CHEMICAL COMPOSITION OF DRAINAGE WATER AROUND KOTA KINABALU CITY CENTRE AREA; AMMONIA, NITRATE AND NITRITE

ELYRICE ALIM @ ALBERT

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT FOR THE BACHELOR OF SCIENCE WITH HONOURS

ENVIRONMENTAL SCIENCE PROGRAM
SCHOOL OF SCIENCE AND TECHNOLOGY
UNIVERSITI MALAYSIA SABAH

APRIL 2007

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS@

JUDUL: CHEMICAL COMPOSITION OF DRAINAGE WATER AROUND KOTA KINABALU CITY CENTRE AREA: AMMONIA, NITRITE AND NITRATE

Ijazah: SARJANA MUDA SAINS DENGAN KEPUJIAN

SESI PENGAJIAN: 2004-2007

Saya ELYRILE ALIM @ ALBERT

(HURUF BESAR)

mengaku membenarkan tesis (LPS/Sarjana/Doktor Falsafah)* ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:

1. Tesis adalah hakmilik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (/)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[/]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[ ]	TIDAK TERHAD	

Disahkan oleh

(TANDATANGAN PENULIS)

Alamat Tetap: KG GONDOHON BUNDU TUHAN, P/S 859, 89308, RANAU, SABAH

Tarikh: 20 APRIL 2007

(TANDATANGAN PUSTAKAWAN)

DR. MIROSLAV RADOJEVIC

Nama Penyelia

Tarikh: 20 APRIL 2007

CATATAN: * Potong yang tidak berkenaan.

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

@ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana secara penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, atau Laporan Projek Sarjana Muda (LPSM).

DECLARATION

I declare that this dissertation is my own product except for the statement where each has been cited.

20 April 2007

ELYRICE ALIM @ ALBERT

HS2004-3200

APPROVED BY

Signature

1. **SUPERVISOR**

   (DR MIROSLAV RADOJEVIC)

2. **EXAMINER 1**

   (DR KAWI BIDIN)

3. **EXAMINER 2**

   (MS KAMSIA BUDIN)

4. **DEAN**

   (SUPT/ KS .PROF. MADYA

   DR. SHARIFF A.K OMANG)

ACKNOWLEDGEMENT

First of all, I want to thank God for His gifts and love, and for never leaving me alone.

I'd like readers to know that I could never write enough to adequately thank all assistance I received during this project.

My gratitude goes to Dr. Miroslav Radojevic, my supervisor, for his guidance throughout the completion of this project, and my partner, Suzita Anan for going through the thicks and thins together.

My deep thanks goes to Mr. Syaufi, our lab assistant who put up with our needs and chaos patiently for months. I owe you a lot. I'm also very grateful to all lab assistants in SST whose territories I've stepped into for any kind of help.

For families and friends, and everybody who know they deserve it, thank you!

ABSTRACT

This study aimed to determine the composition of ammonia, nitrite and nitrate nitrogen in six locations around Kota Kinabalu city centre. This was achieved using the phenate method, hach kit and phenol disulphonic method. pH, dissolved oxygen and conductivity were determined in-situ. Samples were taken on two separate days for each location. Ammonia nitrogen was found to be in the range of 2.25-30.50 mgl^{-1}; nitrite 0.006-0.225 mgl^{-1} and nitrate 7.50- 121.46 mgl^{-1} respectively. Observations suggested that location with relatively higher variability and intensity of activities are likely to have higher content of ammonia nitrogen in its drainage water. The water retention capacity in the occupied drain might have contributed to high ammonia content as well. High nitrate concentration in certain locations could be due to the accumulation of this compound after nitrification; nitrate being the end-product of this process. Study on the effect of sampling distance sampled at four sub-locations along the Api-api large drain showed a gradual decline of the nitrogen compounds downstream, which might be due to dilution or chemical conversion of inorganic nitrogen into organic nitrogen. This study also found that there is a significant inverse relationship (p = - 0.943) between nitrate and pH.

KOMPOSISI KIMIA AIR LONGKANG DI KAWASAN SEKITAR PUSAT BANDARAYA KOTA KINABALU ; AMMONIA, NITRIT DAN NITRAT

ABSTRAK

Kajian ini bertujuan untuk menentukan komposisi ammonia,nitrit dan nitrat nitrogen dalam air longkang di enam lokasi di sekitar pusat bandaraya Kota Kinabalu. Ini dilaksanakan menggunakan kaedah fenat, hach kit dan fenol disulfonik. pH, oksigen terlarut dan konduktiviti ditentukan secara in-situ. Persampelan dilakukan dua kali bagi setiap lokasi. Kepekatan ammonia, nitrit dan nitrat adalah pada julat 2.25-30.50 mgl^{-1}; 0.006-0.225 mgl^{-1} dan 7.50-121.46 mgl^{-1} masing-masing. Daripada pemerhatian, didapati bahawa variasi dan intensiti aktiviti secara relatif di satu-satu tempat menyebabkan kandungan ammonia yang tinggi dalam air longkang di kawasan itu. Ini mungkin juga dipengaruhi oleh kapasiti retensi air yang tinggi. Kandungan nitrat yang didapati amat tinggi di suatu tempat boleh jadi disebabkan oleh akumulasi nitrat oleh proses nitrifikasi. Kesan jarak persampelan, seperti yang dikaji di empat substesen sepanjang longkang besar Api-api mendapati kandungan parameter-parameter utama ini berkurangan secara beransur ke hilir. Ini sama ada disebabkan oleh kesan pencairan ke hilir atau mungkin juga tindak balas fotokimia yang menukar nitrogen bukan organik kepada nitrogen organik. Kajian ini juga menunjukkan nitrat dan pH mempunyai hubungan negatif yang signifikan ($p = -0.943$).

CONTENT

	Page
DECLARATION	ii
VERIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
CONTENT LIST	vii
TABLE LIST	ix
FIGURE LIST	x
ABBREVIATION LIST	xi
EQUATION LIST	xii
APPENDIX LIST	xiii

CHAPTER 1 INTRODUCTION

1.1	PREFACE	1
1.2	SIGNIFICANCE OF STUDY	5
1.3	OBJECTIVES OF STUDY	6
1.4	STUDY SCOPE	7

CHAPTER 2 LITERATURE REVIEW

2.1	NITROGEN CONTENT	9
2.2	FACTORS AFFECTING NITROGEN CONTENTS IN WASTEWATER	13
2.3	AGRICULTURAL-RELATED STUDIES	16
2.4	LABORATORY ANALYSIS	17

CHAPTER 3 MATERIALS AND METHODS

3.1 SAMPLING 21

3.2 AMMONIA ANALYSIS 23

3.3 NITRITE ANALYSIS 24

3.4 NITRATE ANALYSIS 26

CHAPTER 4 RESULTS

4.1 AMMONIA, NITRITE AND NITRATE COMPOSITION; MAIN LOCATIONS 28

4.2 AMMONIA, NITRITE AND NITRATE COMPOSITION; ALONG A DRAIN 29

4.3 OTHER PARAMETER DETERMINED IN-SITU 30

CHAPTER 5 DISCUSSION

5.1 SPATIAL VARIATION AND NITROGEN CONTENT 31

5.2 EFFECT OF SAMPLING DISTANCES 34

5.3 INTER-PARAMETER RELATIONSHIP 36

5.4 WATER QUALITY CLASSIFICATION 38

5.5 COMPARISON: CASE STUDY AND LITERATURE REVIEW 39

5.6 OTHER POSSIBILITIES 40

CHAPTER 6 CONCLUSION

6.1 SPATIAL VARIATION EFFECT 42

6.2 DISTANCE EFFECT 42

6.3 INTER-PARAMETER RELATIONSHIP 43

6.4 SUGGESTIONS FOR FURTHER STUDIES 43

REFERENCES 44

APPENDIX 50

TABLE LIST

Table No.		Page
2.1	Content of nitrogen compound in past studies	12
2.2	Concentration of ammonium nitrogen in mgl^{-1} at various pH and temperatures	15
4.1	Result : NH_3_N, NO_3^- and NO_2^- in every locations	28
4.2	Result : NH_3_N, NO_3^- and NO_2^- along a drain	29
4.3	Result : Other parameter determined in-situ	30
5.1	Water Quality classification	38
5.2	Comparison of correlation	39

FIGURE LIST

Fig. No		Page
1.1	Nitrogen cycle in the aquatic environment	3
1.2	The area of study, Kota Kinabalu city centre	7
5.1	Concentration of ammonia nitrogen, nitrite and nitrate	33
5.2	Composition changes in ammonia nitrogen content along Api-api drain	34
5.3	Composition changes in nitrite content along Api-api drain	34
5.4	Composition changes in nitrate content along Api-api drain	35

ABBREVIATIONS LIST

AAS	Atomic Absorption Spectrofotometer
APHA	American Public Health Association
Cd	Cadmium
cm	Centimetre
Cu	Cuprum
Dept	Department
DBKK	Dewan Bandaraya Kota Kinabalu / Kota Kinabalu City Hall
EDTA	Ethylenediamine tetra-acetic acid
GIS	Geographic Information System
HCl	Hydrochloric acid
IC	Ion Chromatography
ISE	Ion Selective Electrode
JPS	Jabatan Pengairan dan Saliran / Department of Irrigation and Drainge
JKR	Jabatan Kerja Raya / Department of Public Works
Kg	Kampung
mg	Milligram
mgl^{-1}	Milligram per litre
ml	millilitre
nm	Nanometre
N	Nitrogen
NA	Not available
NaOH	Natrium hydroxide / sodium hydroxide
NH_3_N	Ammonia nitrogen
NH_4Cl	Ammonium chloride
NO_2^-	Nitrite
NO_3^-	Nitrate
SB	Sendirian Berhad
WS	Water sample

EQUATION LIST

Equation no		Page
1.1	Nitrogen cycle in a series	1
1.2	Ammonification	2
1.3	Nitrification (Ammnonia transformed into nitrite)	2
1.4	Nitrification (Nitrite transformed into nitrate)	2
1.5	Denirification by bacteria	2
2.1	Beer-Lambert's Law	17
3.1	First step of ammonia reaction into forming monochloroamine	23
3.2	Second step of monochloroamine forming indophenol	23
3.4	Nitrite diazotized with sulphanilamide, soon coupled with N-(1-naphtyl)-ethlenediamine to form an azo dye	25
3.5	Nitrate reacts with phenol disulphonic acid	27
5.1	Nitrate forming radicals via photochemical reaction	35
5.2	Nitrate forming radicals via photochemical reaction	35
5.3	Nitrite forming radicals via photochemical reaction	35

APPENDIX LIST

Appendix	Title	Page
A	Result tables from literature review	
	Local	50
	Dilution	53
	Correlation test	54
B	Calibration curve	
	Ammonia	56
	Nitrate	56
C	Raw data	
	Main parameter	57
	Other in-situ measurements	59
D	Statistical Tests	
	Summary: descriptive statistics	60
	Correlations	62
E	Proposed standard for water quality classification	64
F	Photos	
	Api-api	66
	Fresh Market	70
	Gaya Street	72
	City Park	73
	Kampung Air	75
	Asia City	77

CHAPTER 1

INTRODUCTION

1.1 Background of study

1.1.1 Nitrogen

Ammonia, nitrite and nitrate are nitrogen compounds. Nitrogen is essential to life because it is necessary for the manufacturing of proteins and DNA. Free nitrogen is approximately 80% of the earth's atmosphere. Nitrogen has a gaseous phase and is a major component of earth's atmosphere, however, it is not very reactive and its conversion depends heavily on biological activity (Botkin & Keller, 2003).

Ammonia, nitrite and nitrate nirogen are part of the aquatic nitrogen cycle series. This cycle is dominated by reactions involving biological material (O'Neil, 1993). The reaction, in series can be represented by:

$$N_2 \rightarrow NH_3 \rightarrow NO_2^- \rightarrow NO_3^- \rightarrow \text{amino acid} \rightarrow \text{proteins} \quad (1.1)$$

The process converting nitrate to nitrogen gas is called denitrification, carried out by microorganisms.

Ammonification process can be represented by reaction (1.2) below (O'Neil,1993):

$$(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2 \qquad (1.2)$$

The ammonia (NH_3) reacts with water to make ammonium ion (NH_4) which is then normally incorporated into plant tissue. Ammonium may also take part in another bacterially mediated process; nitrification as shown below (Mackenzie, 1995):

$$4NH_4^+ + 6O_2 \rightarrow 4NO_2^- + 8H^+ + 4H_2O \qquad (1.3)$$

(ammonium) (nitrite)

$$4NO_2^- + 2O_2 \rightarrow 4NO_3^- \qquad (1.4)$$

(nitrite) (nitrate)

Denitrification is carried out by bacteria, such as this one by bacterium *Pseudomonas* :

$$4NO_3^- + 2H_2O \rightarrow 2N_2 + 5O_2 + 4OH^- \qquad (1.5)$$

The nitrogen cycle in aquatic environment could be simplified, as in figure 1.1 below.

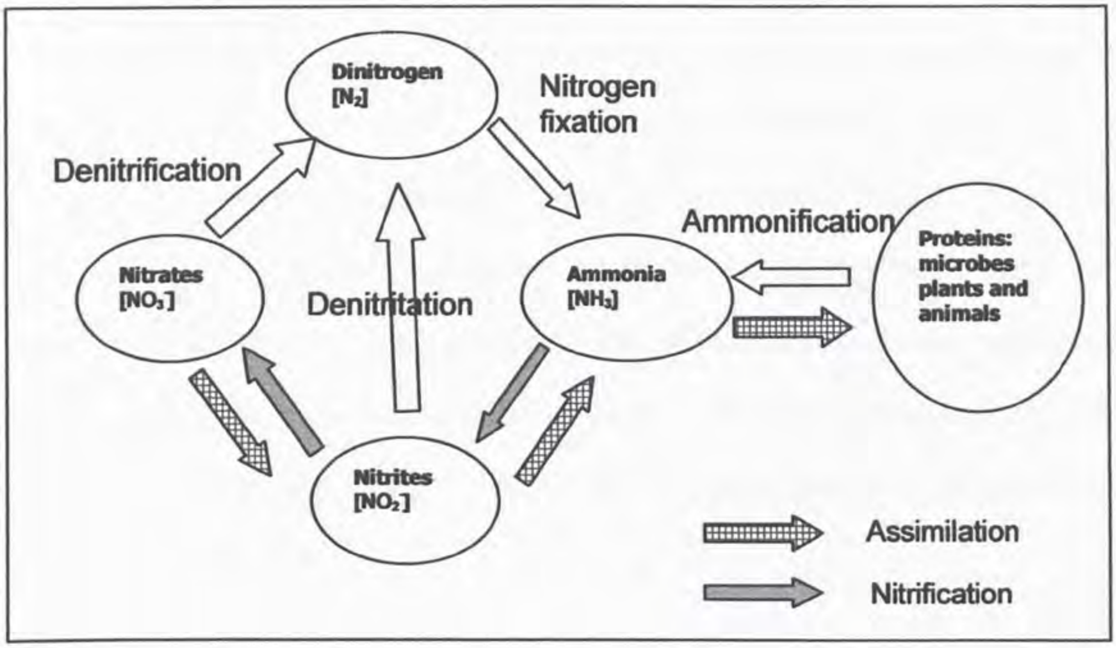

Figure 1.1 Simplified nitrogen cycle in aquatic environment (Source from Horan, 1990 and Jenicek *et al.*, 2004)

The natural biogeochemical cycle of nitrogen is being heavily impacted by anthropogenic activities. Nitrogen is stored in earth in the form of dispersed organic matter, coal, oil and gas. When fossil fuel is burned, nitrogen gases may be released to the environment. Agricultural activities use nitrogen as nutrient, which will not be immediately returned to the soil after decomposition of plants. This gave idea to the use of artificial or animal-originated nitrogen. Excess nitrogen is washed away into streams and river, causing pollution (Mackenzie, 1995).

1.1.2 Drainage

Drainage is a simple, basic infrastructure which serve to remove unwanted water from urban communities; stormwater, external floodwater, marshwater, sullage and toilet wastes. Thus, the need for drainage increase as water supplies improve (Hardoy *et al*, 1995). The local Department of Irrigation and Drainage or Jabatan Pengairan dan Saliran (JPS) stated that the main purpose of urban and rural drainage is to collect excess water, usually stormwater, from land surfaces and convey it to a river, a lake, a swamp, the sea or even a groundwater storage, with minimal nuisance, danger or damage (Jabatan Pengairan Saliran, 2006).

The published information on drain types mentioned only two categories; simply as the open and covered drains (Jabatan Pengairan Saliran, 2006), however, observations and personal inquiries about the drainage system in the study area reveals that there are several types of drains available and in overall could be classified, strictly for the purpose of this study as listed below:

A. Small perimeter drain which serve as water discharge receiver for every building or blocks of buildings and link to other similar type of drain within its surroundings.
B. A larger drain into which the contents of drain type (a) will flow. These, similarly, link with each other and where the contents next destination will be.

C. The largest observed drains, making their way to the sea.

D. Underground large drains, with concrete-tunnel structures built in series in an inland to shore flow, most probably serving only the city centre.

It is also important to be informed that the existing drainage system in the study area is ever changing with new physical developments, and could be built by several institutions, such as the Kota Kinabalu City Hall or Dewan Bandaraya Kota Kinabalu (DBKK), Department of Public Works or Jabatan Kerja Raya (JKR), the Ministry of Housing and Local Government and the Department of Irrigation and Drainage or Jabatan Pengairan danSaliran (JPS). For the same reason, no complete and updated guide to all the existing drains is available. Each of these institutions built their own drain for use related to their responsibilities; but in practical, all the drains are potential recipients of natural water, wastewater or even litters (personal inquiry, Fraser Duing, 2006).

1.2 Significance of study

It is very useful to conduct a study on this subject, concerning that these studied parameters, uncontrolled and ignored in a long term might pose unpleasant phenomena along the drainage facility and it its final destination; the sea. Excess NO_3^- would lead to eutrophication, while NH_3 and NO_2^-; although always not found to be in high concentration in surface water are poisonous to fish and other animals (Reeve, 1994).

1.3 Objectives of study

1. To determine the spatial distribution of ammonia, nitrite and nitrate content of drainage water around Kota Kinabalu city centre area.
2. To determine effects of distance of sampling point to drainage exit on the concentration of ammonia, nitrite and nitrate at one pre-determined site with four chosen serial points along one major drain.
3. To determine, if any, an overall relationships between ammonia, nitrite and nitrate, and in addition, to see how the results change with associated common parameters; pH, conductivity, and dissolved oxygen.

1.4 Study scope

1.4.1 Area of Study

Area studied is limited to several blocks around Kota Kinabalu city centre, as shown in the map below.

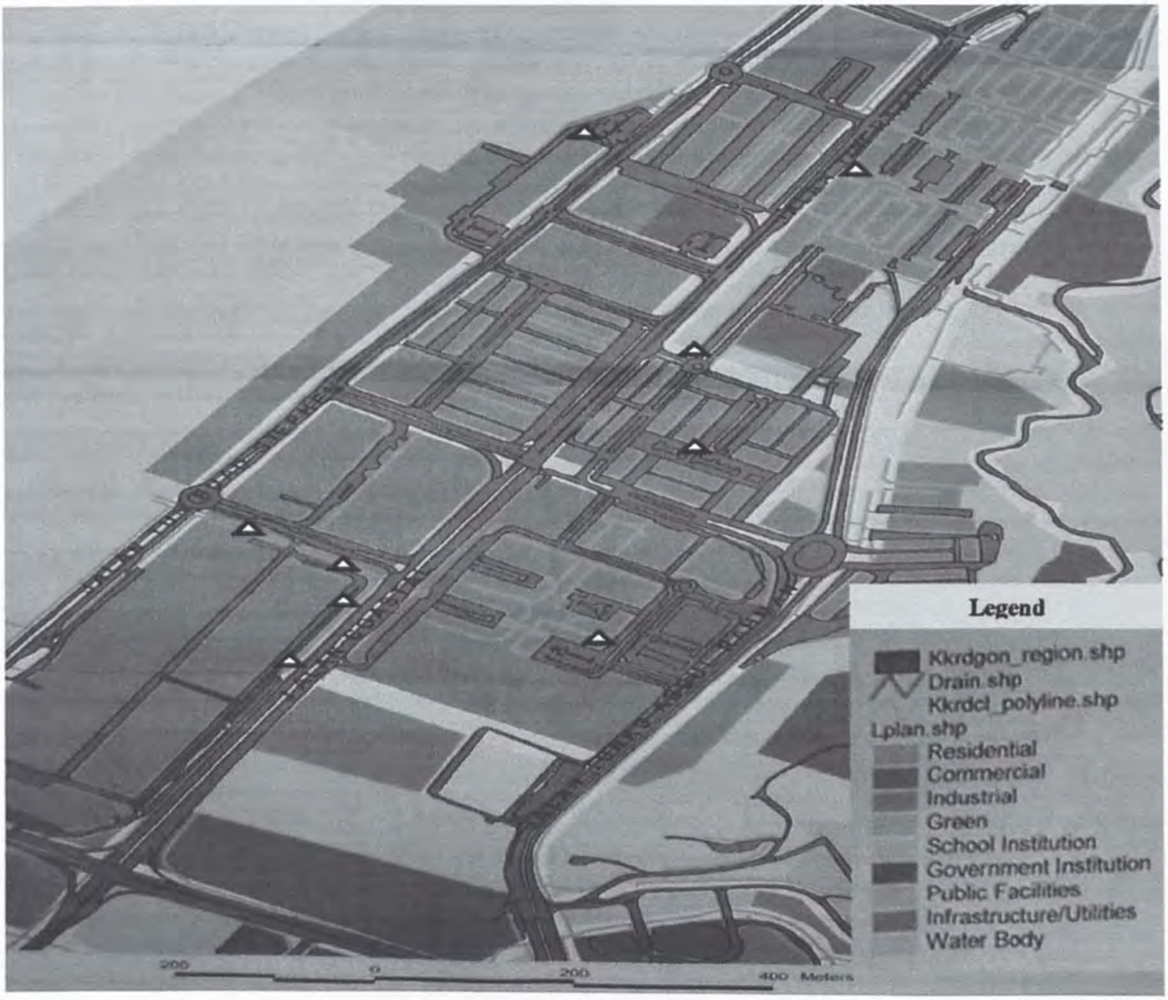

Figure 1.2 The area of study, Kota Kinabalu city centre. The triangles represent the sampling sites.(Source from Dewan Bandaraya Kota Kinabalu, 2006)

1.4.2 Sampling

Sampling is limited to accessible drains, which were of the open-drain category. Specifically, the perimeter drains (type A) close to the larger drains (type B) are chosen as sampling sites as it is the primary recipients of the surrounding water discharge with sufficient volume of water for sampling.

CHAPTER 2

LITERATURE REVIEW

2.1 Nitrogen Content

2.1.1 Nitrogen content in several types of water

Nitrogen content varies in different types of surface water. The concentration in natural water for nitrate is in the range of 0 to 25 mgl^{-1}, 0.0 to 1.0 mgl^{-1} for nitrite and 0 to 2.0 mgl^{-1} for ammonia (Reeve, 1994). Nitrate generally occurs in trace quantities in surface water but may attain high levels in some groundwater.

A common feature of drainage water is high nitrogen content in the form of ammonium or nitrate (Hao & Martinez, 1998). In the effluent of nitrifying biological treatment plants, nitrate may be found in concentration of up to 30 mg as nitrogen per litre. Ammonia is present naturally in surface and wastewater. Its concentration is generally low in groundwater due to soil particle and clay adsorption. Ammonia concentrations in water vary from less than 10 μgl^{-1} in natural and groundwater to more than 30 mgl^{-1} in some wastewater (APHA, 1998).

In domestic sewage in Malaysia, the total nitrogen (as N) was reported generally to be at the concentration of 40 mgl^{-1}, organic nitrogen; 15 mgl^{-1}, and free ammonia; 25 mgl^{-1}, however, amount of nitrite and nitrate were both undetectable (Ministry of Housing and Local Government, 1999).

In a study on urban stormwater which include samples taken from the urban drainage in Arizona, the maximum total N concentration is found out to be 31.6 mgl^{-1} and a minimum of less than 1.5 mgl^{-1}. As for organic N, the same study revealed a minimum of 5 mgl^{-1} and maximum of 18.8 mgl^{-1} (Fossum, *et al.*,2001). A literature study on the sources and pathways of water, nitrogen and phosphorus claimed that 60% of nitrogen are concentrated in 1% of the surface water in the urban. It concluded that drainage system is a diluting system, thus, water separation is crucial to improve the surface water quality (Hermann & Klaus, 1997). Another study agreed on the need to efficiently separate sewage and stormwater flow in the urban area (Asaf *et al.*, 2004). They also found that stormwater concentration were higher at stations draining a larger area. This study, (Asaf, *et al.*, 2004) which was performed in a semiarid zone, suggests that concentrations of the urban storm water's chemical and isotopic composition link to the length of the stormwater flow path.

2.1.2 Nitrogen content around and similar to the local environment

Studies around the study area were mostly carried out for Environmental Impact Assessment purposes, and thus were carried out by commercial consultants and groups.

REFERENCES

American Public Health Association (APHA). 1998. *Standard Methods for the Examination of Water and Wastewater.* 20th ed . APHA, DC.

Asaf, L., Nativ, R., Shain, D., Hassan, M & Geger, S. 2004. Controls on the chemical and isotopic compositions of urban stormwater in a semiarid zone. *Journal of Hydrology*. **294** (4), pg. 270-293.
http://www.sciencedirect.com/science?_ob=ArticleURL&_aset

Bielek, P. 1998. Nitrate in nature's product of soil cover. *Nitrogen, The Confer-N-S First International Nitrogen Conference 1998.* 23-27 Mar 1998. Noordwijkerhout, The Netherlands. pg. 527-530.

Bleeker, A. & Erisman, J.W. 1998. Spatial planning as a tool for decreasing nitrogen loads in nature areas. *Nitrogen, The Confer-N-S First International Nitrogen Conference 1998*. 23-27 Mar 1998. Noordwijkerhout, the Netherlands. pg. 649-654.

Botkin, D. B. & Keller, E.A. 2003. *Environmental Science: Earth as a Living Planet.* 4th ed. John Wiley & Sons Inc, U.S.

Caicedo, J. R., Espinosa, C., Andrade, M. & Gijzen, H. 2002. Effect of Pre-treatment on Environmental and physiochemical characteristics of duckweed based stabilisation ponds. *Water Science and Technology.* **45** (1), pg. 83-89.

Chahatwa. G.R. (edtr). 1996. *Encyclopaedia of environmental water pollution*. Anmol Publications PVT Ltd, New Delhi.

Chemsain Konsultant SB.1997. *Preliminary Environmental Assessment Impact for the proposed residential cum commercial development in Suang Parai, Likas, Kota Kinabalu, Sabah.*Unpublished.

Chemsain Konsultant SB.2005. *Environmental Impact Assessment for the proposed earth extraction for the commercial development on G.N.247/16 at Jln Sharif Osman, Kota Kinabalu, Sabah.* Unpublished.

Dewan Bandaraya Kota Kinabalu (DBKK). 2006. *The Drainage Map of Kota Kinabalu City Centre*. Scale 1:8511. GIS and Mapping Unit, Department of Property Management and Investment, Kota Kinabalu.

Environmental Protection Department, 2004. *The Proposed Water Quality Standards for Malaysia.*http://www.sabah.gov.my/jpas/Assessment/eia/sp-eias/Berita/eia/AnnexB/AnnexB_1.pdf

EPR Kuching SB. 2006. *(rejected) Environmental Impact Assessment for the redevelopment of Kota Kinabalu International Airport, Kota Kinabalu Sabah.* Unpublished

Fraser Duing. 2006. *Personal inquiry.*

Fossum, K. D., O'Day, C. M., Wilson, B.J. & Monical, J.E. 2001. Statistical Summary of Selected Physical, Chemical, and Toxicity Characteristics and estimates of Annual Constituent loads in Urban Stormwater, Manicopa County, Arizona. *Water-Resources Investigations Report 01-4088*. United States Geological Survey (USGS), Tuscon, Arizona.

Gupta, P.K. 2004. *Methods in Environmental Analysis: Water, Soil and Air*. Agrobios,India.

Hao, X. & Martinez, J.1998. Removing nitrate and ammonium from drainage water by simulation of natural biological process. *Water Research*. **32** (3), pg. 936-943.

Hardoy, J.E., Mitlin, D. & Satterthwaite D.1995. *Environmental Problems in Third World Cities*. Earthscan Publication Ltd, London.

Hermann, T., & Klaus, U. 1997. Fluxes of nutrients in urban drainage systems: Assessment of sources, pathways and treatment techniques. *Water Science & Technology*. **36** (8-9), pg 167-172.

Hidaka, T., Vamada, H., Kawamura, M. & Tsuno, H. 2002. Effect of dissolved oxygen conditions on nitrogen removal in continuously fed intermittent - aeration process with two tanks. *Water Science and Technology*. **45** (12), pg.181-188.

Horan, N. J.1990. *Biological Wastewater Treatment Systems: Theory and Operation*. John Wiley & Sons, Chichester.

Huang, C. P., Wang, H.W. & Chiu, P.C. 1998. Nitrate reduction by metallic iron. *Water Research*. **32** (8), pg. 2257-2264.

Jabatan Pengairan dan Saliran (JPS) Sabah. 2006. *Current Issues: Urban and Rural Drainage*. http://www.did.sabah.gov.my/eng/urbandrainage.asp.

Jenicek, P., Svehla, P., Zabranska, J. & Dohanyos, M. 2004. Factors affecting nitrogen removal by nitritation / denitration. *Water Science and Technology*. **49** (5-6), pg. 73-79.

Kashulina, G., Reimann, C., Finne, T.E., Caritat, P. & Niskavaraara, H. 1998. Factors influencing NO_3 concentrations in rain, stream water, ground water and podzol profiles of eight small catchment in the European Arctic. *Nitrogen, The Confer- N- S First International Nitrogen Conference 1998.* 23-27 Mar 1998. Noordwijkerhout, The Netherlands. pg. 559-568.

Larson, R.A. & Weber, E.J. 1994. *Reaction Mechanisms in Environmental Organic Chemistry*. Lewis Publisher, Boca Raton.

MacCarthy, P., Klusman, R.W., Cowling, S.W & Rice, A.J. 1993. Water Analysis. *Analytical Chemistry*. 65 (12), pg. 244R-293R.

Mackenzie, F. T. 1995. *Our Changing Planet; An Introduction to Earth System Science and Global Environmental Change.* 3rd ed. Pearson Publication, New Jersey.

McBride,R.M.,Yin,K.L.S. & Chien, D.S.1996. *Preliminary Environmental Impact Assessment for the proposed housing development at Kuala Menggatal, Sabah.* Unpublished.

Ministry of Housing and Local Government. Aug 1999. *Guidelines for Developers ; Sewerage Policy for New Developers.* 2nd ed. Sewerage services Department, Malaysia Water Association. Kuala Lumpur. 1 , pg. 138-139.

Nielsen, M., Revsbech, N. P., Larsen, L. H. & Jensen, A. L. 2002. On-line determination of nitrite in wastewater treatment by use of a biosensor. *Water Science and Technology*. **45** (4-5), pg. 69-76.

Onay, T. T & Pohland, E.G. 1998. In situ nitrogen management in controlled bioreactor landfills. *Water Research*. **32** (50.5), pg 1383-1392.

O'Neill, P. 1993. *Environmental Chemistry.* 2nd ed. Chapman and Hall, London .

Patnaik, P. 1997. *Handbook of Environmental Analysis: Chemical Pollutants in Air,Water, Soil, and Solid Wastes*. Lewis Publishers, Boca Raton.

Rainbow Bay SB.1999. *Final report for The Proposed 352 acres Likas Bay Reclamation Project detailed Environmental Impact Assessment*. Unpublished.

Reeve, R. N. 1994. *Environmental Analysis; Analytical Chemistry by Open Learning*. John Wiley & Sons, Chichester.

Sawyer, C.N. & McCarty, P. L. 1978. *Chemistry for Environmental Engineering*.3rd ed. McGraw-Hill International, Tokyo.

Scheiner, D. 1976. Determination of ammonia and Kjeldahl nitrogen by indophenol method. *Water Research*. **10**, pg. 31-36.

Sinoh Environmental SB. 1998. *Environmental Impact Assessment for the proposed Low Density Housing Development Project on lot C.L.075368419 Trivy Hill, Jalan Utara Sandakan Sabah*. Unpublished.

Silveria, A.L. 2002. Problems of modern urban drainage in developing countries. *Water Science and Technology*. **45** (7), pg 31-40.

Sorensen, B.H. & Jorgensen, S.E. 1993. *The Removal of Nitrogen Compounds From Wastewater*. Elsevier Science Publishers, Amsterdam.

Tokutomi, T. 2004. Operation of a nitrite-type airlift reactor at low dissolved oxygen. *Water Science and Technology*. **49** (505-506), pg 81-88.

UP Environmental Service SB.1996. *Final Report of Preliminary Environmental Impact Assessment for the proposed Kapasi Commercial Centre, Kota Kinabalu*. Unpublished

WGBIS, 2006. *Technical report: 115/June 2006.*
http://wgbis.ces.iisc.cmet.in/energy/water/paper/Tr-115/chapter5.htm.

Wike, E.L. 1985. *Numbers: A Primer of Data Analysis*. Bell & Howell Company,Columbus.

Yun, Z., Jung Y.H., Lim, B.R., Choi, E. & Min, K.S. 2004. The stability of nitrite nitrification with strong nitrogenous wastewater: Effects of organic concentration and microbial diversity. *Water Science and Technology*. **49** (5-6), pg. 89-96.