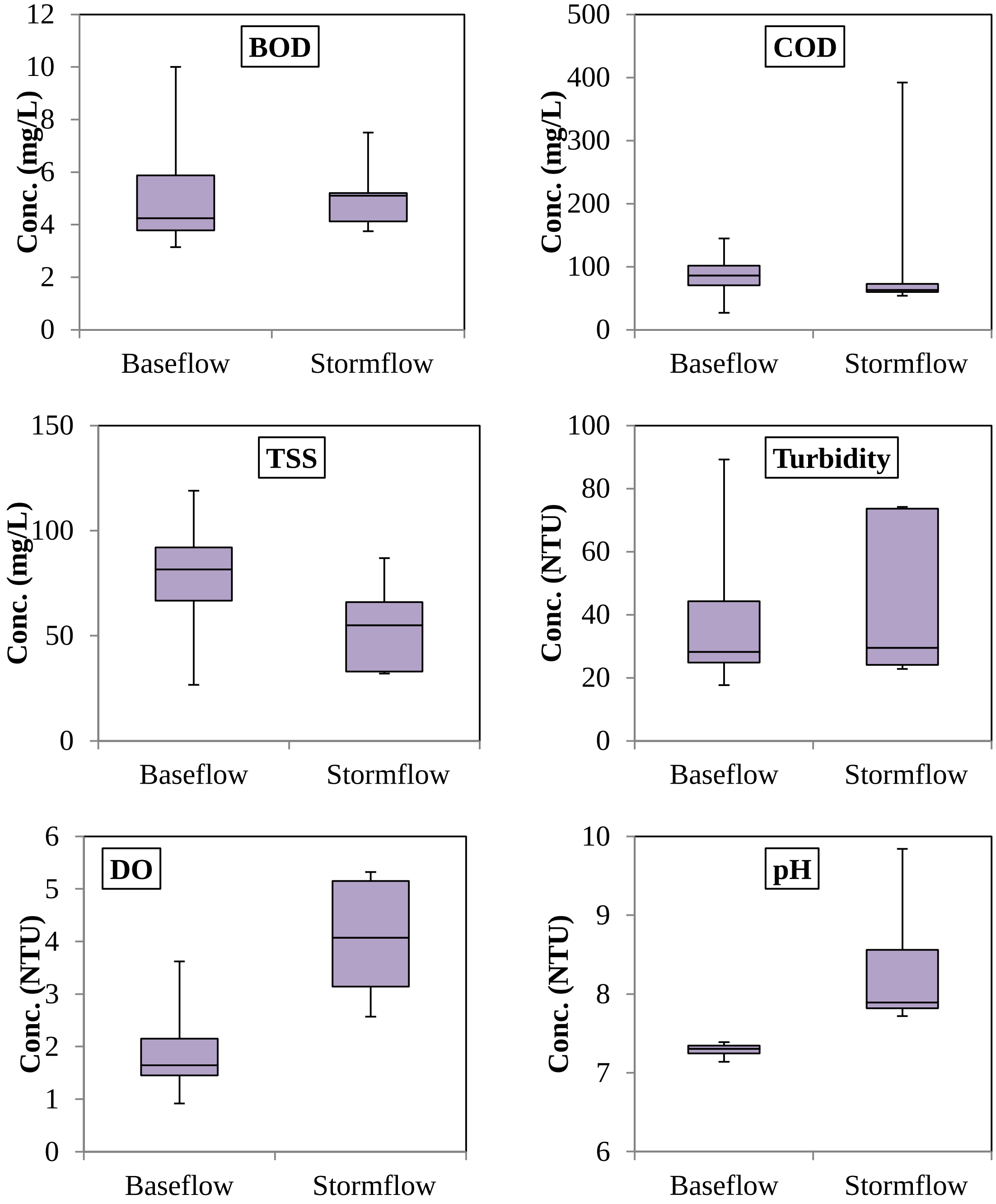


Figure B4 Box plot comparison of BOD, COD, TSS, turbidity, DO and pH concentration against event flow at U2

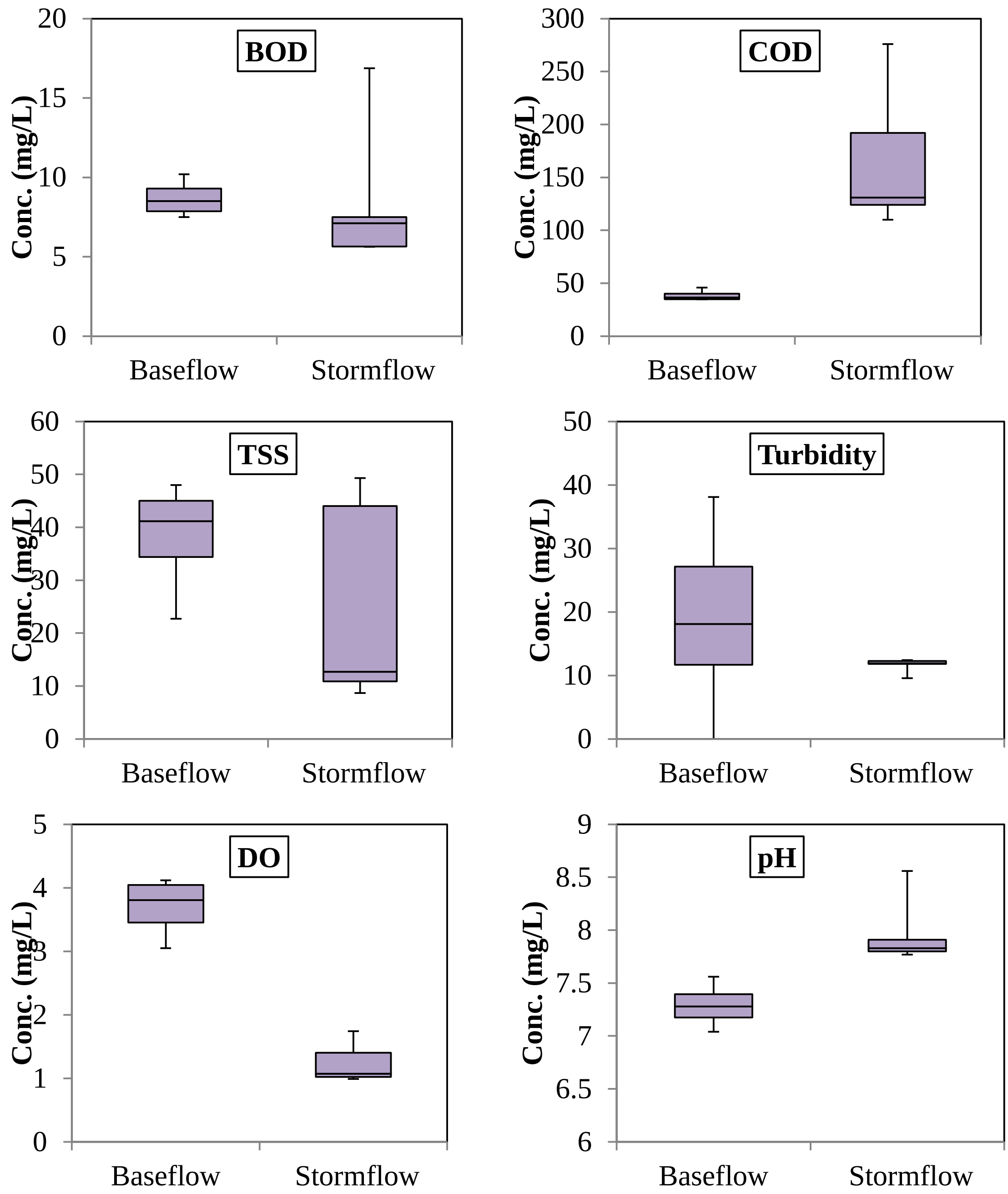


Figure B5 Box plot comparison of BOD, COD, TSS, turbidity, DO and pH concentration against event flow at U3

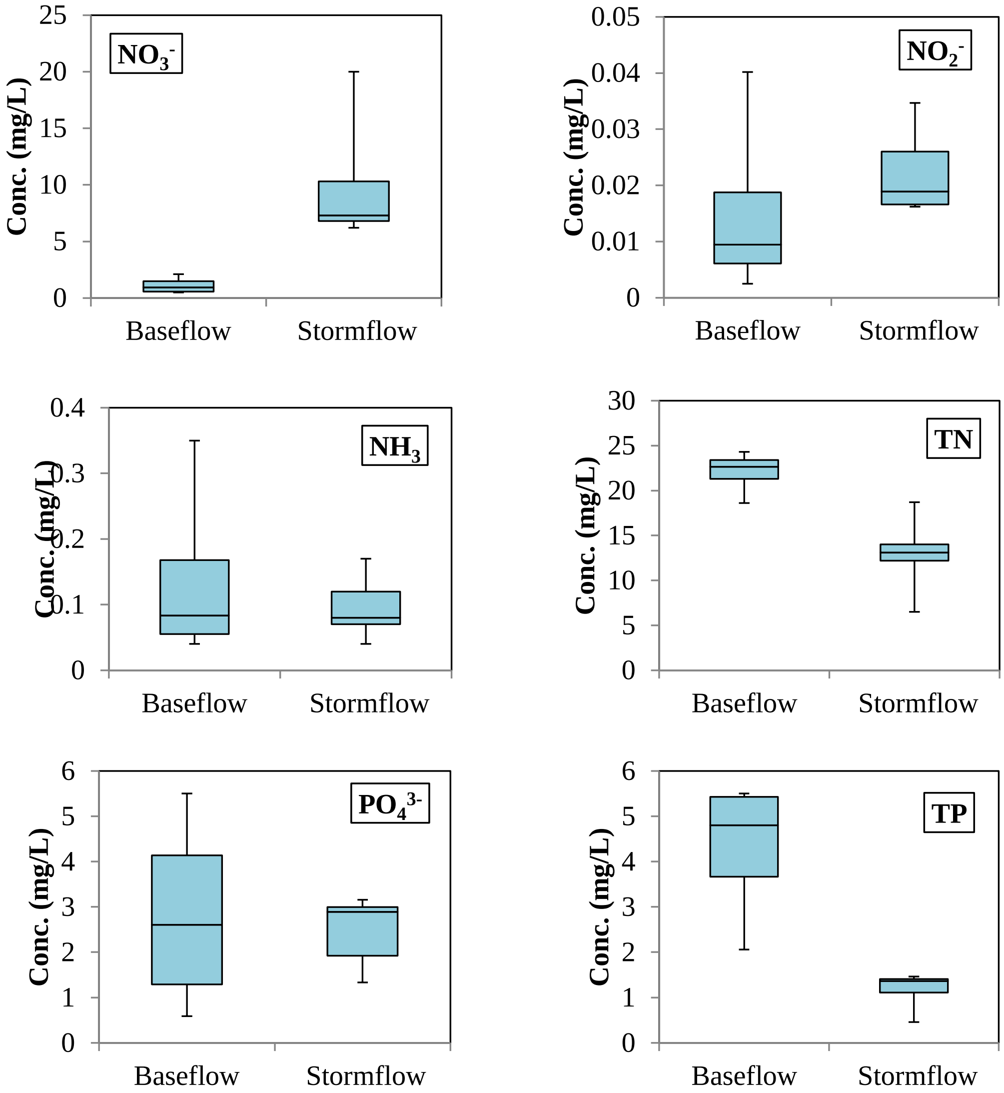


Figure B6 Box plot comparison of nutrients (NO_3^-, NO_2^-, NH_3, TN, PO_4^{3-} and TP) concentration against event flow at A1

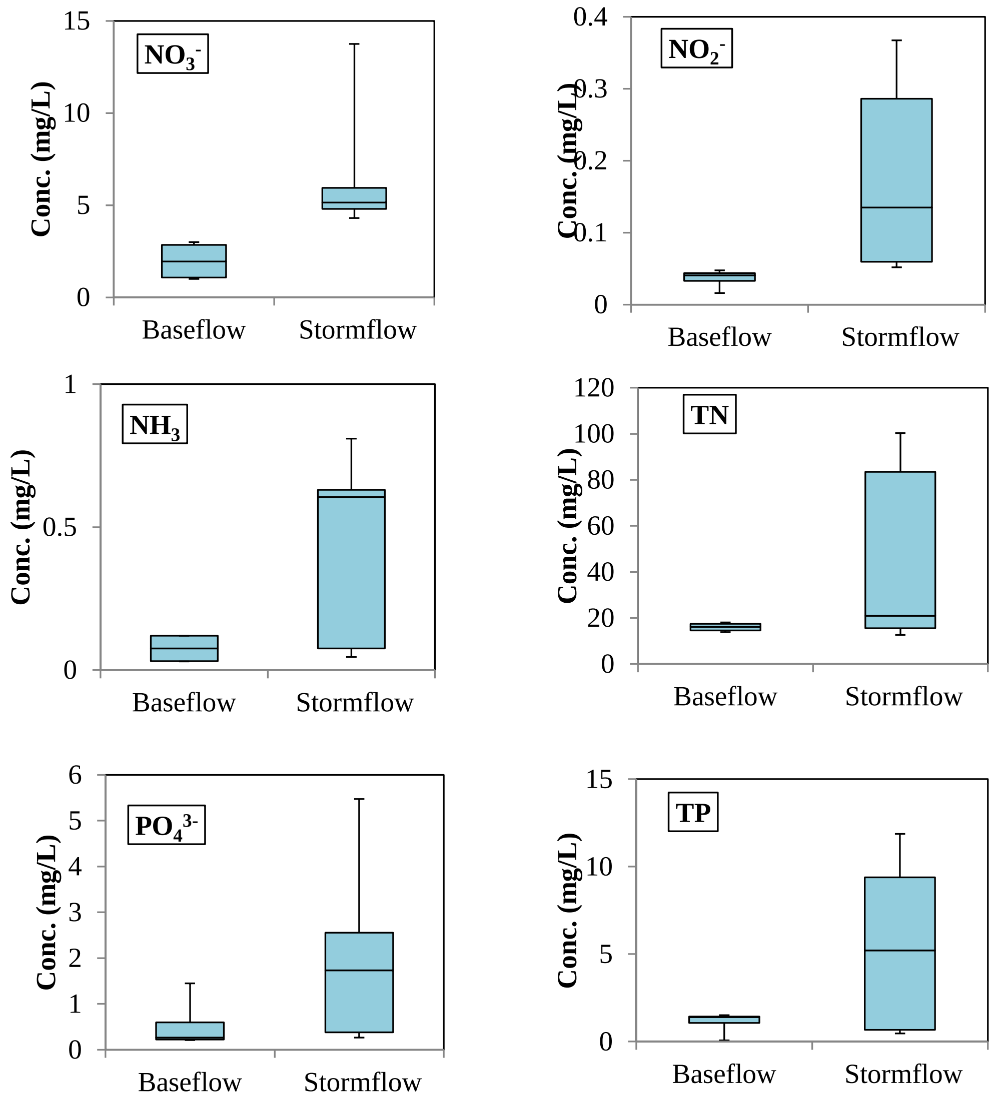


Figure B7 Box plot comparison of nutrients (NO_3^-, NO_2^-, NH_3, TN, PO_4^{3-} and TP) concentration against event flow at A2

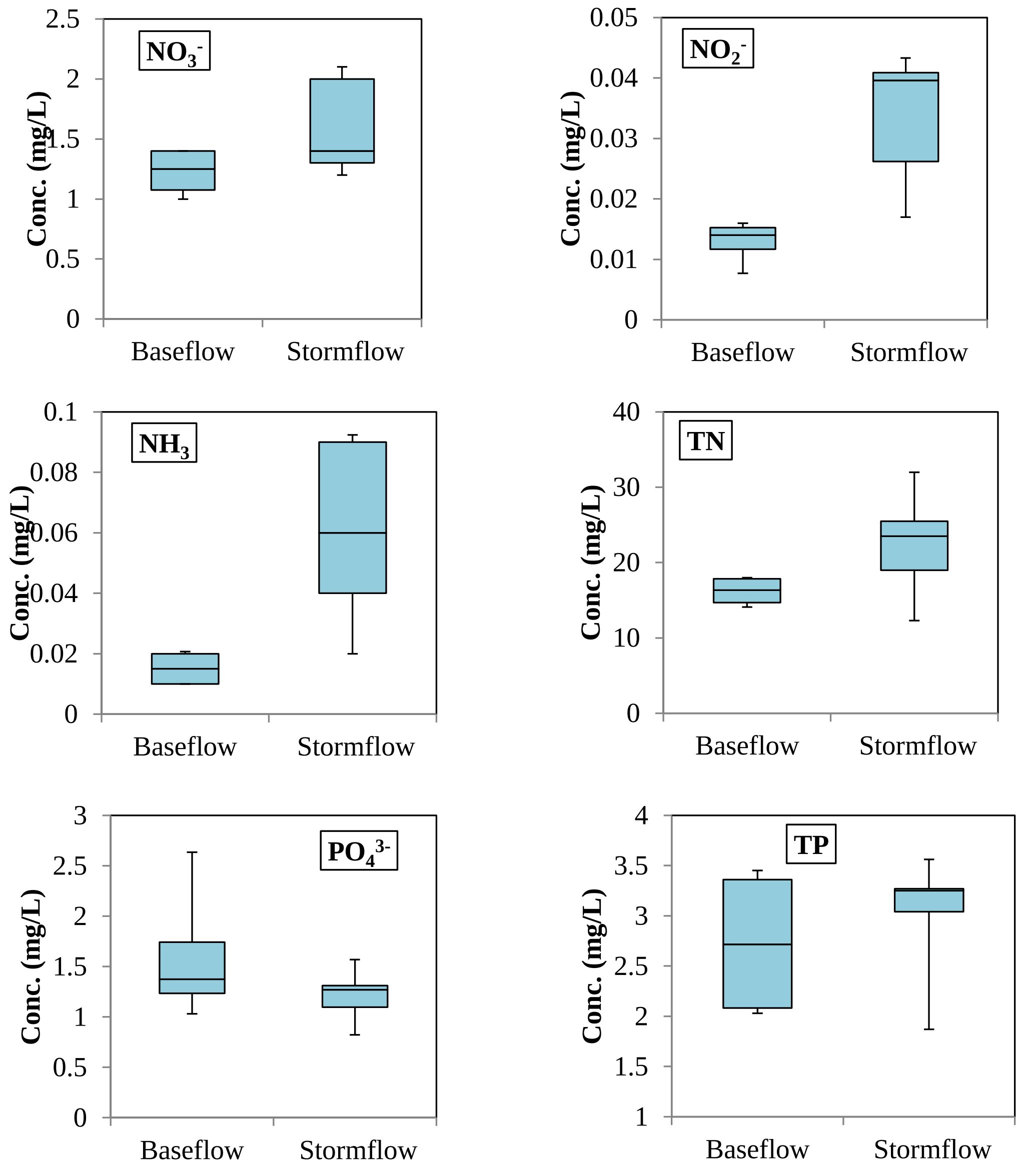


Figure B8 Box plot comparison of nutrients concentration against event flow at U1

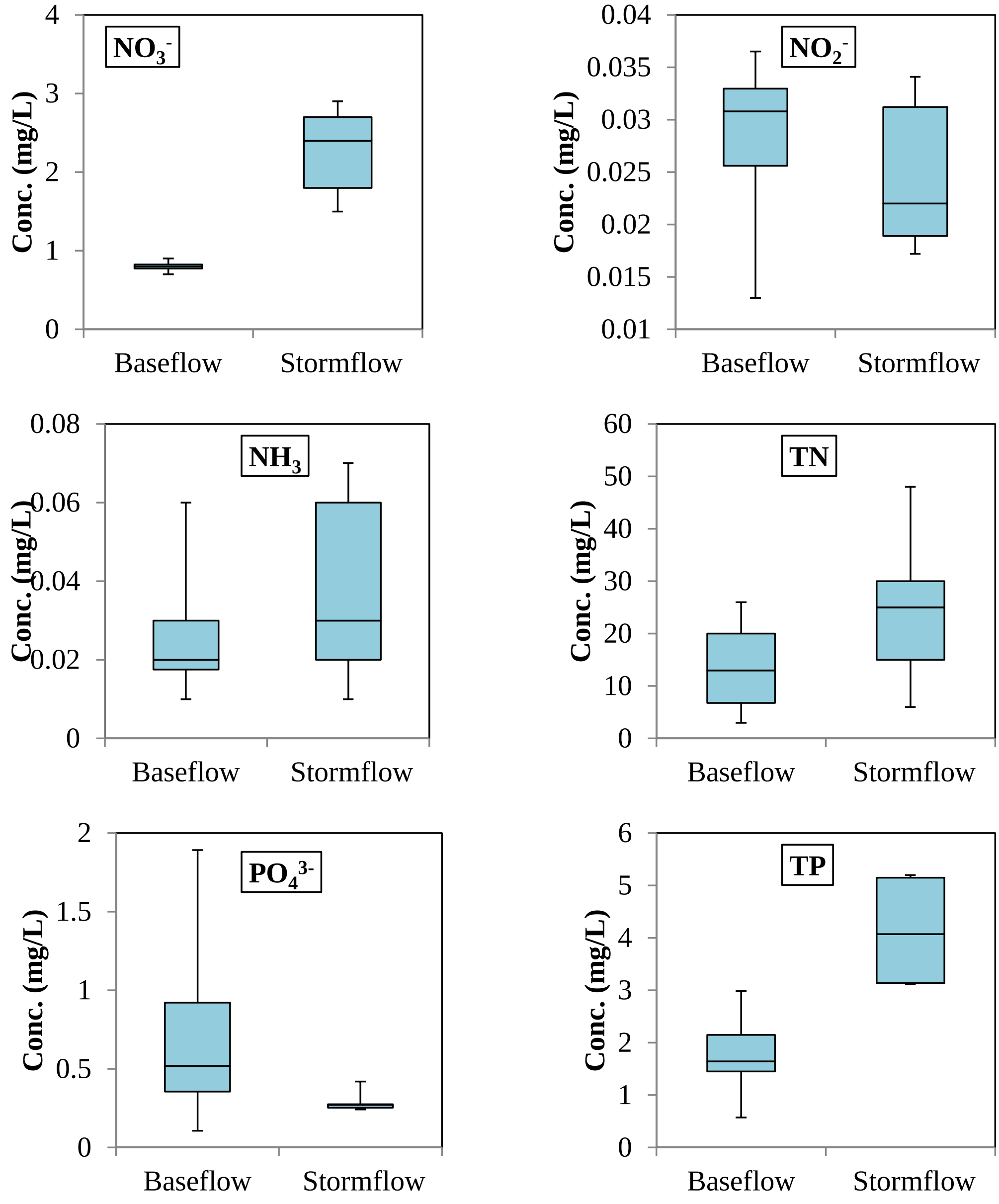


Figure B9 Box plot comparison of nutrients concentration against event flow at U2

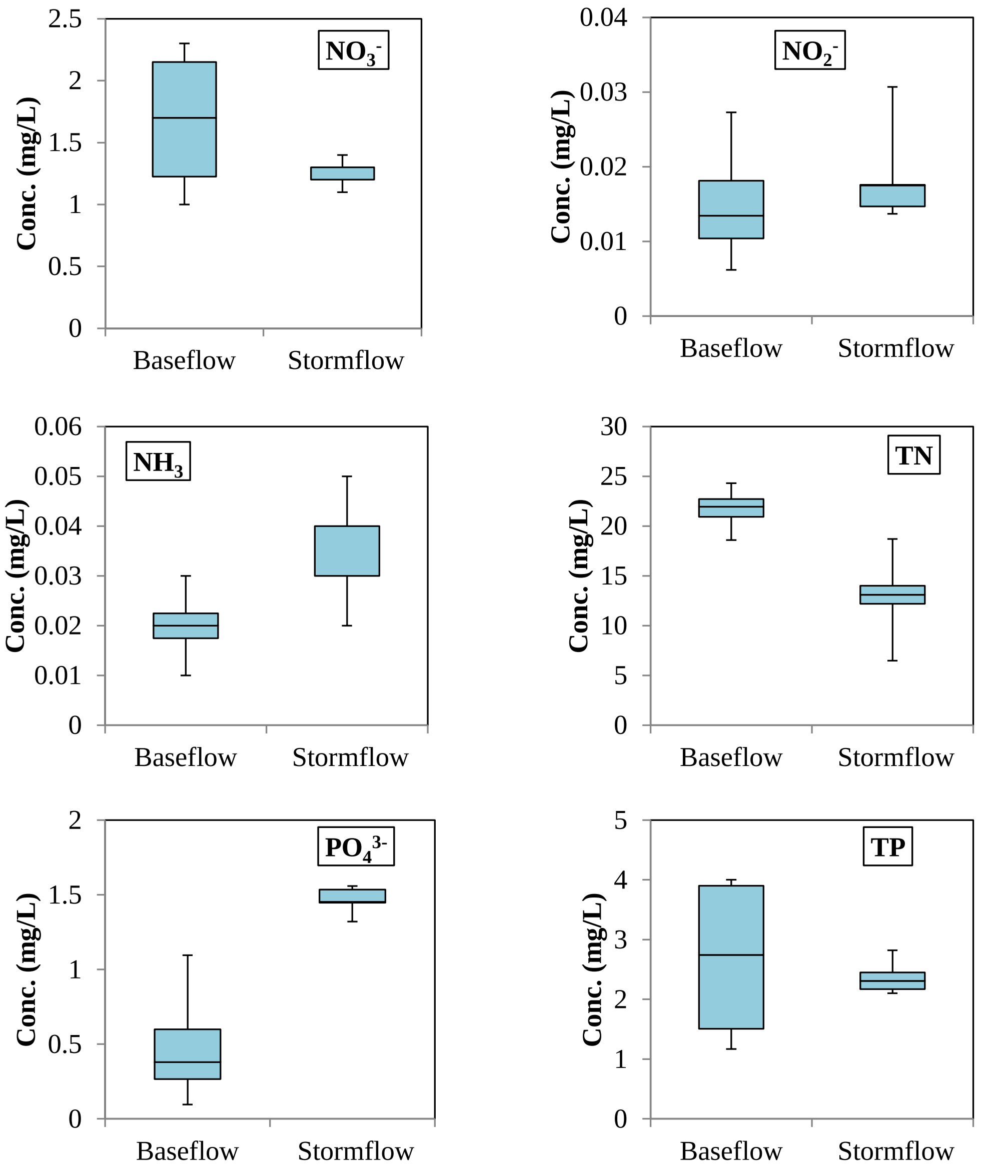


Figure B10 Box plot comparison of nutrients concentration against event flow at U3

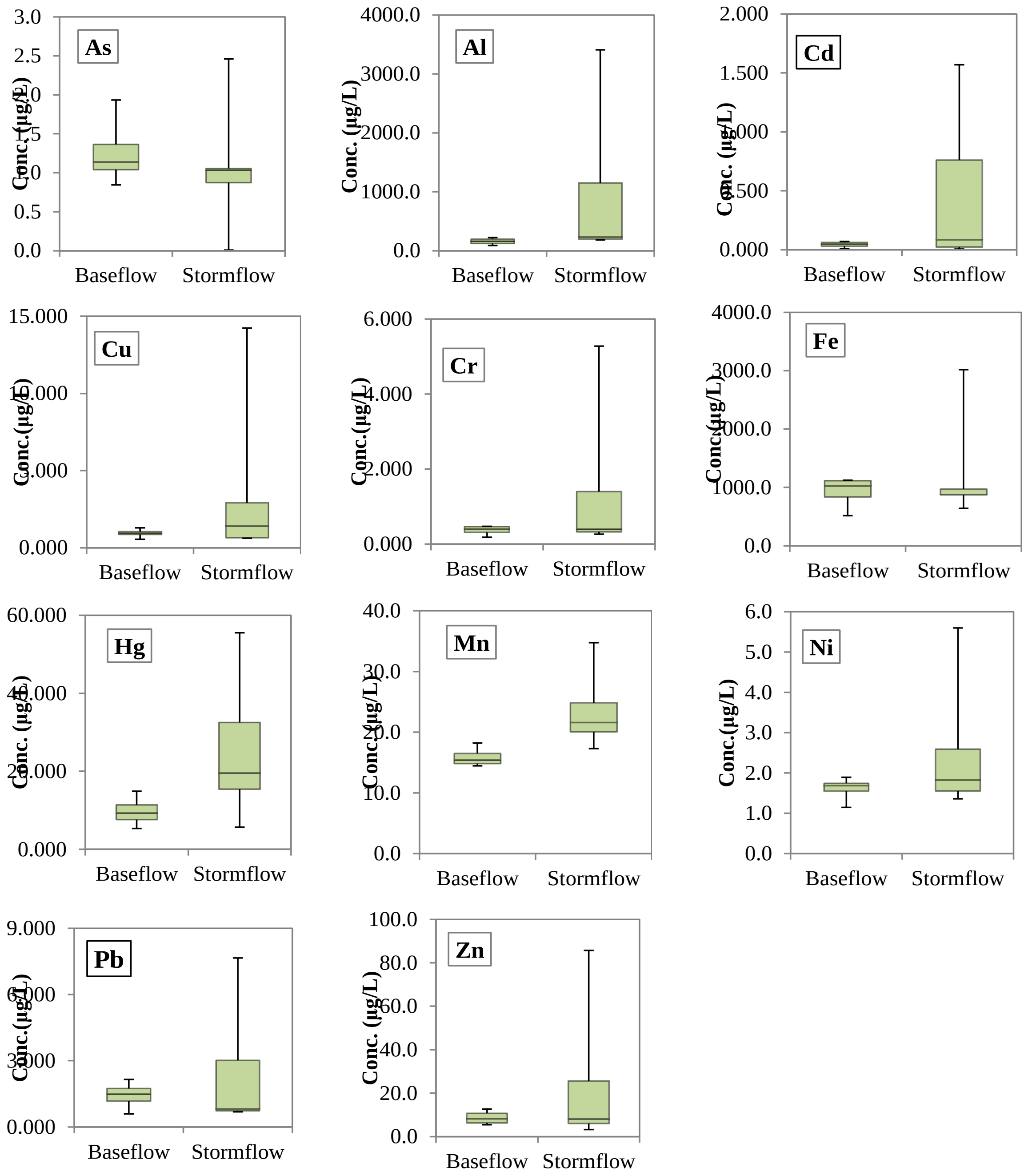


Figure B11 Box plot comparison of heavy metals concentration against event flow at A1

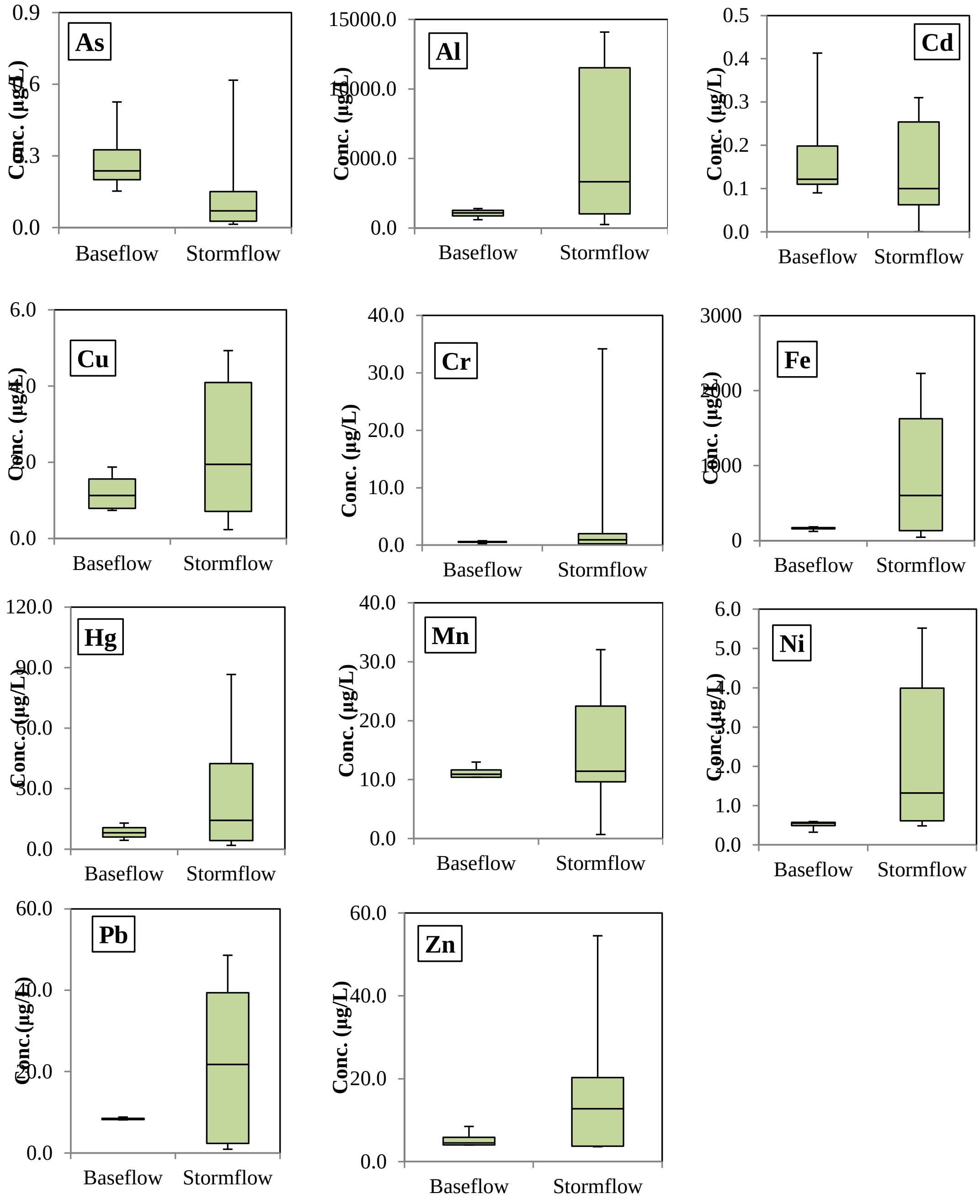


Figure B12 Box plot comparison of heavy metals concentration against event flow at A2

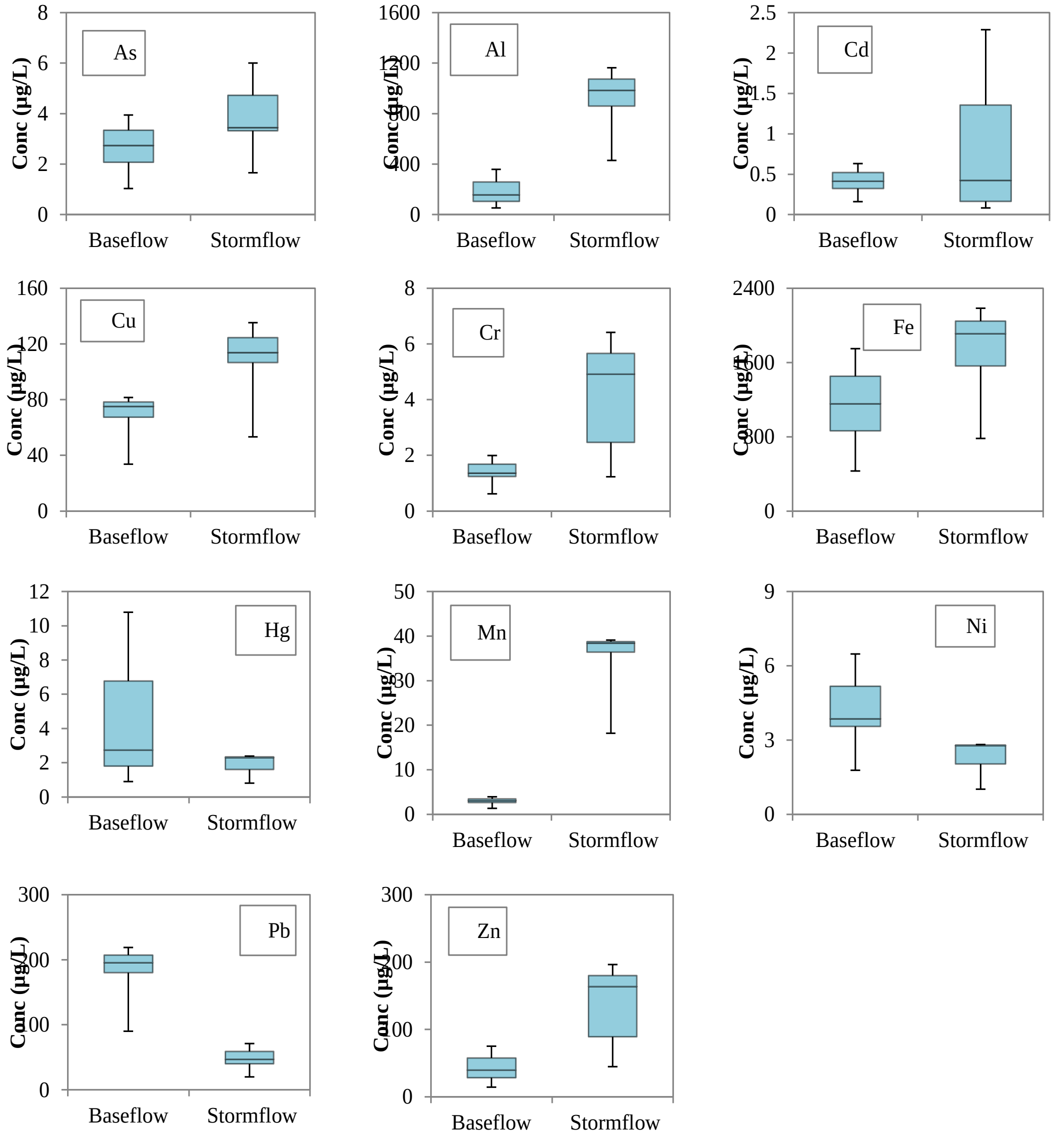


Figure B13 Box plot comparison of heavy metals concentration against event flow at U1

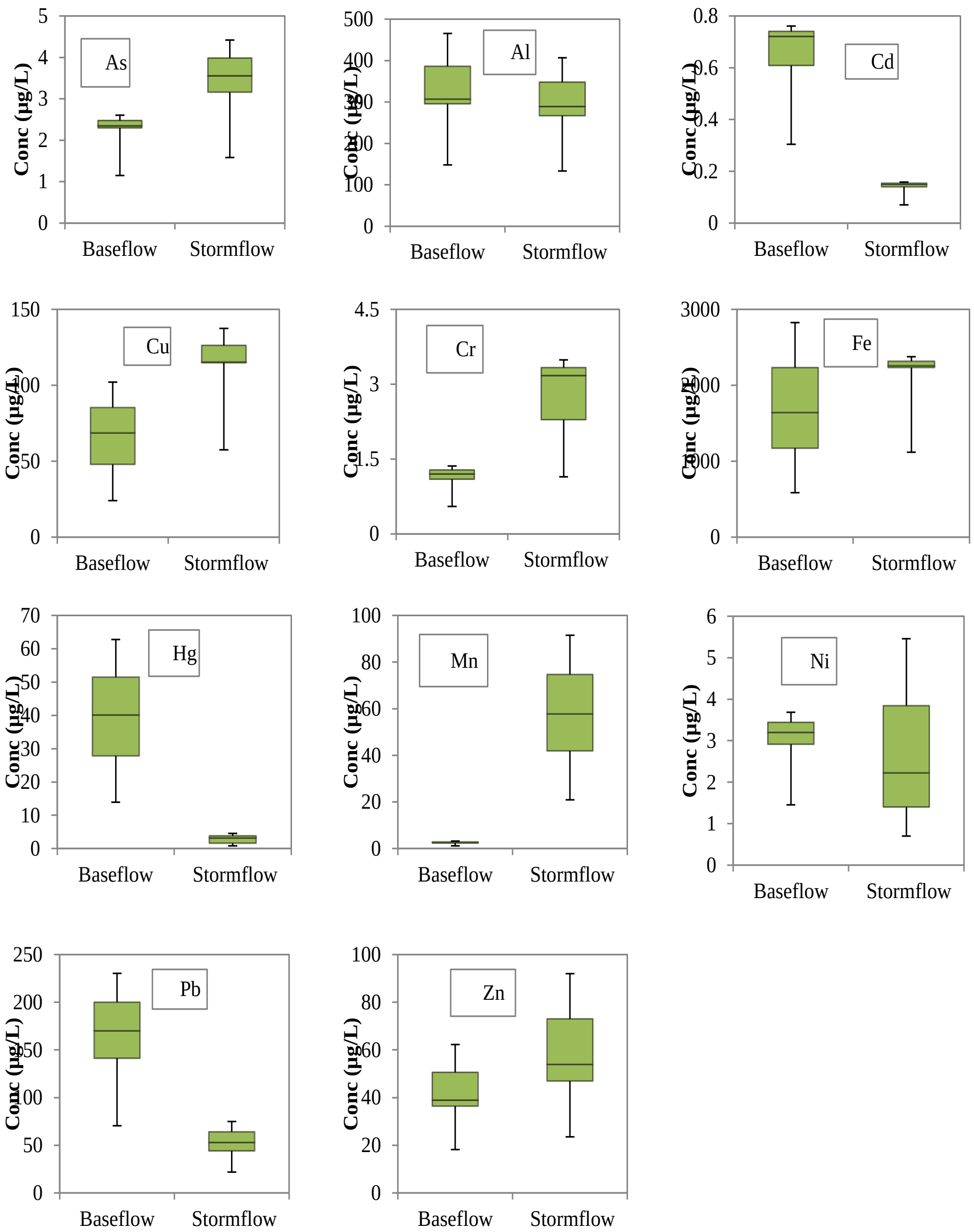


Figure B14 Box plot comparison of heavy metals concentration against event flow at U2

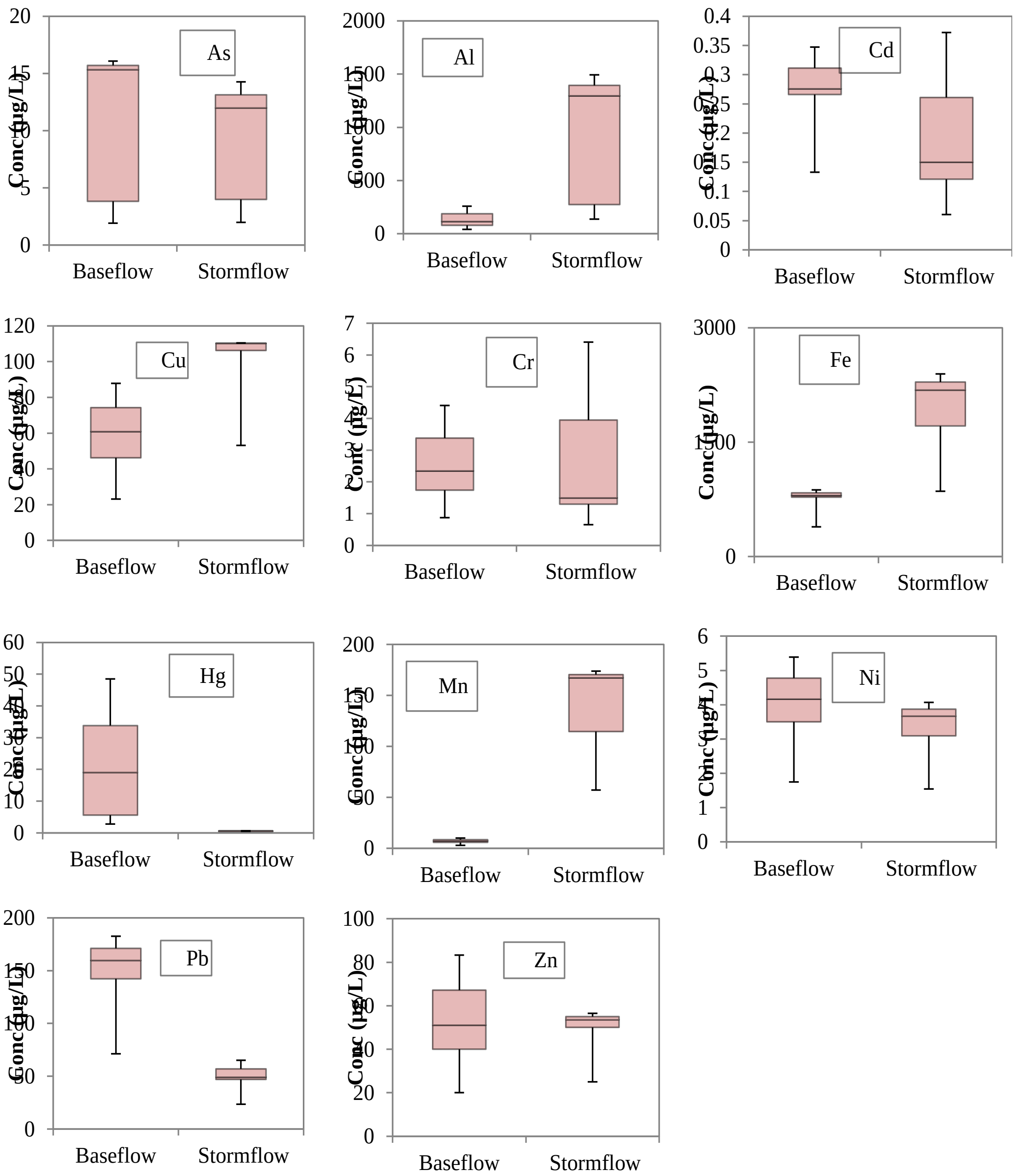


Figure B15 Box plot comparison of heavy metals concentration against event flow at U3

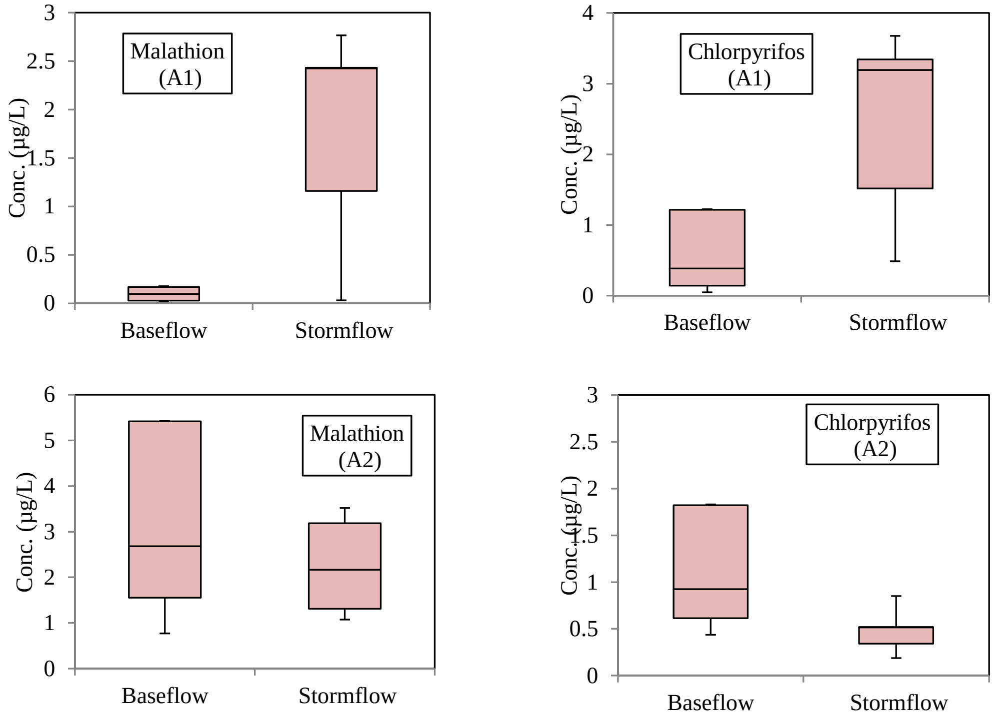


Figure B16 Box plot comparison of pesticides concentration against event flow at A1 and A2

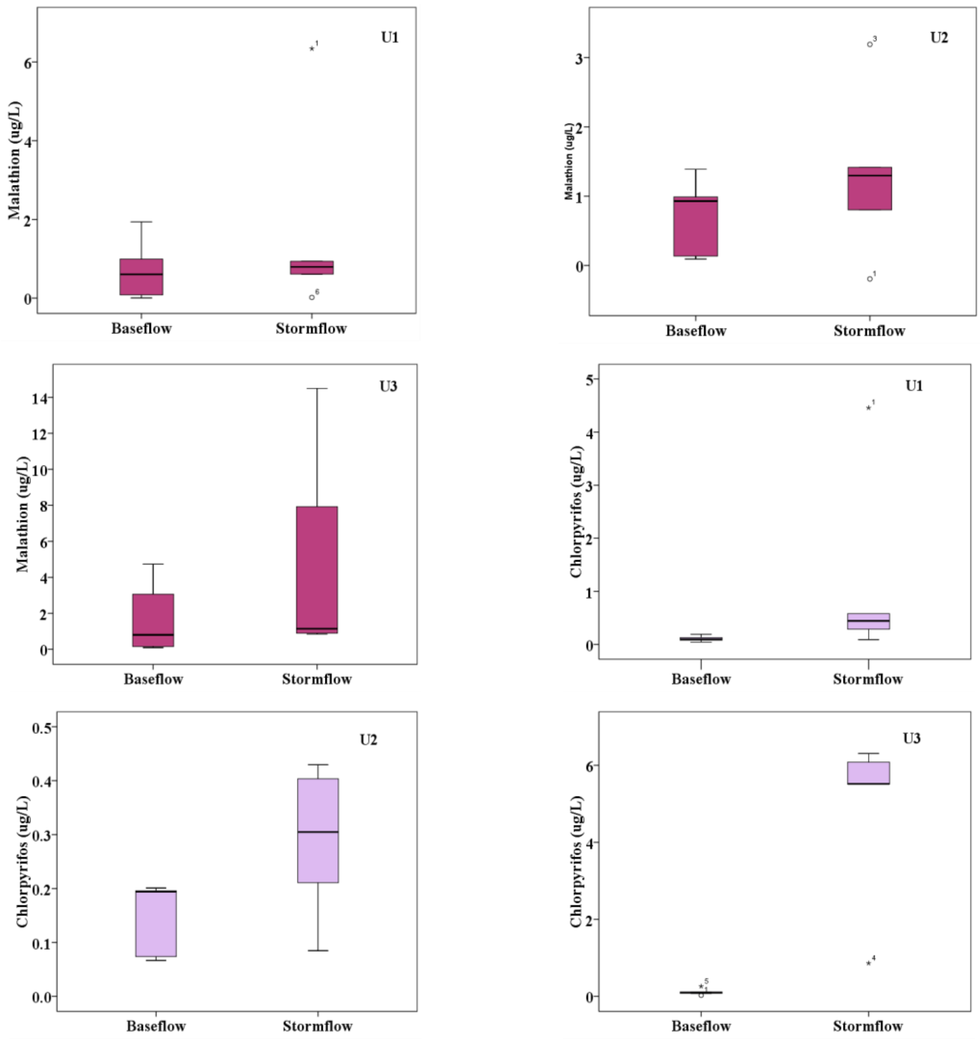


Figure B17 Box plot comparison of malathion and chlorpyrifos concentration against event flow at U1, U2 and U3

APPENDIX C

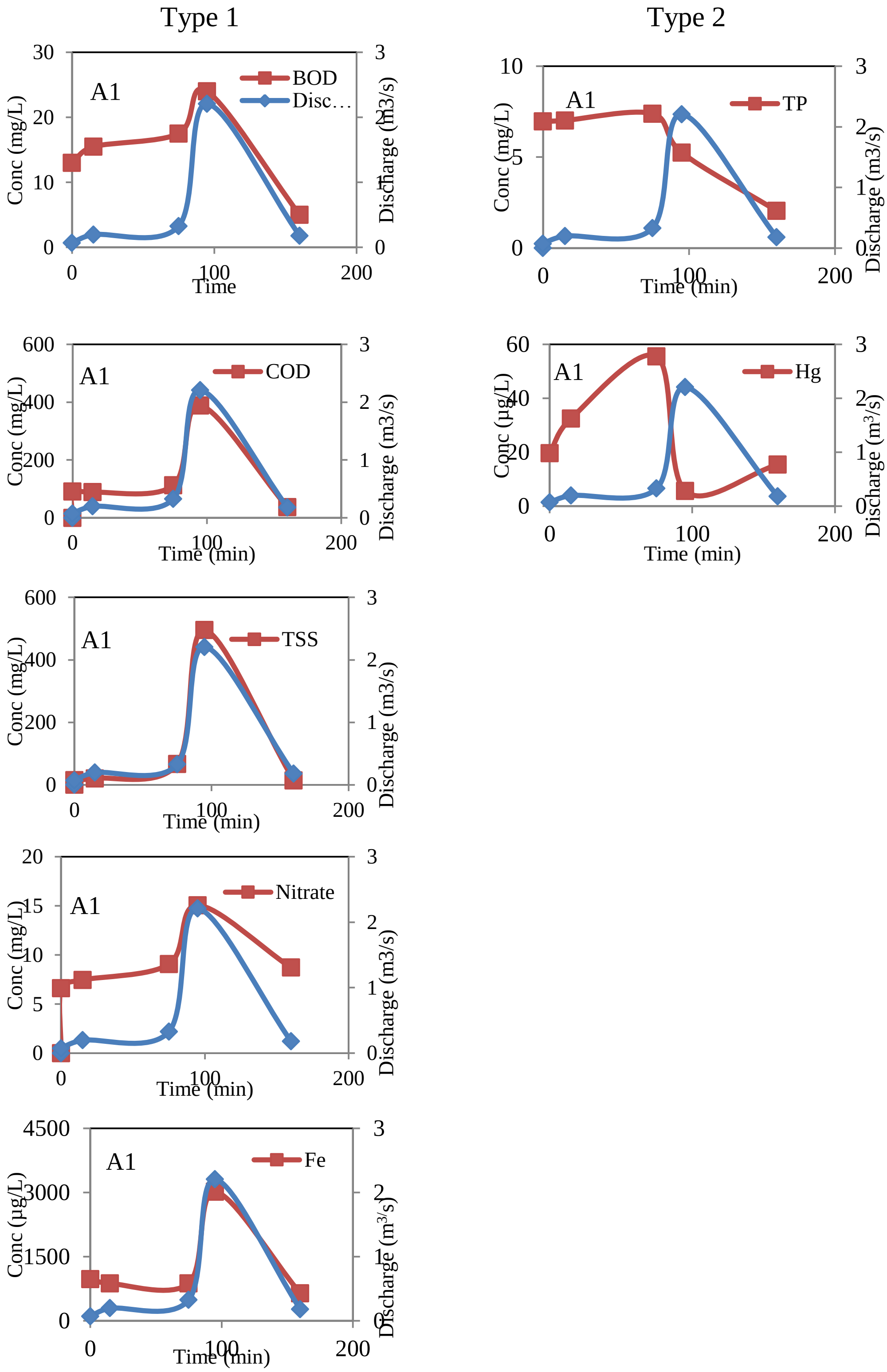


Figure C1 Pollutograph of Type 1 and 2 pollutants that exceeded Class II NWQS at A1

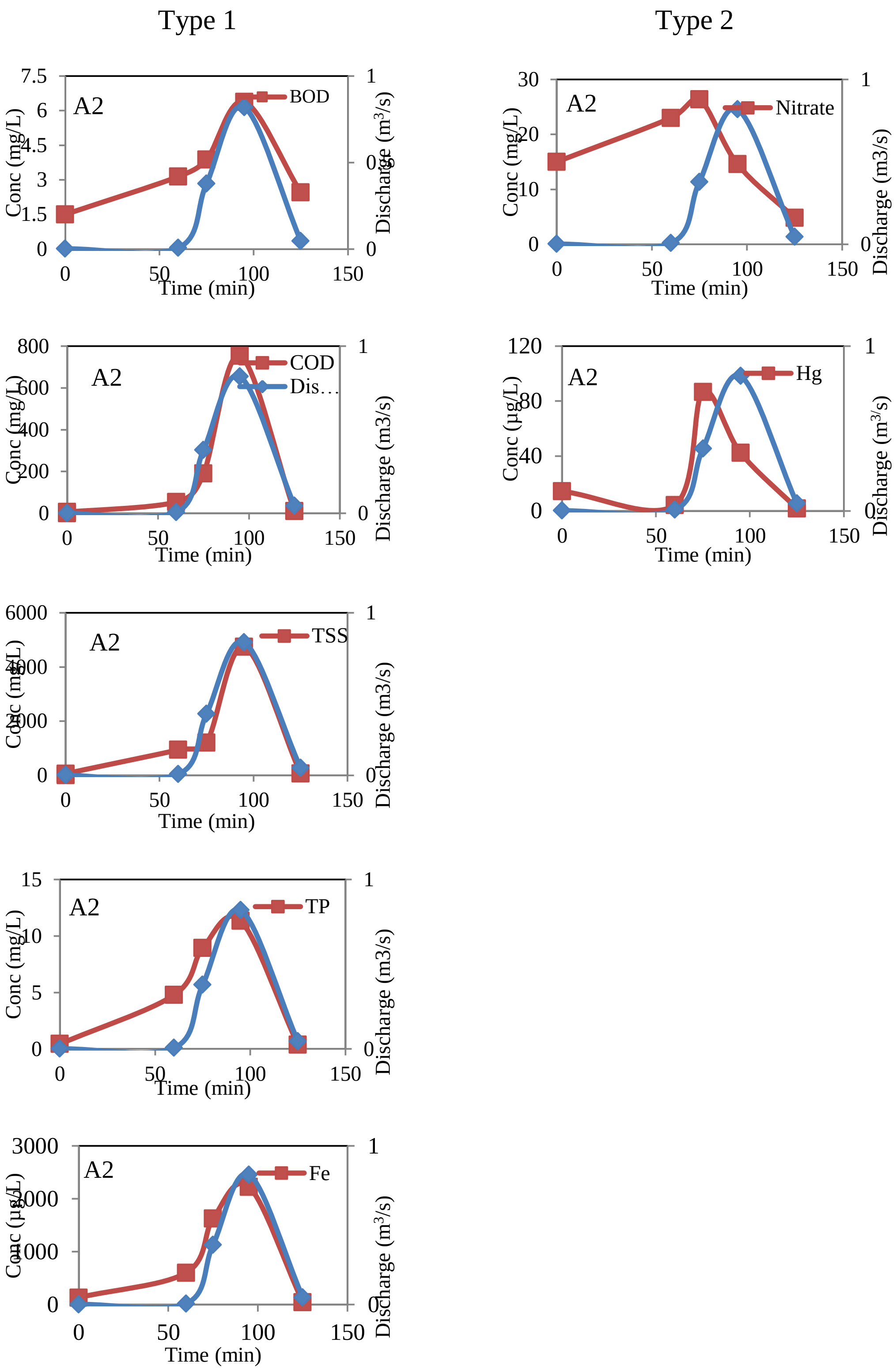


Figure C2 Pollutograph of Type 1 and 2 pollutants that exceeded Class II NWQS at A2

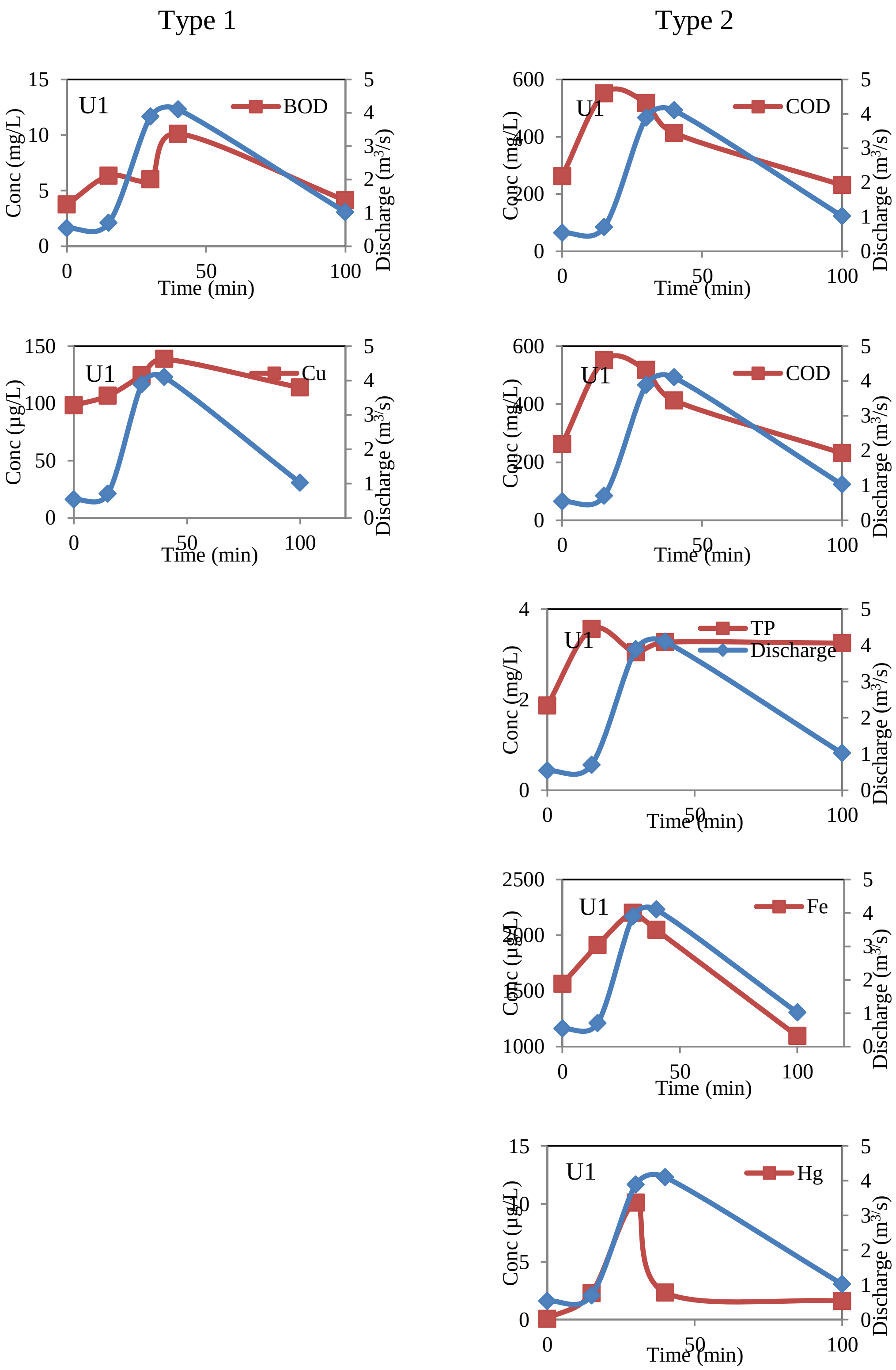


Figure C3 Pollutograph of Type 1 and 2 pollutants that exceeded Class III NWQS at U1

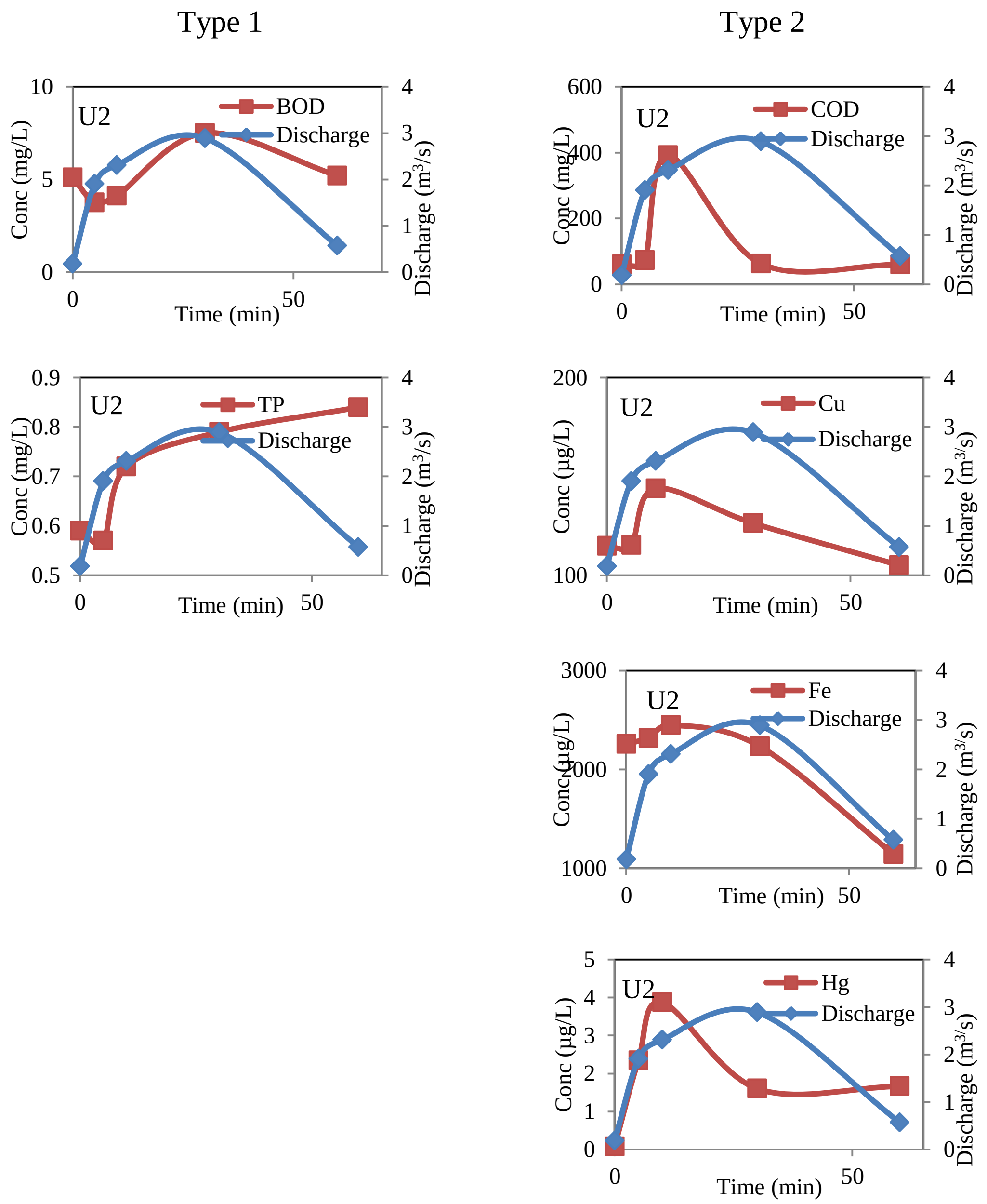


Figure C4 Pollutograph of Type 1 and 2 pollutants that exceeded Class III NWQS at U2

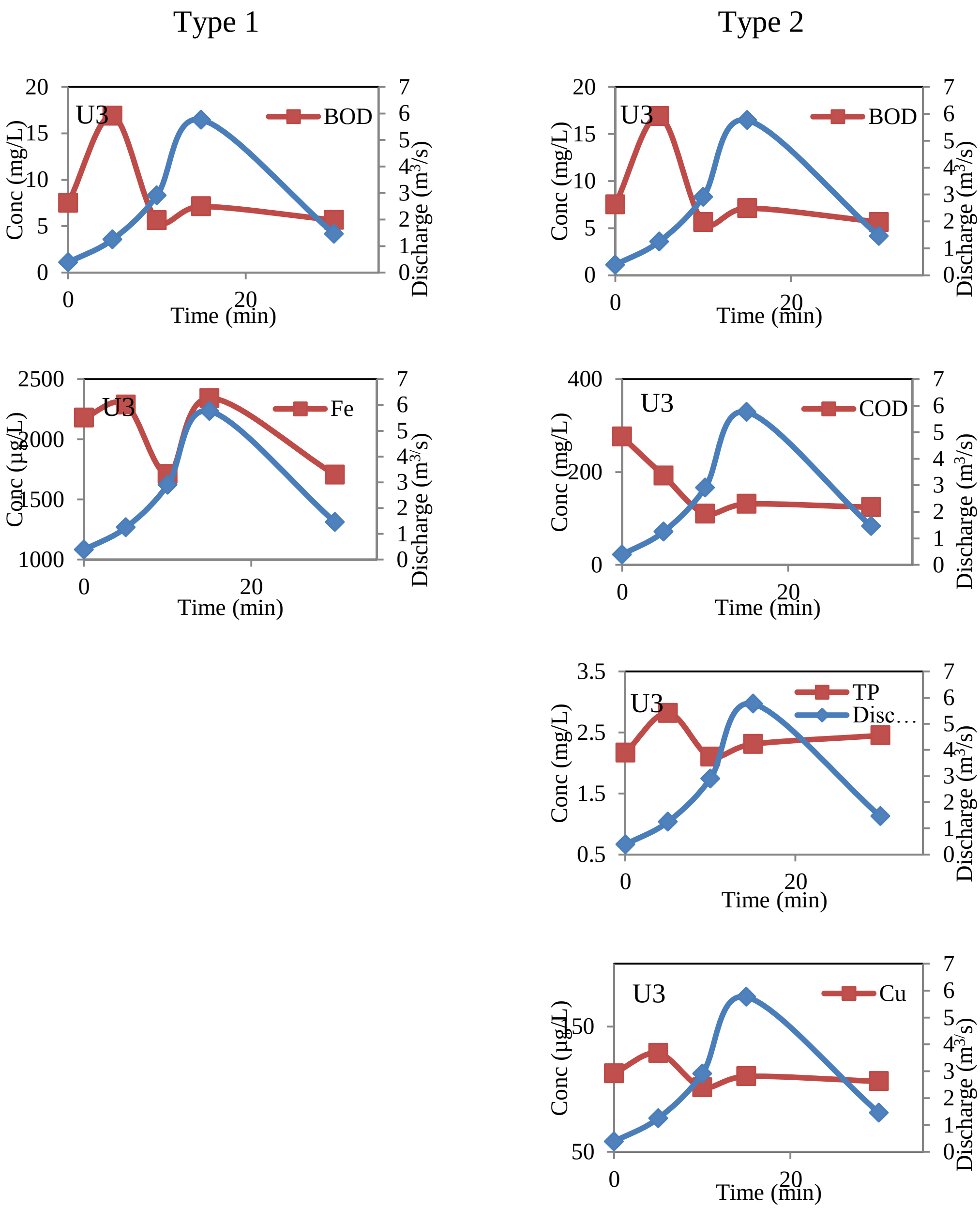


Figure C5 Pollutograph of Type 1 and 2 pollutants that exceeded Class III NWQS at U3

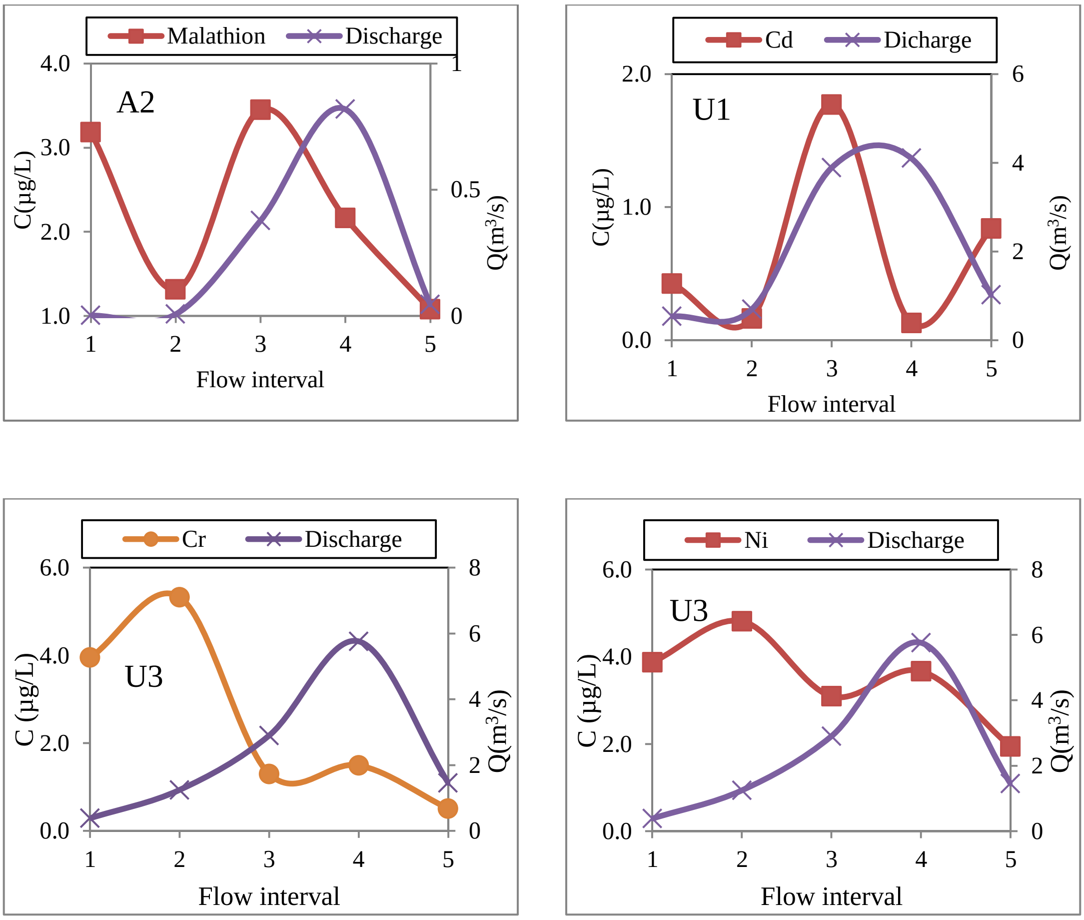


Figure C6 The multiple peak of pollutograph