AN ESTIMATION OF THE DETERIORATING WATER QUALITY OF RAWAL LAKE, ISLAMABAD

T06504

Akhtar Hussain

Reg. No. 09-FBAS/MSES/F07

Submitted in partial fulfillment of the requirements for the
Master of philosophy in Environmental Science
at faculty of basic and applied sciences
International Islamic University,
Islamabad

Supervisor 15th January, 2010

Dr. Naeem Ali

13-7-2010

m.d.

Water resources development
Sustainable development
Water resources development - Economic aspects
Fresh water
Water quality
Natural resources water

IN THE NAME OF ALLAH, THE MOST MERCIFUL AND BENEFICIENT

Dedicated To my loving
Parents, respected teachers
& my dear fiancé

Title of Thesis: An Estimation of the Deteriorating Water Quality of Rawal Lake, Islamabad

Name of Student: Akhtar Hussain Lashari

Registration No. 09-FBAS/ MSES/F07

Accepted by the Faculty /Department of FBAS/Environmental Science INTERNATIONAL ISLAMIC UNIVERSITY ISLAMABAD, in partial fulfillment of the requirements for the MS Degree in Environmental Science.

Viva Voice Committee

Dean

Chairman/Director/Head

External Examiner

Supervisor

Member

ABSTRACT

Globally, a rapid increase in population over the past century exerted an enormous pressure on fresh water resources. Pakistan, being a developing country, is also facing freshwater crisis. Rawal Lake, an important freshwater reservoir in the vicinity of capital city of Pakistan has been facing signs of deterioration over the past few years. So, a short study was planned to analyze the water quality (12 physico-chemical parameters) of Lake and associated nullahs (freshwater streams) that use to feed it.

Five sampling sites were selected to check the quality of water and in them three {Pushta (S_3), Spillway (S_4) and Center (S_5)} were located at Lake and the remaining two were at source nullahs (S_1 = Mallpur and S_2 = Bari Imam). Water quality of Lake and the source nullahs was monitored during three times (9:00 am, 2:00 pm and 7:00 pm) of the day.

Results exhibited that, except bacterial count (ave.) (2171.66 CFU/ml), (Coliform (>1600 MPN/ ml) and TSS (5.83 mg/l), most of the water quality parameters of the Lake were falling within permissible limits set by WHO and PSQCA. Similar patterns of results were noted in the water samples of main source nullahs. However, the two nullahs showed quite higher levels of contaminants than Lake. Comparatively, Bari Imam nullah showed a higher degree of contamination than Mallpur nullah. A continuous increase in contaminants was noted in water of; nullahs and lake, during the day. In addition, water quality varied considerably at three sampling sites (Pushta, Spillway and Centre) of the lake during the day. A significant high level (ave.) of TSS (S_1 =46.66 mg/l; S_2 =16 mg/l), EC (S_1 = 502 µS/cm; S_2 =643.3 µS/cm) and bacterial count (S_1 = 1867.6 CFU/ml; S_2 =2123 CFU/ml) in nullahs clearly indicated that have been contaminated from adjacent areas. Furthermore, these nullahs have been pouring their contaminants in Lake. High levels of contaminants may deteriorate freshwater ecology of the source nullah and the Lake. Moreover, human consumption of water from such sources may cause some serious health problems.

Acknowledgments

I am grateful to my Allah, whose blessings enabled me to achieve my goals. Tremendous praise for His Holy Prophet Hazrat Muhammad, who is forever a torch of guidance for knowledge seekers and whole humanity.

I have great reverence & admiration for my research supervisor Dr. Naeem Ali. I am highly indebted for his patience, moral support, sincere criticism and able guidance throughout the study.

I am grateful to Prof. Dr. Mohammad Irfan Khan, chairperson, Department of Environmental Sciences, International Islamic University (I.I.U), Islamabad, who took me as his student in MS and helped me in fulfilling my research desires by providing his thoughtful expertise and research facilities.

A great depth of loving thanks to PCRWR Peshawar Lab workers Mr. Zia-u-Rahman, Mr. Abdullah and Mr. Asgar Ali Khan, and Rawal Lake administrative committee including Mr. Atta-ur-Rahman and Mr. Ashfaq Ahmed for their help, care and enjoyable company throughout my research work. Moreover, I will never forget the enjoyable company of class fellows like Mr. Shafiullah Laghari, Mr. Waqar Ahmed Soomro, Mr. Jawad Ali, Mr. Khalid Hussain Rind, Mr. Feroz Khan and Mr. Mubarak Ali Lashari at I.I.U., Islamabad.

A non-payable debt to my loving parents, their wish motivated me in striving for higher education; they prayed for me, shared the burdens and made sure that I sailed through smoothly.

Sweet thanks to my fiancé Miss. Rozeena for her prayers and patience in bearing me during crunch times of my study.

May God bless you all.

Akhtar Hussain Lashari

Table of Contents

No.	Title	Page No.
1	Abstract	iv
2	Acknowledgment	v
3	List of Table	vi
4	List of Figures	vii
5	List of Abbreviations	viii
	CHAPTER 1	
1.1	**INTRODUCTION**	1
1.2	Pollution	3
1.3	Water resource conditions and their availability in Pakistan	4
1.4	Water Pollution in Pakistan	8
1.5	Rawal Lake and its importance	11
1.6	Aims and objective	14
	CHAPTER 2	
	METERIAL AND METHODS	
2.1	Study Area	15
2.2	Sampling site	15
2.3	Methods used for physico-chemical Parameter	16
2.3.1	pH	16
2.3.2	Electric Conductivity (E.C)	17
2.3.3	Total dissolved solids (TDS)	18
2.3.4	Total Suspended Solids (TSS)	19
2.3.5	Alkalinity	20
2.3.6	Chloride (Cl)	21
2.3.7	Total Hardness	22
2.3.8	Calcium (Ca)	23
2.3.9	Magnesium (Mg)	25
2.3.10	Sulphate (SO4)	26
2.3.11	Isolation of Bacteria from the sample water	27
2.3.12	Isolation of Coliform Bacteria from the sample water	29
2.5.13	Sodium (Na) & Potassium (K)	30
	CHAPTER 3	
	RESULTS	
3.1	Results	32
	CHAPTER 4	
4.1	**DISCUSSION**	44
	CONCLUSION AND SUGGESTION	51
	REFERRENCES	53
	APPENDIX	61

List of Tables

No.	Title	Page No
3.1	Characterization of water samples of source nullahs and different sites of Lake in morning (9:00 am).	61
3.2	Characterization of water samples of source nullahs and different sites of Lake in Noon (2:00 pm)	62
3.3	Characterization of water samples of source nullahs and different sites of Lake in Evening (7:00 pm)	63

List of Figures

No.	Title	Page No
3.1.1	Total bacterial count of water samples at main source nullahs and different sites of lake	37
3.1.2	Total Coliform count of water samples at main source nullahs and different sites of lake.	37
3.1.3	Total Suspended Solids of water samples at main source nullahs and different sites of lake	38
3.1.4	pH of water samples at main source nullahs and different sites of lake	38
3.1.5	Electric Conductivity of water samples at main source nullahs and different sites of lake.	39
3.1.6	Total Dissolved Solids of water samples at main sources nullah and different sites of lake	39
3.1.7	Total Hardness of water samples at main source nullahs and different sites of lake	40
3.1.8	Calcium Concentration of water samples at main source nullahs and different sites of lake	40
3.1.9	Magnesium Concentration of water samples at main source nullahs and different sites of lake.	41
3.1.10	Total Alkalinity of water samples at main source nullahs and different sites of lake	41
3.1.11	Chloride Concentration of water samples at main source nullahs and different sites of lake	42
3.1.12	Sulphate Concentration of water samples at main source nullahs and different sites of lake	42
3.1.13	Sodium Concentration of water samples at main source nullahs and different sites of lake	43
3.1.14	Potassium Concentration of water samples at main sources nullahs and different sites of lake	43

List of Abbreviations used in the Dissertation

$Ag\ N_{O3}$	Silver Nitrate
ave.	Average
^{0}C	Centigrade
Ca	Calcium
$CaCO_3$	Calcium Carbonate
Cm	Centimeter
CFU/ml	Colony forming Unit per milli liter
Cl	Chloride
Conc.	Concentration
E.C	Electric Conductivity
E.Coli	Escherichia coli
EDTA	Ethylene Diamine Tetraacetate Dehydrate
Fig.	Figure
Govt.	Government
HCL	Hydro Chloric acid
HKH	Himalayas, Karakoram and Hindu kush

H_2SO_4	Sulphuric acid
K	Potassium
L/l	liter
M	Molar
Max	Maximum
m^3	Meters per cube
MDGs	Millennium Development Goals
Mg	Magnesium
Mg	Milligram
Min.	Minimum
Ml	Milli liter
Max.	Maximum
Mol/l	Mole per liter
MPN	Most Probable Number
Na	Sodium
Nacl	Sodium Chloride
NaoH	Sodium Hydro oxide
NGV	No guideline value

NWFP	North West Frontier Province
pH	Power of hydrogen
PO_4	Phosphate
Ppm	Part per million
PSQCA	Pakistan Standard Quality Control Authority
S_1	Site One = Mallpur Nallah
S_2	Site Two = Bari Imam
S_3	Site Three = Main Pushta
S_4	Site Four = Spillway
S_5	Site Five = Center
SO_4	Sulfate
TDS	Total Dissolved Solid
TSS	Total Suspended Solids
µS/cm	Micro Siemens per centimeter
W	Weight
WHO	World Health Organization
%	Percentage

FORWARDING SHEET

The thesis entitled "An Estimation of the Deteriorating Water Quality of Rawal Lake Islamabad" submitted by Akhtar Hussain Lashari in partial fulfillment of MS Degree in Environmental Science has been completed under guidance and supervision. I am satisfied with quality of student's research work and allow him to submit this thesis for further process of as per IIU rules & regulations.

Date:

Signature: __________

Name: Dr. Naeem Ali

INTRODUCTION

CHAPTER 1

1.1 Introduction:

Rapid increase in population over the past century has increased pressure on existing water resources both in quantitative and qualitative terms. The quality of available water through out worldwide is not able to meet the needs of much larger population for much longer as demand continues to increase. The immune system of small children is very sensible for any disease. The studies conducted by World Health Organization (WHO) that shows that every child out of the eight children suffer in the water related diseases and most of the affected children are the age of five years. In fact, more people die by the untreated water per year then all kinds of violence and war. In the Pakistan water resources are under tremendous pressure with respect to quantity and quality which supplies to the public, as 40% of hospital beds are occupied with the patients of water related diseases. The Millennium Development Goals (MDGs) have some sets for to control the intensity of poverty, the ill of inequality, curse of hunger and illness. The countries which are the members Millennium Development Goals that promised to reduce by half according to such goals, the proportion of peoples who are not sullied to safe drinking water and basic sanitation.

Water is a major constituent for the survival of living matter. Our healthy body is filled up by water at the ratio of two third and if water scarcity occurred living matter would be die in few days. Healthy men have to take eight glasses of water per day. Proper intake of water may secure us by the risk of bladder cancer by 40%, colon cancer by 45% and it can reduce the risk of breast cancer in females. Earth is covered by 70% of water, and 95.5% of that constitutes present in Salt Ocean. The remaining 2.5% is fresh water, out of it 1% of fresh water is useable or potable. Fresh water fulfills our drinking water need if it used in a proper way and in management. Population is may be dispersed evenly but water is not so, hence it may fulfill the requirements of our water needs. Asia continent occupies the 60% of the world population but it has only 36% of water as compare to water resources. If the low water intake occurred a man can reached till death by the dehydration. However, most of the human population enforces to meet with very basic human need of water, although these supplies may cause risks to their health because of its quality, with regards to basic hygiene [1].

Since ancient times, the commodity of water is considered to be the most suitable medium for to clean, disperse, transport, and dispose of wastes because of solvent in nature. Water requirements have emerged for drinking and hygiene, agriculture supply including (livestock and irrigation), fisheries department, transport through voyage, cooling in fossil fuel power plants, all industrial production, generation of hydropower and some recreational activities such as fishing and bathing. Bathing in the contaminated water cause pathogens which directly enter into the eyes, in some cases nose, ears and as well in wounds and cause health risks [2]. When we talk about the water distribution at global scale, over 50 billion cubic feet of water is distributed in the earth's atmosphere, oceans, ice masses, all kinds of lakes, rivers, streams, soil and water (vapors, frozen water, marine, lentic, lotic and fresh water) [3]. While our national water have total area of 7,800,000 hectors, including 3,100,000 hectors occupies rivers and major tributaries, 56,000 hectors for canals, 110,000 hectors having natural lakes, 92,000 hectors of water reservoirs, 108,000 hectors of ponds and fish farms, 300,000 hectors of delta marshes (Indus), and over 4,000,000 hectors contributes waterlogged areas [4]. Although 70% of the global surface is covered by water, less then 3% is fresh water. While the 70% of fresh water present in the form of ice at the poles, reminder 98% lies underground. It is estimated that the 5% of worldwide consumption of water is for all domestic use, 75% is for irrigation and 20% for industrial use. Due to increase in population, global and climate change, drought cycles, water becomes now a scarce resource with time and space. Almost 2 billion peoples in 80 countries around the world can not avail the full use of water which is a basic need of the life [5].

1.2 Pollution

Literally, pollution means "destruction of purity" or "to render unclean". When "Any un healthy change in physico-chemical, and biological characters of air, water, and soil which harms to human health, plants, animals, living conditions and cultural assets" is called Environmental Pollution [6]. Any substance which causes the Pollution is called a Pollutant. A Pollutant defined as "Any type of solid, liquid or gaseous substance which is present in such a concentration that may be injurious to the environment" is called as Pollutant [7]. Pollution has number of unwanted effects related to plants, animals, property, and disruption of natural life-support system, nuisance and aesthetics. Extremely polluted air and water can cause illness and other impacts both in terrestrial and marine life. Soil pollution can affect the normal growth of plants, crops and can contaminate surface and ground water and thus reduces the amount of land for cultivation and habitation. Environmental pollution may be largely attributed to the abuse of natural recourses for industrial development. The incorporation of poisonous industrial pollutants (gases, liquid and solids), municipal waste and undesirable noise, heat from there and other sources degrade the global atmosphere, hydrosphere and lithosphere. Heavy and many trace metal are one of the environmental toxins released by metal-based industries and metal using projects and the vehicular traffic. These metals cause several carcinogenic impacts and other impairment both in animals and plants [8].

Fresh water is that kind of commodity which is degradation by many environmental issues. Preserving the quality and availability for fresh water commodity resources is one of the critical environmental and social challenges for Pakistan. Being a cheap readily available resource, there is not enough appreciation just how much stress human demands for water are placing on natural ecosystem. Stress on water resource is only because of multiple sources that may leaves some types of diverse forms. Urbanization, increasing industrial activities and dependence of the agriculture sector on chemical and fertilizers has led to the overcharging of the caring capacity of our water bodies to assimilate and decompose wastes. Therefore deterioration in water quality results the pollution of lakes, rivers and ground water aquifers [9].

1.3 Water resource conditions and their availability in Pakistan

The Pakistan surface water resources are dependent upon the Indus River and the five major tributaries, the Jhelum, Chenab, Ravi, Beas and Sutlej, which lies on its eastern side. In the Treaty of Indus Basin between India and Pakistan in 1960, the availability of water to Pakistan becomes limited by only western rivers like Indus, Jhelum and Chenab, which provide about 173 billion m^3 water per year. While only Indus

River alone provides 65% of the total river flow, with the share of the Jhelum 16% and Chenab 19%. In Pakistan the continual flow of rivers increases in the month of spring and in early in the summer, with the starting of monsoon rains and then snow melts on the mountains which also discharge water in July and August. The river flows are at their minimum during the months of November to February, when the mean monthly flows are only about one tenth of those in the months of summer. Beside the side of three major rivers, there are numerous small rivers and some streams flow seasonally, and rainfall has no water contribution during the winter months. Almost all groundwater resources are exist along with 1,600 km-long Indus Plain, which extends from the Himalayan foothills to the Arabian Sea which covers an areas of 21 million hectors.

The water stored in extensive and deep alluvial deposits under unconfined conditions. These aquifers are used for the irrigation purposes, on other hand for reservoir purposes. The aquifer are been built because of water storage which comes from the natural precipitation, the water comes from rivers and little bit seepage from the old unconstructed dikes of canals, watercourses and application losses in the irrigated lands during the past 90 years. The ground water resources beside the Indus plain areas are also present in the mountain valllies of Baluchistan and North West Frontier Province (NWFP). On the national level the actual potential is 81.6 billion m^3 [10].

The Islamic Republic of Pakistan, is being a second largest South Asian country, has a total land mass of 79.61 million hectares (ha), of which 70 million ha is arid and semi-arid (including 11 million ha of deserts). In Pakistan country their is great variety of plain areas that are ranging from the high mountain ranges like Karakoram, Himalayas, and Hindu Kush (HKH region) with intermingled valleys along with these ranges, while irrigated lands are also present to the rugged rocky plateaus of Pothwar, Punjab and South West Baluchistan. There are four distinct climatic seasons are present in our country, April, May and June are considered to be extremely dry and hot months while hot, humid and rainfall months are August, July and September. October to November is cool and dry and December to February is not hot and dry months but coldest months of the year.

Being an agricultural country the agriculture economy bloomed at different diversities of the climate, and variety of different crops. Pakistan has many sources of water by different ways including precipitation (mostly in dry areas), surface water (mostly in plain areas) and groundwater. Most of the ratio of annual rain fall is 70% occurred during the months of July to September (the monsoon period). The ratio of annual rainfall is low and quite irregular, ranges from less than 100 mm in the southern side to about 1,500 mm in the north side on the southern slopes of the Himalayas mountains. It is generally minimum from Himalayas towards the south, with the lowest rainfall which crossing southern Punjab and upper Sindh. The rain gives some beneficial contributes to the crops mostly in the irrigated areas of the Indus basin which is estimated to be 9.24 billion m^3 or 7.55 million acre/feet. Barani areas (non-irrigated areas i.e. 4 million ha) rainfall is used for irrigation purposes and for the drinking water for the poor residential and other livestock. Rain contribution which is exposed to crops in the barani areas has been estimated at 7.34 billion m^3 (6 million acre/feet) [11].

The pressure on water resources of the country is derived from multiple sources due to multiple uses and multidimensional purposes. Increases of human population and development in industrial sector and its activities and agricultural sector which lays on chemicals and fertilizers that results into the water pollution. The quality of water depend upon the varieties of water constituents present in it, if the water bodies like (lakes, groundwater aquifers, and fresh water rivers) are contaminated, it results a bad effect over the human health and may cause water borne diseases. Need of water is increases day by day with passage of time, while on other hand water shortage occurred at an alarming rate within the communities. It has been decreased from about 5,000 m^3 per capita in the year of 1951 to 1,100 m^3 currently, while is above the level of internationally recognized scarcity rate. In future it may be less due to some water management authorities which will be less than 700 m^3 per capita by 2025.

Groundwater is the main water source in Pakistan. Whole human population including rural and urban completely depend upon the ground water and also some other forms of sources of water for their water based needs. Punjab has about 80% fresh water from underground, with some saline water in the south side desert areas like in cholistan. Water contains some variation with geographic location changes. The water with some contents of fluoride or arsenic was found locally in Punjab province. Due to industrial localities, the water becomes contaminated neighbor that localities due to waste water and discharges. In Sindh, the ratio of fresh water is less then 30% while mostly it is brackish water and having some content of fluoride throughout the province. In NWFP, increasing generalization or custom of wells were found which are also resulted into saline layers. Baluchistan ground water resources are saline as compared to the other provinces of Pakistan. When we compare the water quality of provinces then the Punjab rural areas water resources are the best among them. According to a report that 7% of the rural population of Pakistan depends on a dug well or a river, canal or stream. In Sind, about 24% of the rural population depends upon these sources like river, canals and streams. In NWFP and Baluchistan the rural human population has no any proper water management system, but they used water from a dug well or from a river/canal/stream about 46% and 72% respectively. About 60% of the population of Pakistan gets their drinking water from hand or motor pumps as main source, while in the rural areas it is more then 70%. In Sindh this is low ratio, where the groundwater quality is generally saline and about 24% of the rural population gets their drinking water from surface water or from the dug wells [12].

1.4 Water Pollution in Pakistan

Water is universal solvent by that property it also, highly prone to the contamination by microbes toxic organic and inorganic compounds. Contaminated water cause various water borne diseases and abnormalities including diarrhea, dysentery, typhoid or acute fever, cholera, and some types hepatitis to all users [13]. Low quality of water and sediments can affect the aquatic ecosystem in both ways directly or indirectly because water and mud are considered to be a common diet taken by aquatic animals [14]. Typically, the overall requirements for domestic supply (drinking, eating, hand washing, laundry and in some cases bathing) also contributes water withdrawals on small scale [15]. Several countries in arid zone particularly those with irrigation are now facing serious problems with salt balance as rivers becomes exploited. Pakistan is in the Middle East region. The increase in industrialization in developing countries may cause such activities that may harm to our regular water bodies like water reservoirs, streams and rivers by the disposal of waste water and solid waste while the industries are the main sources. On other hand small scale of domestic waster and industrial based effluents also cause pollution in residential areas. Some types of small water courses also cause water pollution in Pakistan like Ravi River (Lahore), Malir, Layari (Karachi) and Leh stream in the area of Rawalpindi [16].

In Pakistan, there are several potential sources to contaminate drinking water. Bacteriological contaminations in drinking water cause health problem and pollution of water day by day within the rural and urban areas of Pakistan. Such contamination is attributed to leakage of pipes, pollution from sewerage pipes due to problem within the distribution system, intermittent water supply, and shallow water tables due to human activities. A second strong source for ground water contamination in irrigated and industrial areas is chemical pollution caused by toxic substances from the industrial effluents, textile dyes, pesticides, nitrogenous fertilizers, arsenic and other chemicals. In addition, excessive monsoon rains, floods, herbicides, fungicides, untreated municipal waste, sewage breakdowns, and coastal water pollution due to waste discharges and oil spills are extremely hazardous for drinking water. For the sake of public health, it is absolutely essential to establish drinking water quality standards and criteria that are chemically balanced and medically safe [17].

Lakes are the main source of freshwater supply for human populations that have an individual pattern of physico-chemical characterization which are largely determined by the geomorphologic and climatic and some geochemical conditions. Changes in morphology, geography and vegetation or plantation and activities at recreational site may effect over the overall quality of water [18], the climate, and the inputs and outputs both natural and man-made [19] The exploitation of water resources in catchment area and some their neighbor areas cause water pollution [20], and finally there is large scale degradation of water and their quality, biodiversity of water, habitat and biological integrity of running and fresh water system [21].

Generally, the shallow lakes shows a large variety in different types of biodiversity and livestock with the passage of time [22]. And disturbance of lake caused by many sources may adverse effects on lake ecosystems [23]. Variability in water can alter the tropic level, ecosystems, and nutrient flow, decomposition, metabolism, animal and plant interactions [24].

Nowadays the increase in the water quality degradation of fresh water lakes and rivers are one of the greatest challenges faced by water quality management [25]. Pollution and water quality degradation are interfering to each other with vital and legal water uses at local, regional and international scale [26]. Due to the impacts on social, economic, health and other aspects, fresh water pollution problems are under consideration at international scale nowadays [27]. The quality of fresh water reservoirs might also be degraded by microbiological and chemical pollution [28]. Excessive and misuse of fertilizers and pesticides in the catchments area also deteriorates the surface water quality by entering into the lakes by runoff [29]. Contamination of fresh water bodies are caused by disposal of agricultural runoff, effluent released by industries and factories and domestic sewage which enters into water bodies without any proper treatment [30].

Lake water is also polluted by agricultural runoff and the both municipal and industrial wastewater [31], which is full of trace metals constituents, some organics, excessive nutrients like fertilizers and some types of pesticides [32]. The nutrient enrichment, also called eutrophication which is also considered to be a major environmental problem in lakes and water reservoirs [33]. Excessive fertilizers like nitrates and phosphates are the root cause of eutrophication of lakes [34]. During the last few decades the gradual eutrophication were observed in the aquatic ecosystems in the worldwide. In the eutrophication process the surface water receives excessive nutrients which result in high biomass productivity and also high fish yields [35]. Exploitation of water resources is mostly caused by manmade activities like agricultural and industrial, and some natural processes like the weathering processes, seasonally precipitation rate, and erosion of soil are the reasons of general deterioration in surface waters which is generally in the usage of drinking, agricultural sector, recreational purposes and for the betterment of environment and the health [36]. Modification in the biology of water is due to some modification and changes in land like a forestation and deforestation and some grazing activities, and the organic load of nitrogen and phosphorus originated by waste water from industries and urban areas [37].

1.5 Rawal Lake and its importance

Rawal lake is an artificial reservoir in our home land Pakistan, it provides water needs for twin cities i.e. Rawalpindi and Islamabad. It is 8.8 km^2 in land area. This reservoir lies within the isolated section of the Margalla Hills National Park in eastern side of the capital city, Islamabad. It was constructed 73 years ago. It is catchment area of 275 km^2 with a live storage capacity of 5.30×10^7 m^3. The total storage capacity is 47,500 acre feet (12994 MG). Live storage is 43,000 acre feet 11763 MG. Highest flood level is 1752 feet. The lake is feed by 4 major and 43 small tributaries. Rawal lake which was constructed on the bank of Kurgan River having catchment area of 106 squire miles. The Rawal lake supplies water to 1.5 million peoples in Rawalpindi which is the fourth most populated city in the country [38].

The villages which are situated near to the Rawal lake are Bani Gala Bhara Kahu, Mallpur, and Noorpur Shahan. The estimated population of these villages is about 5000. A number of housing colonies, residential areas are coming up in the Rawal Lake catchment area without any consideration that this will adversely affect the nature of Rawal Lake water. The major pollution causing activities specifically including car washes, recreational activities and human settlement in Bani Gala, Bhara kahu, Mallpur, and Noorpur Shahan. But still there is no proper action performed by the environment concern agencies. Proper management of this vital resource of water like Rawal Lake, in the proximity of Capital city of Pakistan is important if full benefits are to be gained and maintained for the future [39].

Rawal Lake Reservoir is currently facing many problems such as serious environmental degradation, water pollution and over fishing is also important. The domestic and municipal waste from residential colonies and village of Bani Gala enters into lake at the Eastern side. The contamination of lake water by Pb, occurs due to gasoline from fishery boats and tour ships [40]. The drastic rise in population at the catchments which created many ecological changes in the quality of surface water, it may cause pollution in lake. A forestation on the bank of the reservoir for the reconstruction and extension in Rawal Lake View Park has a potential anthropogenic impact on the biodiversity. Fish production of the reservoir is also affected during current years and also contaminated fish with deformed bones in the lower part of the lake are found, showing high health hazardous to wild life particularly birds [41]. Due to water contamination in surface water and deterioration of water quality over all causes 30% decrease in maximum number (Max.no. 3089 from 7652) of birds of Rawal lake from 1993 to 2003[42].

According to estimation there are 170 poultry farms and 360 poultry sheds are present in the catchment area of Rawal lake. It is also observed that some disposal o the poultry wastes directly flow into the lake. Recreational activities are another source of pollution. The tourists also deteriorate the quality by throwing bottles, shoppers and other material into the lake. Other activities like, car washing, boating and fishing in some way or the other are adding up a significant portion of pollutant as oil, alkalis and particulate material (dissolved and suspended). Agriculture is also contributing the Rawal Lake water body. The excess irrigation water is drained out through nullah and enters in to the lake. Pesticides and herbicides usage in irrigated land also contributed in toxic pollution in water. These toxic chemicals are flow away by streams and finally enter into the Rawal lake. Hence these activities are practiced at small scale in the catchment area, but it also contributed in the deterioration of Lake. This activity can be a major problem if it practiced at large scale by the neibouring population. Rawal lake catchment area is subjected to deforestation due to grazing of livestock and cutting of Wood for fuel by villagers. The villagers do not have any energy sources except wood available in the catchments area. Plantation has also been removed for the construction of roads, housing schemes and commercial buildings within the catchment area. Deforestation encourages the erosion of the soil causing siltation of lake bed and increase in water turbidity problems. In addition to the pollution generated by human activity, the lake also receives natural pollutants from the catchment area, which contains various wild animal species and fouls. The excreta of these animals are deposited in the catchment area and enter the lake via heavy rain fall. Bacteria decompose this organic matter in the presence of oxygen thus oxygen depletion results in the eutrophication of the lake [43].

1.6 Aims and objective

- To determine the quality of Rawal lake by analyzing the different parameters like physical, chemical and micro biological.
- To determine the quality of source nullahs (streams that pour their water into the lake) by analyzing different physico-chemical and microbiological parameters.
- To determine the possible effects of water quality of source nullahs (streams) on Rawal lake water.

MATERIAL AND METHODS

CHAPTER 2

Material and Methods:

2.1 The Study Area

Rawal Lake lies between latitude of 33° 42' 0 N and longitude of 73° 10' 0 E at an altitude of 530 m. Lake is located at the foot of the Murree hills along the Murree road, Islamabad. The Murree road runs parallel to the western and northern bank at a distance of 50 to 100 m approximately and connects Islamabad to Murree and North Eastern Areas i.e. Azad Jammu and Kashmir. On the western side, Golf club is located while on its southern sites Rawal town and Canal lodges are located. The residential colonies and village of Bani Gala are situated on the Eastern side of Rawal lake.

2.2 Sampling site

Five different sites were selected for water sampling sources of water in dam (Mallpur S_1 and Bari Imam S_2) and the remaining 3 from dam, one from the 20 meters distance from north of Rawal Lake called main Pushta (S_3), second at spillway (S_4) and last one at centre (S_5). The Water samples were collected trice a day at different timings (9 am, 2 pm and 7 pm). The sampling was done for just to get a slight comprehensive nature of water. The sampling was carried out on 19th march 2009. Different physical and chemical parameters of samples were analyzed. All water samples were collected within the limited time in 1.5 liter plastic bottles. Before the collection of water samples all bottles were first mixed with sample water twice a time. Discrete water sampling was done at each sampling site at the depth of 20-25 cm. The samples were stored and preserved at the temperature between 2 to 10 centigrade in ice box, to minimize change in water chemistry. After this the waste water sampling, the samples were carried out for analyze their microbiological and chemical parameters by using the following procedures.

2.3 Methods which were used for physico-chemical Parameters:

2.3.1 pH

Determination of pH is a relatively reliable indication of its acidity or alkalinity tendency.

Instruments

Portable pH meter, Model 64, Orabico analytical sys. Inco, Volumetric flasks.

Reagents

Potassium Tetraozilate dihydrade and potassium Hydrogen Phthalate.

Solution

Tetraoxilate guffer

0.04 M Tetraoxilate buffer solution (Ph-1.68) solution was prepared by dissolving into 12.61 grams of the potassium tetraoxilate dehydrate in distilled water and diluted it with 1000 ml Phthalate buffer in volumetric flasks. 0.05 M Phthalate buffer solution like (Ph-4.00) was being prepared with the help of dissolving 10.12 g of potassium hydrogen phthalate in distilled water and then dilute to1000-ml volumetric flasks.

Procedure

The instruments were turned on and as per the instruction were mentioned in the instruction manual. Electrodes and the sample bottles were rinsed with distilled water. Selected two nearest reference buffer solution of known pH value and pH meter was calibrated accordingly, repeated with the second solution to recalibrated of the pH meter, rinsed the beaker and electrodes with the sample and put the sample in the bottle, inserted the electrodes in the sample to the measure the pH of the sample and the noted the constant reading. Reading in duplication was taken for all samples in the same way.

2.3.2 Electric Conductivity (E.C)

Instrument

JENWAY 4010 Conductivity meter, England. Bright electrode, Platinum electrode, Range $10\text{-}10^4 \mu\mho/\text{cm}$ was used during the study.

Chemicals

Solution potassium chloride (0.01 M) was dried at 105 ^{0}C temperature to constant weight in an oven, placed in a desicator for cooling. For 0.01 M solution, KCL was weighted exactly 0.7496 g and dissolves this KCL in distilled or purified water and diluted to the 1000 ml in a volumetric flasks.

Procedure

The instrument was calibrated first by the standard procedure mentioned in operation manual. The electrode was rancid with chromic acid solution and rancid it with some amount of distilled water. The electrode was amerced in the standard KCL solution of known conductivity at 25 ^{0}C. Calibration of the conduct meter was done with different two standard solutions. Repeat two different standard solutions for calibration of the conductivity meter. Cell constant can be calculated by using the following formula;

$$Q = K/L$$

Where;

Q = Electrode constant

K = Known conductivity of KCL standard solution

S = Detected conductivity of KCL standard solution

The conductivity of the water was determined using the same procedure as that for the calibration purpose. The beaker and the electrode were rinsed many times, and dip the electrode in the sample and noted the reading which was the connectivity of the sample.

2.3.3 Total Dissolved Solids (TDS)

Apparatus:

Electric water bath, ovens 101-1, 202-1, China, Top leading balance, Porcelain evaporating dish 100 ml capacity and desiccators were used.

Procedure

Total dissolved solids were determined by the following procedure. The collected samples were filtered through the whatmann 40 filter paper and collected the filtrate in the beaker. Selected an evaporating dish, washed with chromic acid, and then distilled water. Place it in an oven at 105 ^{0}C till the constant weight. Note the initial weight of the empty with and accuracy to 0.0002 g i.e. (W_1). Transferred 100 ml filtrates of the effluents sample in the dish and placed it on the boiling water bath, to evaporate the sample to dryness. Then placed the dish in the oven, at 105 ^{0}C for 2 hours, followed by cooling in a desicator for half an hour, weighted it with a accuracy to 0.0002 g. Placed in the oven again at 105 ^{0}C for half an hour and weighted again after cooling in the desecrator for half an hour. Repeated the same procedure till the constant weight was obtained i.e. (W_2). Total dissolved solids in water were collected by using the following formula.

$$\text{Total Dissolved Solids (mg/l)} = (W_2-W_1) \text{ X } 10^3/100$$

Where;

WI = Shows weight of the empty dish

W2 = Shows weight of the dish and residue

100 = Shows volume of the sample taken

2.3.4 Total Suspended Solids (TSS)

The beaker was filled with 250 milli liters of water. A Filter paper was weighted to the accuracy of 0.0002 g (sample A) and then the water sample was filtered. After filtration, filter paper was removed from the funnel and was dried at 100 ^{0}C until a constant weight was reached (sample B). Calculations were made by using the following formula;

Total Suspended Solids (mg/l) = Sample A- sample BX1000 / Sample volume used.

Where; Sample A = Shows weight of the filter paper + Dried residue (mg)

Sample B = Shows weight of the filter paper

2.3.5 Alkalinity

The method used for alkalinity was 2320 standard method (1992). The chemicals used for this analysis carbon dioxide, free distilled water, sodium carbonate solution (0.05 mol/l), HCL (0.02 M), Phenolphthalein indicator and methyl orange indicator.

A 100 ml water sample was mixed with two or three drops of phenolphthalein indicator in a conical flask. The phenolphthalein alkalinity of the sample was determine by titrating with standard acid (HCL 0.02 M) until the disappearance of pink color. The alkalinity to phenolphthalein was considered to be 0 in case no color was produce after addition of few of phenolphthalein. The methyl orange alkalinity of the sample was determine by titrating with standard acid (HCL 0.02 M) until the color changes from yellow to orange.

Total alkalinity as $CaCO_3$ (m.mol/L) = $\frac{1000 \times B \times C}{V}$

Where;

B = ml of standard acid solution to reach the end point of methyl orange;

C = Concentration of acid in mo/l; and

V = ml of sample

Using 100 ml of sample and 0.1 mol/l standard acid solutions, the numerical value of alkalinity is directly expressed in m.mol/l by number of ml of titrant consumed.

2.3.6 Chloride (Cl)

Chloride (Cl) ion is one of the major inorganic anions in water and waste water. The method used for this analysis was titration (Silver nitrate) standards method. Represented samples were collected in clean and chemically resistant plastic bottle. The maximum sample portion required was 100 ml. No special preservative was necessary for the storage of sample, Chloride is determined in a natural or slightly alkaline solution by titration with standard silver nitrate using potassium chromate as a indicator. Silver chloride is quantitatively precipitation before red silver chromate is formed. Bromide, Iodide and cyanide are measured as equivalent of chloride ion. Main interference is the contents of thiosulfate, thiocyanite, cyanide, sulfite, sulfide, iron and orthophosphate.

Reagents:

1) Standard silver nitrate solution
2) Potassium chromate indicator
3) And aluminum hydroxide suspension.

A 20 ml ample was taken in a conical flask and adjusted the pH range 7 to 10 with H_2SO_4 or NaOH. A few drops of K_2CrO_4 indicator solution was added and titrated against standard solution of $AgNO_3$ (titrant) up to pinkish yellow end point. 100 ppm NaCl Standard was used to conform accuracy.

$$\text{Concentration of Cl mg/l} = \frac{(A-B)\times M\times 35.45\times 100}{V}$$

Where;

A and B are the volumes of silver nitrate solution required by the sample and blank respectively.

M = concentration (mol/l) of $AgNO_3$; and

V = ml of sample

2.3.7 Total Hardness

The method used for this analysis was EDTA titration standard method 1992. EDTA forms soluble chelates of calcium and magnesium ions. When a small amount of Eriochrome black T indicator is added to solution containing calcium magnesium ions at pH 10.0±0.1, the solution became wine/red in color. When the solution is titrated with EDTA the calcium and magnesium are complex and at the end point the color of solution changes from wine/red to blue. Several metal ions can interfere with the titration by the producing fading or indistinct end points. To minimize these interferences, sodium sulphide solution is added. The approximate concentration of various ions can be tolerated if sodium sulphide is added. Interfering substances are aluminum 20 mg/l, cadmium 10 mg/l, cobalt 0.3 mg/l, copper 20 mg/l, ferrous ions5mg/l, lead 20 mg/l, manganese ions 1 mg/l, nickel 0.3 mg/l, polyphosphate 10 mg/l, zinc 200 mg/l. A 25 ml of sample was taken and diluted to 50 ml with distilled water in a conical flask. One ml of buffer solution and 1-2 drops of Erichrome black T indicator was added. Then the standard EDTA titrant was added slowly with continuous stirring, until last reddish ting color disappeared from the solution. The end point of the solution was normally blue. The duration of the titration was not extended beyond 5 minutes measured from the time of addition of buffer.

$$\text{Hardness as } CaCO_3 \text{ (mg/l)} = \frac{(A-B) \times C \times 100}{V}$$

Where;

A = ml of EDTA for titration of sample;

B = ml of EDTA for titration of blank

C can be calculated from the standardization of the EDTA titration and equivalent to;

$$\frac{\text{ml of standard calcium solution; and}}{\text{ml of EDTA titration}}$$

V= ml of sample

2.3.8 Calcium (Ca)

The method used for this analysis was Disodium Ethylene Diamine Tetra-acetate Dehydrate (EDTA) titration method. When EDTA is added to water containing calcium and magnesium ions, soluble EDTA chalets are formed. The stability is constant for the calcium chelate which is larger than that of the magnesium chelate consequently, in the titration, calcium reacts before the magnesium. Calcium can be determined in the presence of magnesium by EDTA titration when an indicator is used that reacts with calcium only e.g. Murexide gives a color change when all of the calcium has been complexed by EDTA at a pH of 12 to 13.

Orthophosphate precipitates calcium at the pH of the test and therefore, produces low results. Strontium and Barium interfere with the calcium determined by virtue of the fact that they also form EDTA chelates and alkalinity in excess of 30mg/l may cause an indistinct endpoint with hard water, the concentration level of ions which cause interfere with the calcium hardness.

Reagents:

a) Sodium hydroxide (NaOH), IN;
b) Murexide indicator; and
c) Standard EDTA titrant, 0.01 M.

A sample of 50 ml was used or a smaller portion diluted to 50 ml so that the calcium content was about 5-10 mg. Then, added 2 ml of NaOH solution or a volume sufficient to obtain a Ph of 12-13. After stirring well, 0.1-0.2 gm of the Murexide indicator was added. In addition to that EDTA titrant was added slowly, with the continuous stirring until the proper end pint reached.

$$\text{Concentration of Ca (mg/l)} = \frac{AxBx400.8}{V}$$

Where;

A = ml of EDTA titrant used for titration of sample

B = ml of standard calcium solution; and

$$\overline{\text{Ml of EDTA titrant}}$$

V= ml of sample

2.3.9 Magnesium (Mg)

Reagents:

Water sample, K+ solution (167 ppm, 78 ppm, 50.7 ppm)

Apparatus:

Flame photometer, beakers

Procedure:

1) Determine the sensitivity of K+ ion solution (167 ppm, 78 ppm, 50.7ppm) by flame photometer
2) Then determine the concentration of K+ in the water sample by flame photometer
3) Took fine sensitivity reading on flame photometer

Calculations:

To prepare K+ sol. of concentration (167 ppm, 78 ppm, 50.7 ppm) $C1\ V1 = C2\ V2$

C1 = concentration of K+

C2 = concentration of water

V1 = volume of K+

V2 = volume of water

1. For 4.3 ml K+ solution: C2 = 3900 x 4.3 / 100 = 167 ppm
2. For 2.17 ml K+ solution: C2 = 3900 x 2.17 / 100 = 78 ppm
3. For 1.3 ml K+ solution: C2 = 3900 x 1.3 / 100 = 50.7 ppm
4. For 0.43 ml K+ solution: C2 = 3900 x 0.43 / 100 = 16 ppm

Sensitivity of K+ solution

1) For 167 ppm K+ solution: Sensitivity = 167 ppm
2) For 78 ppm K+ solution: Sensitivity = 67 ppm
3) For 50.7 ppm K+ solution: Sensitivity = 50 ppm
4) For 16.7 ppm K+ solution: Sensitivity = 16 ppm

Sensitivity of water sample = 4 ppm

2.3.10 Sulphate (SO_4)

Instrument:

UV-VIS Spectrophotometer (U-1100), HITACHI

The method used for this analysis was sulpha Ver 4 HACH Method (8051) (powder pillows). The range of measurements was 0 to 70 mg/l. Sulphate ions in the sample react with the barium in the sulpha ver 4-fulfate reagent and form insoluble Barium-sulphate turbidity. The amount of turbidity formed is proportional to the sulphate concentration.

A 25 ml of deionized water was taken in the beaker. The contents of sulphate reagents powder pillows were added and swirled to dissolve. The beaker was placed undisturbed for 5 minutes to reach its reaction period. The contents of beaker were taken in a reference cell and placed into the cell holder of UV-VIS Spectrophotometer adjusted at wavelength of 450nm. The bottom zero was pressed to display zero reading. Then the standard solution of 5,10,20,30,40,50,60 and 70 mg/l sulphate were prepared into separate beakers and the contents of the sulpha ver 4-sulphate reagent powder pillows were added and swirled to dissolve. After 5 minutes (reaction period) the absorbance were taken. Similarly the water samples were treated and their absorbance was compared with in order to determine their concentration.

2.3.11 Isolation of Bacteria from the sample water

Dilution Plate Method (for the determination of plate count/ml)

A series of dilution tubes were set up, containing 9 ml of distilled water in each tube. Only pour 1 ml of sample water into dilution tube and agitated for 1 minute. Seria, dilutions were made and inoculated 0.1 ml of the final three dilutions onto isolation media plates, separated with a sterile spreader. Plates were incubated at the temperature of 28 ^{0}C only for 24 hours then the colonies were counted with the help of desirable counter. Media used for the preliminary isolation of bacteria was nutrient agar and Saboraud Dextrose agar respectively.

Composition of nutrient agar

Peptone	5.0 g
Beef extract	3.0 g
Agar agar Distilled water	15.0 g
pH	7.0

Composition of saboraud Dextrose Agar

Dextrose	40.0 g
Peptone	10.0 g
Yeast extract	4.0 g
Agar agar	18.0 g
Distilled water	1000.0 ml
pH	5.6

Isolation, Purification and Sub culturing (bacteria).

Once the colonies developed, the agar plates were sorted on the basis of colony morphology, the bacterial colony was isolated and transferred to new plates for screening, and also they were determined properly on Agar slants as pure isolates.

Bacteria were initially grouped according to plate morphological characteristics, such as pigment and colony forms. Pinpoint colonies were then picked, sub cultured on agar plates and subjected to further biochemical test.

2.3.12 Isolation of Coliform Bacteria from the sample water:

Procedure

To test drinking water, presumptive, confirmed, and complete tests were performed, and a minimum of 15 tubes were used. The number of positive tubes could then be checked with table and "Most Probable Number" (MPN) of coliform organisms determined. A statistical estimation of coliform presence is considered to be the of water quality indicator.

Presumptive Test

Wash hands with soap and water. Opened the sealed plastic package and removed the presumptive assemblies. Remove cap carefully, not to touch the open end of the tube. Took 10 ml of lactose broth solution in all of the 15 tubes, and were cottoned. All the tubes were auto claved for 15 minutes at 120o C. With the help of pipet, add 10 ml some conc. 1 ml and finally 0.5 ml of the water sample in each group of five tubes. Placed the tube assemblies in auto calve at 37°C for 24 hours. After 24+/-2 hours, shook each tube slowly and then examined it for the gas production. Record the presence or absence of gas formation. All presumptive tubes showing gas formation were followed up with confirmed test.

Confirmed Test

Transfer all primary fermentation tubes showing any amount of gas within 24 hours incubation to the confirmed phase. Gently shake primary fermentation tube showing gas. Place these tubes in the incubator at 35+ /- 0.5° C for 48 hours. A positive confirmed test for coliform is indicated by gas collection in the inner fermentation vial. Lack of gas indicates a negative test.

Completed Test

All the negative tubes were then incubated for 72 hours at 35 +/-0.5 °C.

Interpretation

In all five of the completed fermentation tubes for a given sample indicated negative results. The water was accepted as meeting the bacterial standard set by international standard. Gas production in fermentation tube within 24 hours or less is considered a positive reaction and indicates coliform of fecal origin. Failure to produce a gas constitutes a negative reaction. Calculated the fecal coliform densities and counted them with the help of colony counter. The results of the fecal coliform MPN are given in tables showing the results of each sample.

2.3.13 Sodium (Na) & Potassium (K)

Instrument

Flame photometer was used.

Solution preparation.

Sodium stock solution (100 ppm): 2.543 grams of NaCl was mixed with the water (deionized) and the volume which becomes 100 ml in addition with the water of deionize.

For the preparation of Na solution for calibration: 1 ml of 1000 ppm Na stock solution was pour for preparation the volume of 50 ml with deionzed water for the preparation of

20 ppm stock solution. Again on 2.5, 5, 7.5, 10 and 12.5 ml of 20 ppm of solution which is standard for to prepare the 1, 2, 3, 4, and 5 ppm standard solution in total volume of 50 ml with deionized water for the construction of calibration curve.

Potassium stock solution (1000 ppm): 1.91 g of KCl was dissolved in 1000 ml volumetric flask with little deionised water and the mark was filled with the deionized water.

Potassium Standard Solution for calibration: 1ml 1000 ppm K of stock solution was dissolved to make a total volume of 50 ml with deionized water for the preparation of 20 ppm stock solution. Again on 2.5, 5, 7.5, 10 and 12.5 ml of 20 ppm K standard solution were added to make 1, 2, 3, 4, and 5 ppm standard solution in total volume of 50 ml with deionized water respectively for the construction of calibration curve

Procedure

A series of standard solutions of each cation, i.e. sodium or potassium were simultaneously run in the concentration range of unknown samples on flame photometer. The calibration curves of each cation for concentration various emission intensity were obtained and concentration of unknown was calculated from calibration curves for each cations.

RESULTS

CHAPTER 3

3.1 Results

In order to check the deteriorating quality of Rawal lake, water quality of lake and associated nullahs (streams) was examined. Out of five sampling sites, two were located at main sources i.e., S_1 at Mallpur nullah and S_2 at Crash nullah (Bari Imam) and the remaining three at different points (S_3 (Main Pushta), S_4 (Spillway) and S_5 (Center)) in the lake. Sampling was carried out during three times of a day i.e., morning (9 am), noon (2 pm) and evening (7 pm). Physico-chemical parameters viz; pH, Electric conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Hardness, Magnesium, Calcium, Total Alkalinity, Chloride, Sulphate, Sodium, Potassium, Coliform and Total Bacterial Count were analyzed of water samples (Tables. 3.1.1, 3.1.2 and 3.1.3).

Results showed that the most of the water quality parameters which were analyzed were in the range of permissible guide line limits of World Health Organization (WHO) and Pakistan Standard Quality Control Authority (PSQCA). However, parameters like Bacterial count (as total count and coliform count) and Total Suspended Solids (TSS) were exceeding the required limits in most of water samples collected at different sites, including sources and the lake. Generally, the sources were showing higher level of contaminants but a general decline in all water quality parameters were observed from sources towards lake. Moreover, a constant rise in almost every single contaminant of water was evident from morning to evening.

The Total bacterial count (CFU/ml) was 1640 and 1932 at Mallpur (S_1) and Bari Imam (S_2) respectively, and this bacterial count kept on increasing during the day and was highest i.e., 2013 and 2317 in the two respective sources particularly at evening. There was observed an increased in total bacterial count (ave.) in lake from morning to evening from 1824 to 2357. It was maximum at the Spillway (S_4) (3245, 4600, 4519), intermediate at Pushta (S_3) (1672, 1800, 1943) and was minimum (556, 600, 610) at the center (S_5) during the three times of the day (Fig. 3.1.1). At lake, Coliform count (MPN/ml) at S_1 and S_2 was constant i.e., greater than 1600 and this count remained constant even at S_3 (Pushta) during the day. However, it was minimum (17, 23 & 44) at the center (S_5) during three sampling times of the day (Fig. 3.1.2).

Generally TSS (mg/l) was considerably higher than permissible limits of WHO in all the water samples but it was considerably higher at two sources as compared to Lake. It was 110 and 15 in morning, 12 and 16 in noon and 18 and 17 in the evening at S_1 and S_2 correspondingly. A continuous shift in TSS values (from 4-10) was observed at three sites during the whole day (Fig. 3.1.3).

Over all, there was observed a no great shift in pH values from sources to Rawal lake. Generally the pH remained ≥ 7 & ≤ 8 at both sources and the remaining 3 sampling sites of lake (Fig. 3.1.4).

Electric conductivity (µS/cm), typically of high quality drinking water ranges between 5-500 and considering this desired limit, its (ave.) was specifically higher at S_2 (643) than S_1 (502) during the day. Specifically, it was 476, 510 and 520 at S_1 and 632, 650 and 648 mg/l at S_2 in the morning, noon and evening respectively. A gradual incline in E.C (ave.)

(393 to 406) was observed from morning to evening in the Lake. Maximum EC (407, 412 & 418) was observed in the all the 3 samples collected at spillway (S_4), during the day (Fig. 3.1.5).

TDS (mg/l) values in all the samples collected from sources and the lake were in the range, not exceeds the guideline limits which are set by WHO. However, they were comparatively higher in water samples collected from S_2 (410, 416 & 431) than in S_1 (303, 326 & 326) during the respective three sampling times of the day. TDS increased (ave.) (226 to 258) from morning to noon but then afterward it remained constant till evening in the lake. It was higher (241 mg/l) at the center (S_5) in the morning but then was highest (264) at S_4 at noon and evening in the lake (Fig. 3.1.6).

Total hardness (mg/l) values were random at different sites. Comparatively, it was found highest at sources, specifically at S_2, where a change in it was noted from 218 to 232 during the day. Moreover, a continuous shift in hardness values was observed in water samples at three sites from 108 to 161 mg/l during the day in Rawal Lake (Fig. 3.1.7).

The entire samples analyzed for calcium (as CaCO3) were within permissible limit of WHO. Both the water sources exhibited high values of calcium compared to lake water samples. Calcium was highest i.e., 152 mg/l at S_2 in the evening. The average concentration (mg/l) of calcium were 76.6, 84.6 and 142 at morning, noon and in evening at 3 site in the lake. However, the concentration of calcium varied from 64 to 92 at 3 sampling spots during the day but it was observed highest at the spillway (92) during noon (Fig. 3.1.8).

Magnesium levels (mg/l) were higher at S_2 then S_1. There was a gradual increase in magnesium concentration in both sources. The highest values were observed at noon i.e., 72 mg/l and 90mg/l in S_1 and S_2 respectively. The concentration of magnesium varied at three spots during the day in the lake, it was maximum i.e., 56 at S_2 in morning and 58 mg/l at S_5 in the evening (Fig. 3.1.9).

The total alkalinity was comparatively highest in S_2 the S_1 and it was specifically observed maximum (218) in the evening. Maximum value of total alkalinity i.e., 110, 128 & 131 was noted at S_4 during the three respective times of the day. however, the average total alkalinity was 104 mg/l in the evening in the Rawal lake (Fig. 3.1.10). Maximum chloride was found in S_2 (37mg/l) compared to S_1 (28 mg/l). Chloride was slightly higher at S_3 during the day and the average concentration was 21.6 mg/l in evening at the Lake (Fig. 3.1.11). Comparing two sources, the concentration (mg/l) of sulphate was highest (135mg/l) in the evening at S_2. It was maximum (135) at S_2 in the evening. At lake, maximum concentration (ave.) of sulphate was 71 at noon though highest at; S_3 (75) in the morning, S_4 (78) in noon and S_3 (71) in evening (Fig. 3.1.12).

Initially, in the morning, sodium (mg/l) concentration was higher (35) at S_2 as compared to S1, but its concentration became almost same in the evening at the both sources (40 at S_1, 39 at S_2). Though in the lake, the concentration of sodium varied at different sampling sites during the day; however it was highest at S_4. The average concentration of sodium in the evening was 25.83 (Fig. 3.1.13). The concentration (mg/l) of potassium remained quite low then the permissible limits even at sources, though were slightly higher at S_2 (3.1, 3.3, 3.9) than S_1 (2.9, 2.9, 3.1) in three consecutive samples of the falling day. The average concentration of potassium remained almost same during the day though varied from site to site in the lake from 1.2 to 2.9 mg/l (Fig. 3.1.14).

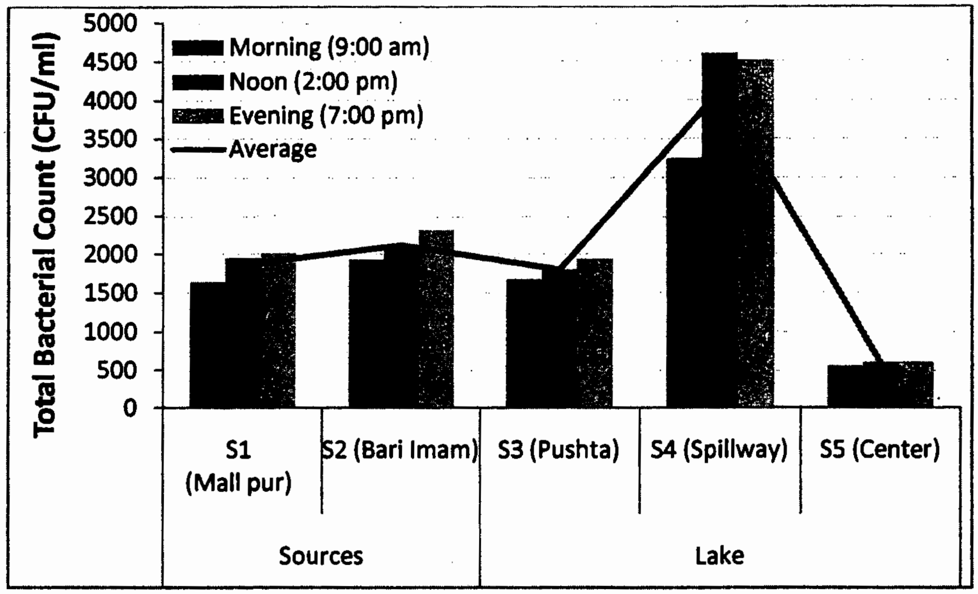

Fig. 3.1.1: Total bacterial count of water samples at main source nullahs and different sites of lake

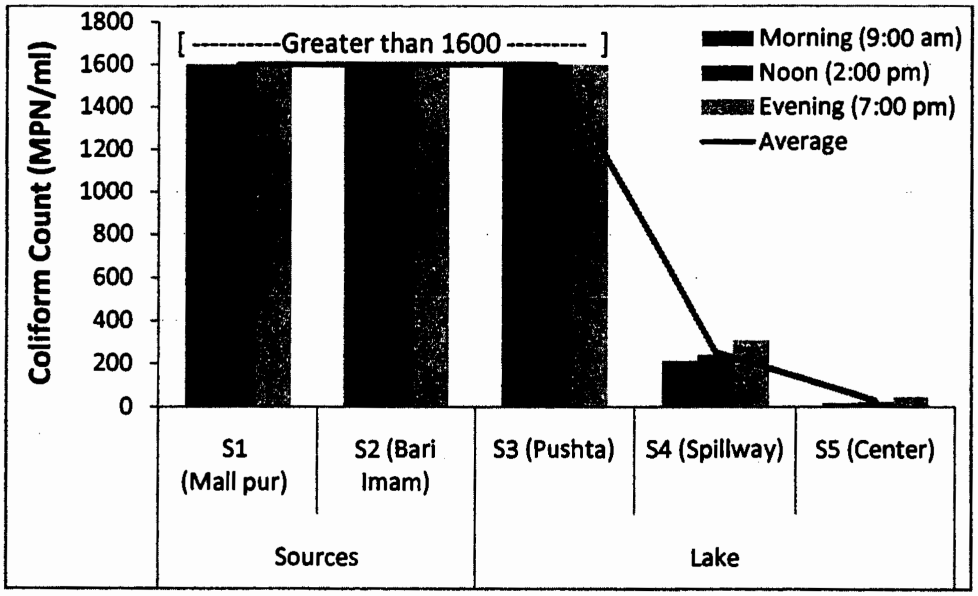

Fig. 3.1.2: Total Coliform count of water samples at main source nullahs and different sites of lake

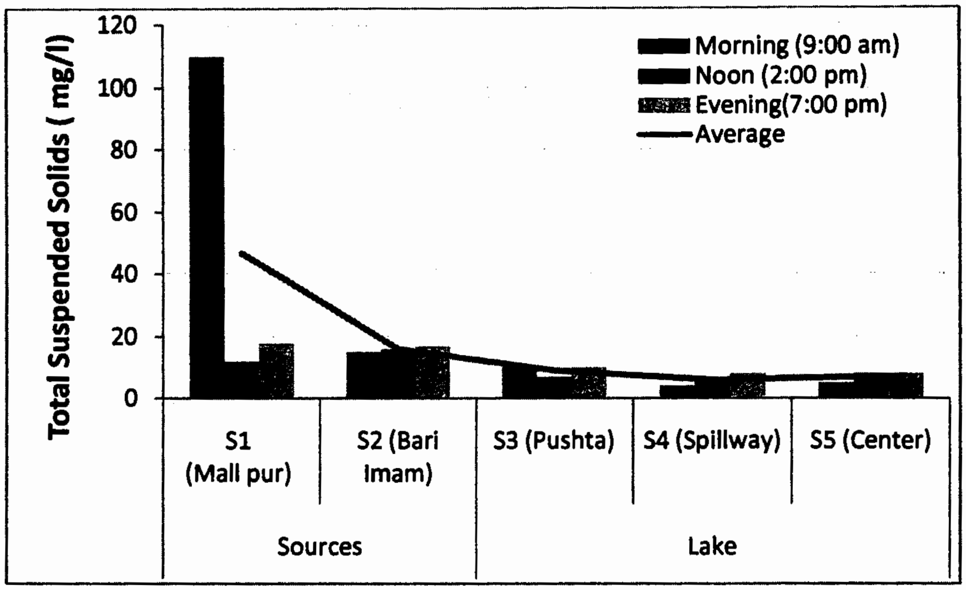

Fig. 3.1.3: Total Suspended Solids of water samples at main source nullahs and different sites of lake

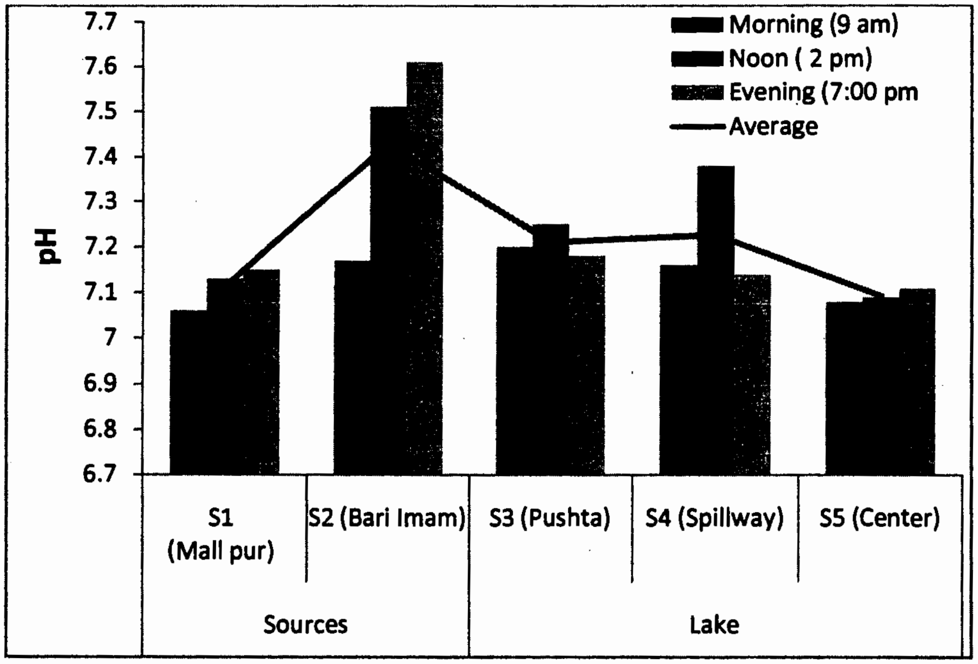

Fig. 3.1.4: pH of water samples at main source nullahs and different sites of lake

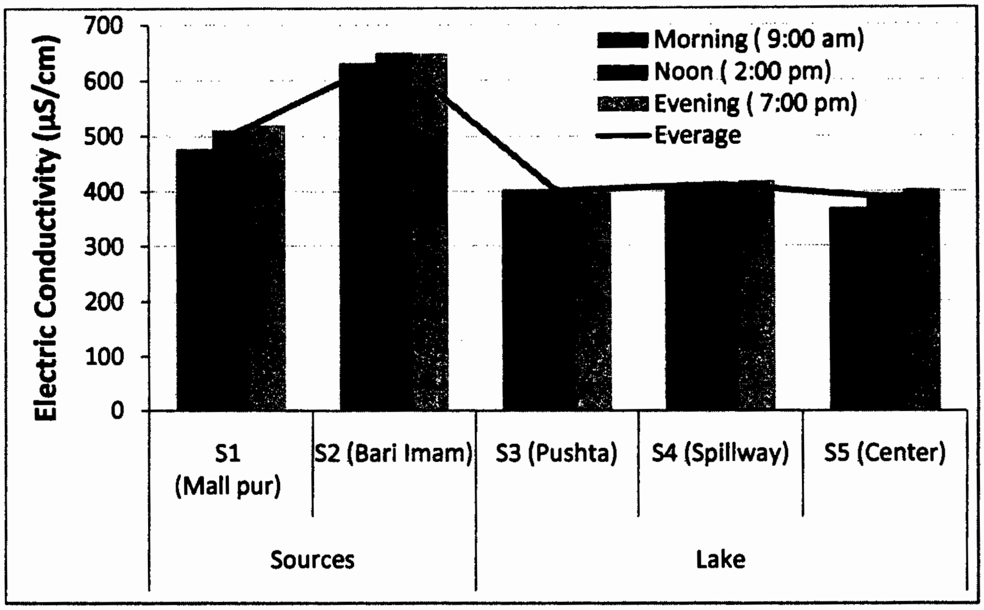

Fig. 3.1.5: Electric Conductivity of water samples at main source nullahs and different sites of lake

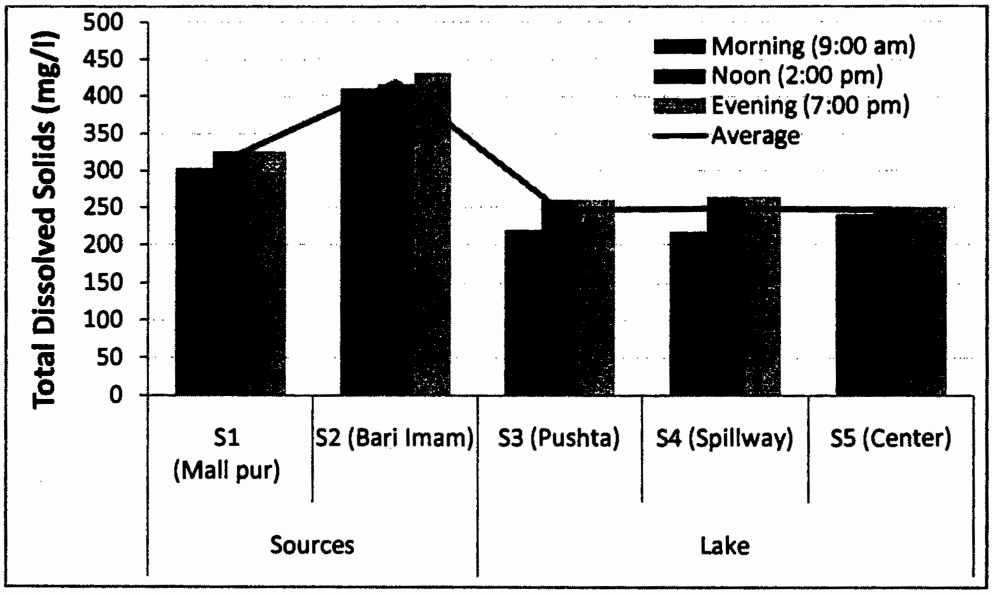

Fig. 3.1.6: Total Suspended Solids of water samples at main source nullahs and different sites of lake

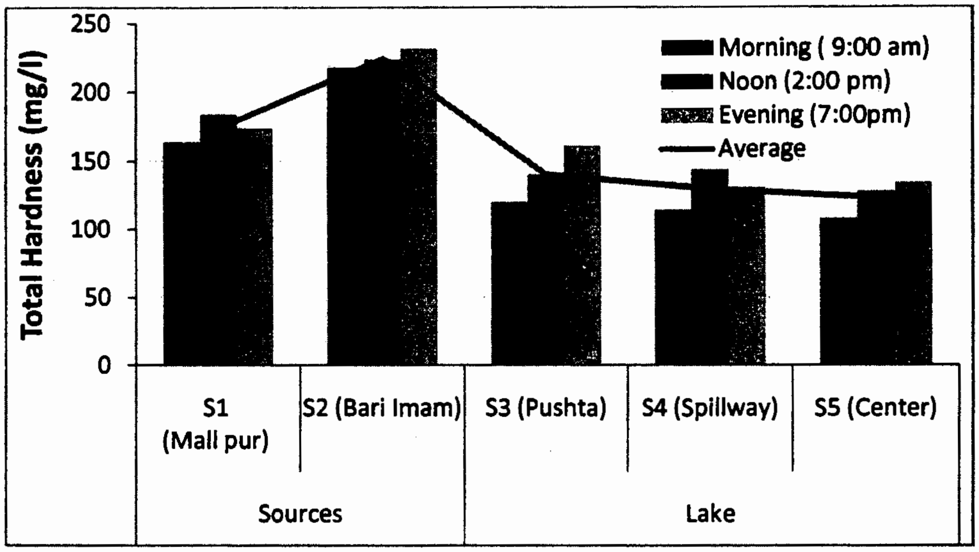

Fig. 3.1.7: Total Hardness of water samples at main source nullahs and different sites of lake

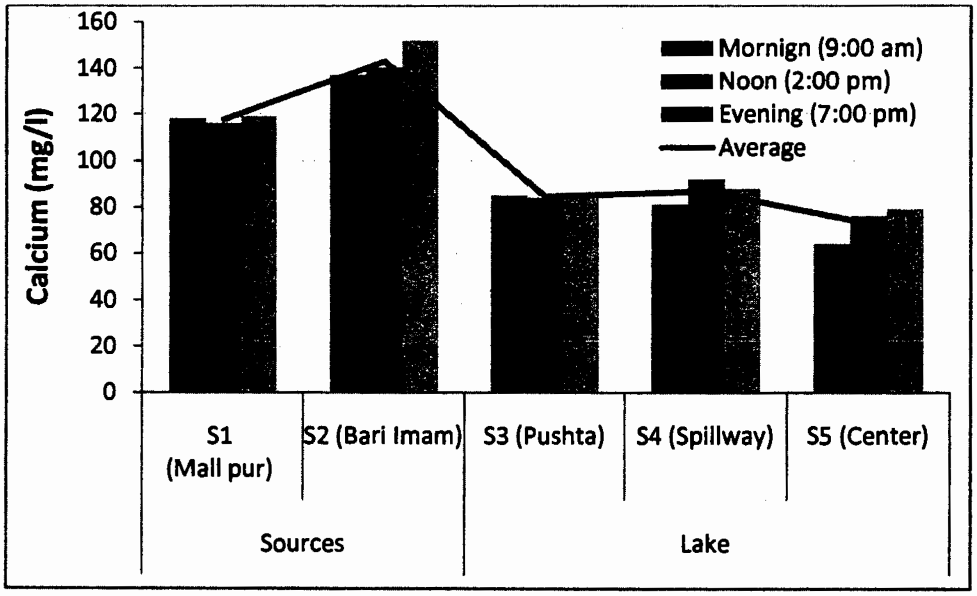

Fig. 3.1.8: Calcium Concentration of water samples at main source nullahs and different sites of lake

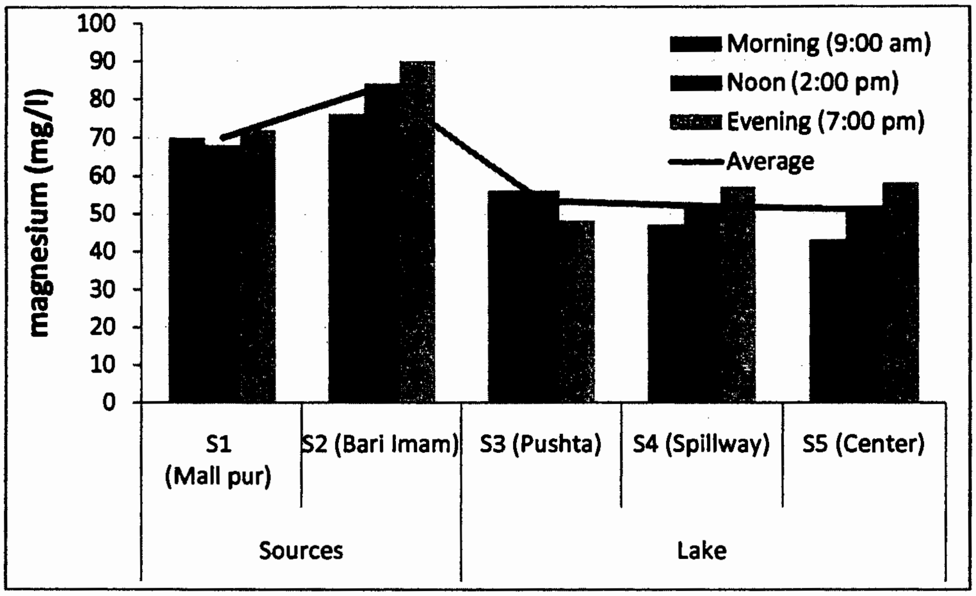

Fig. 3.1.9: Magnesium Concentration of water samples at main source nullahs and different sites of lake

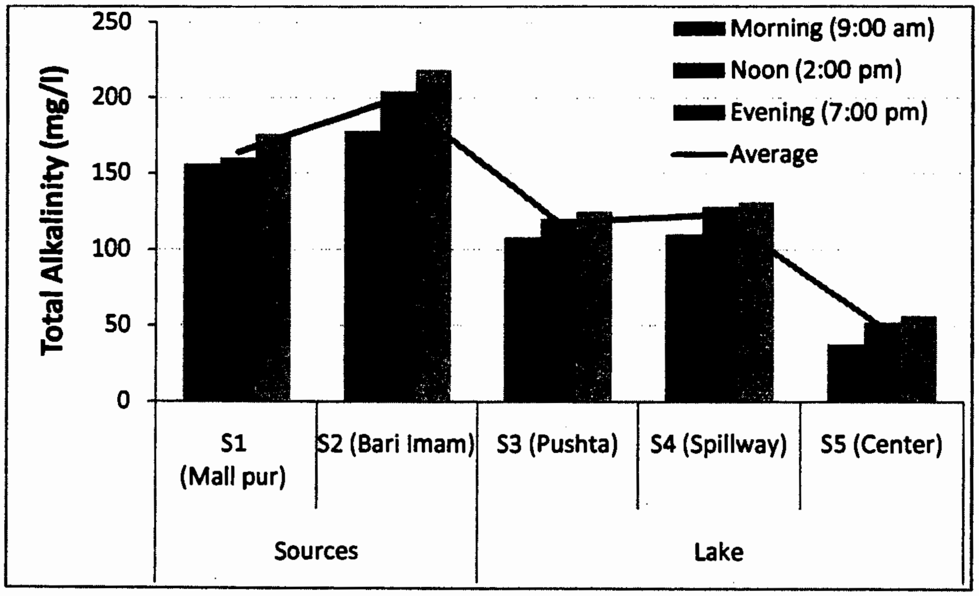

Fig. 3.1.10: Total Alkalinity of water samples at main source nullahs and different sites of lake

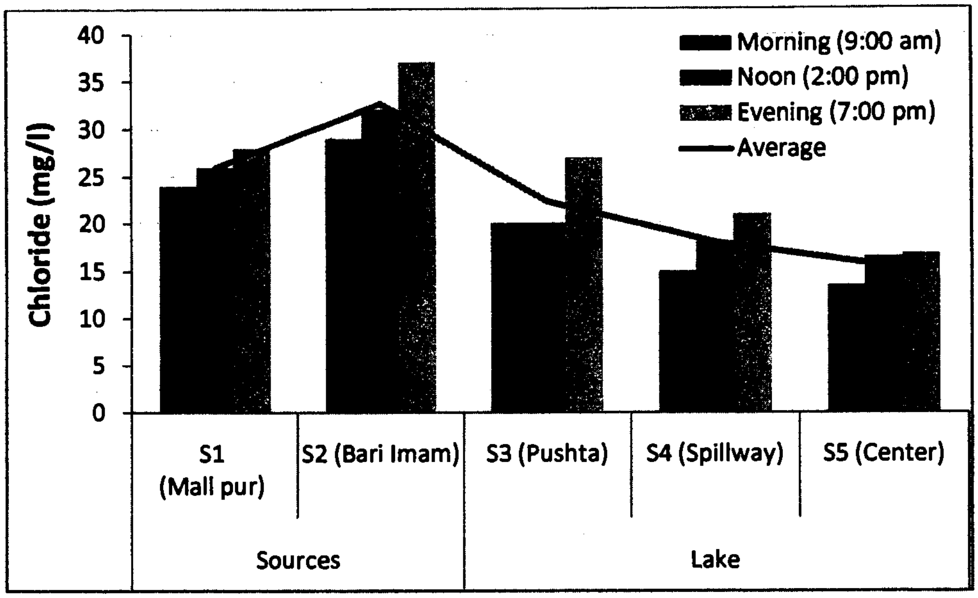

Fig. 3.1.11: Chloride Concentration of water samples at main source nullahs and different sites of lake

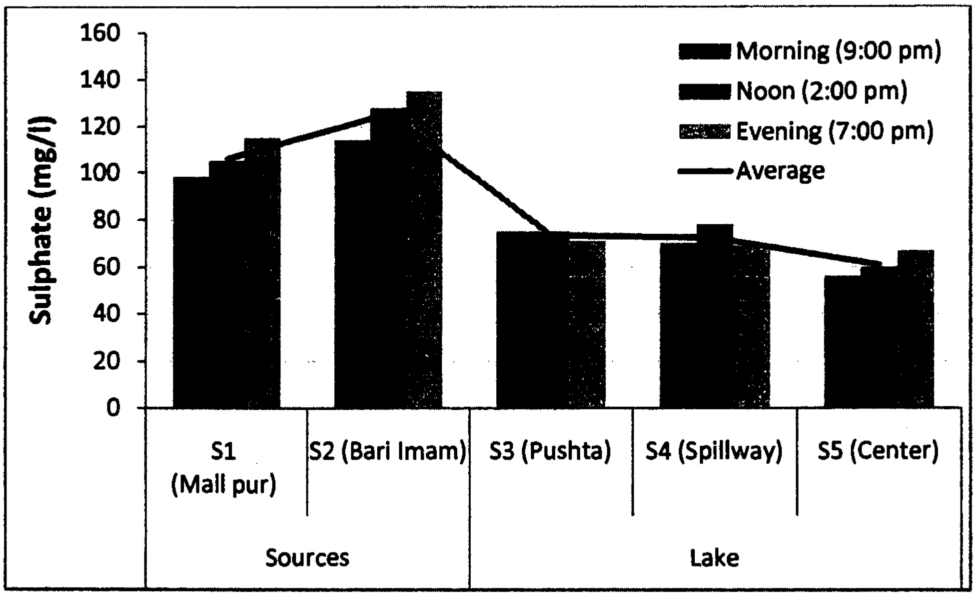

Fig. 3.1.12: Sulphate Concentration of water samples at main source nullahs and different sites of lake

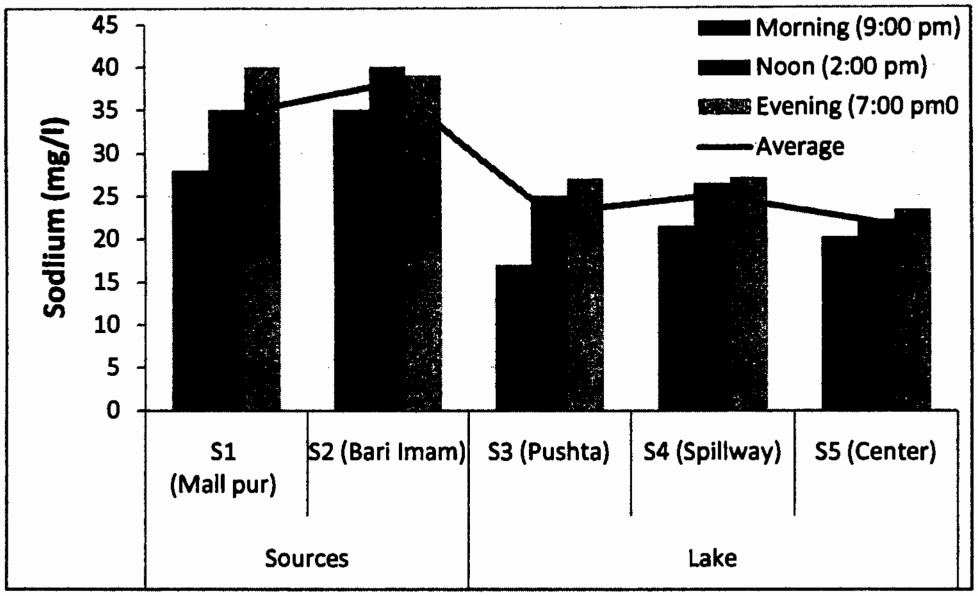

Fig. 3.1.13: Sodium Concentration of water samples at main source nullahs and different sites of lake

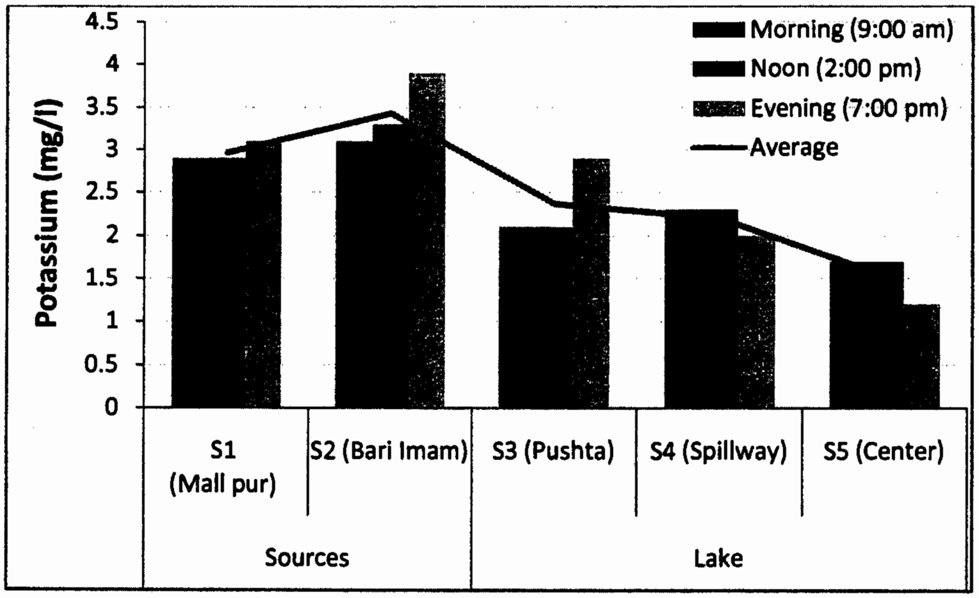

Fig. 3.1.14: Potassium Concentration of water samples at main source nullahs and different sites of lake

DISCUSSION

CHAPTER 4

4.1 Discussion

The supply of safe drinking water is beneficial for health and well-being of humans. In developing countries, more than 60 percent population lack pure drinking water. The World Health Organization (WHO) has reported that approximately half of the world human populations in the countries which are under development have no safe and pure water for to drink. The municipal water supply treatment plants if they not operate properly then it may be a source of diseases which leaves a bad effect over the large population. Hence the water should be monitored in a good drinkable quality and the sources of the water supply that provide water on regular basis should be pure and safe.

Current study was planned for to observe the quality of water of Rawal lake and the affects of associated source nullah (streams) on it. The results favorably indicated the fact that water quality of Lake has been seriously threatened by contaminants coming from major source nullahs. Comparatively, Mallpur nullah proved to be a major contributor in the deterioration of lake water quality. Similarly, Ahmed in 1998 also reported that nullahs that are originating from margallah hill are one of the major contributors of pollutants in Simly and Rawal Lake [44]. Except, bacterial count and TSS, all the water quality parameter of lake and source nullahs were falling within the prescribed limits of WHO and PSQCA (Table. 3.1.1). The possible source of bacterial contamination in the source nullahs and Lake Source might be domestic and commercial sources [45]. The present study revealed that the total bacterial count (CFU/ml) was in the range of 1805 to

588.66 (ave.) in the lake. While it was 1867.66 (ave.) and 2123 (ave) at Mallpur and Bari Imam respectively during the day. Total Coliform count (MPN/ml) was 28 (ave.) to >1600 (ave.) in the lake during the day, while it was >1600 (ave) at both sources during the day. Thus high total bacterial and coliform counts indirectly suggest us that water sources might have certain pathogenic organisms. However, other then pathogenic strains, even certain coliform can be at times problematic and may cause certain diseases [46], like cholera [47], diarrhea, hepatitis or typhoid and dysentery. Water which is fecal contaminated is considered to be a risk for human health [48]. The total bacterial count (CFU/ml) was 1640 and 1932 at Mallpur (S_1) and Bari Imam (S_2) respectively and this bacterial count kept on increasing during the day and was highest i.e., 2013 and 2317 in the two respective sources particularly at evening (Fig. 3.1.1) Similarly, total bacterial count (ave.) in Rawal Lake was observed during the day from 1824 to 2357. Increased in bacterial count during the day it surely indicated that water sources are being continuously contaminated from the residential areas around them.

Total solids include both the suspended and dissolved solids. Water with high solid contents is considered to be polluted. TSS may be on an account of clay, humus and other fine debris or particulate matter discharged into the water ways bodies. Suspended solids give the water a muddy or dirty appearance. They make water unfit for drinking, and domestic usage. TSS reduces light penetration in the water bodies. In other words, TSS overall reduces the gross productivity of the fresh water ecosystems [49]. Generally TSS (mg/l) was considerably higher than permissible limits of WHO in all the water samples collected at sources and Lakes (Fig. 3.1.3). A continuous shift in TSS (from 4-10) was observed at three spots during the whole day. Water samples with high TSS values again indicated that water sources have been contaminated from residential areas present around them.

pH is a particular and an important water parameter mostly used in the properties of natural waters. pH is the parameter which indicated the acidity and alkalinity of all kinds of water. Ph also regulates the biological processes and biochemical reactions within the living bodies. Most of the aquatic plants and animal species are adopted to live in a narrow range of pH from slightly acidic to slightly alkaline condition and drastic pH changes adversely affect them. pH of Rawal lake water samples was in the range of WHO prescribed limits (6.5-9.20). It was ≥ 7 & ≤ 8 at both sources and the remaining 3 sampling sites of Rawal Lake. pH greater than 7 is always objectionable in drinking water. In the present study, pH values were slightly higher than 7, besides, they kept on increasing though minute from morning till evening (Fig. 3.1.4). This slight change though non-significant also suggests that the contaminants in the form of detergents and bleaching agents were continuously being poured in water sources from the residential areas [50]. Total Dissolved Solids (mg/l) values showing no any greater value when the standard values of WHO which are 1000 mg/l. However, they were comparatively higher in water samples collected from S_2 (410, 416 & 431) than in S_1 (303, 326 & 326) during the three sampling times of the day respectively (Fig. 3.1.6). Total Dissolved Solids (TDS) increased (ave.) (226 to 258) from morning to noon but then it remained constant till evening in the lake. High level of TDS due to certain heavy metals may cause certain diseases in man and cattle as well [51]. Primary sources of TDS can be agriculture runoff, leaching of soil contaminants [52]. There are two reasons if the concentration of TDS increased in surface water, one is the industrial activities and second is earth crust which containing rocks. Variation in TDS can also be due to water flow in rivers and streams at different seasons [53].

Maximum chloride (mg/l) were found in S_2 (37) compared to S_1 (28). Chloride was slightly higher at S_3 during the day and the average concentration was 21.6 mg/l in evening at the Lake (Fig. 3.1.11) Chloride ion (Cl^{-1}) is most common anion found in the fresh water and though it is comparatively higher in marine and coastal water bodies. Portable water may contain small quantity of chloride without any harmful effects [54] while the permissible limit of chloride is 250 mg/l. Domestic use of Sodium chloride is also a main source of its presence in our surface water by residential areas besides the catchment area [55]. Excess of chloride may cause corrosion, harm metallic pipes and affect growing plants [56]. Total hardness (mg/l) values have a slight variation at the different sampling sites. Comparatively, it was found highest at sources (especially at S_2), where a change in it was noted from 218 to 232 during the day. Moreover, a continuous shift in hardness values was also observed in water samples at three sites from 108 to 161 mg/l during the day in Rawal Lake (Fig. 3.1.7). Natural water is classified into hard water and soft water. Mg and Ca content were also showing the total hardness in the water, these are interdependent to each other. Hard water does not lather with soap due to dissolved calcium and magnesium carbonates and bicarbonates [57]. The high level of calcium and magnesium were also showing variation at different sites because of the residue of soaps, (which originate from the residential areas), detergents and also because of parent bed rock materials [58]. Hardness can alter the pH of water. Such water is not suitable for drinking because it causes stomach disorders and results in dysentery. Such water is also not suitable for washing because a lot of detergent is wasted. It also reduces the efficiency of automobiles and industries by accumulation in pipes and boilers, reducing the internal pipe diameters. There is huge scientific information indicating certain inorganic or mineral constituents of drinking water correlate with morbidity and mortality of living organisms. The incidence of many chronic diseases, particularly cardiovascular associated with water characteristics specifically to hardness [59]. It has been reported that an inverse correlation exists between the incidence of cardiovascular diseases and the level of hardness [60].

Sodium ion are also present in the natural water, however it is higher in marine water. Sodium in water is originated mostly geologically with the help of leaching of surface and underground deposits of salt (e.g., sodium chloride) and also originated from sodium aluminum silicates decomposition and some types of minerals. Sodium is transport also by the human activities mostly through the use of Sodium chloride in household in other purposes. It is believed that excess intake of sodium in drinking water may effect our blood circulatory system or it cause low blood pressure, in contrast, while it is taken in low diet it may cause heart problems along with kidney failure and circulatory ailments [61]. In the morning, the sodium (conc.) (mg/l) was higher (35) at S_2 as compared to S_1, but its concentration became almost same in the evening at the both sources (40 at S_1, 39 at S_2). Sodium concentration varies at different sampling sites during the day, though it was highest at S_4.

Overall, the sodium concentrations in water samples of source and lake remained within the permissible limits (200 mg/l) of WHO. Both the water sources exhibited high values of calcium compared to lake water samples. Calcium was highest i.e., 152 mg/l at S_2 in the evening. The average concentration (mg/l) of calcium were 76.6, 84.6 and 142 at morning, noon and in evening at 3 site in the lake (Fig. 3.1.8). Our earth's crust is composed of many particular elements in which the Calcium is the third most constituent or we can say that Calcium compound account 3.64% of the earth's crust [62]. Calcium is an essential element for plants and animals, being a constituent of plant cell wall and bone in animals. Ground water lakes and rivers have calcium in the form of bicarbonates, causing a temporary hardness. Running water across such calcareous rocks gets enough calcium salts. Calcium deficiency causes leaves to curl or roll, reduction in root growth, fruiting and fiber formation work stoppage and bone deformation [63].

Magnesium levels (mg/l) were higher at S_2 than S_1. There was a gradual increase in magnesium concentration in both sources during the day. The highest values were observed at noon i.e., 72 mg/l and 90 mg/l in S_1 or at main Pushta and S_2 respectively. The concentration of magnesium varied at three spots during the day in the lake (Fig. 3.1.9) Being a major constituent of natural water, magnesium is also present in earth at the number of eighth by their accumulation among all elements. Magnesium and calcium, imparts the property of hardness in water [64]. At the sources there would be washing and bathing activities hence magnesium, calcium and pH and total suspended solid could be high. Alkalinity is the property of water that neutralizes the effect of acid in the water and its permissible limit is 500 mg/l. The alkalinity is also caused by the activities or functions of hydroxide, carbonate and the bicarbonate. Practically, the alkalinity is greater in the domestic water then that of pure water of surface that supplied to population [65]. The total alkalinity was comparatively highest in S_2 than S_1 and it was specifically observed maximum (218) in the evening. Maximum value of total alkalinity i.e., 110, 128 & 131 was noted at S_4 during the three respective times of the day; however, the average total alkalinity was 104 mg/l in the evening in the Rawal lake

Sulphate is the element which also found in earth's crust [66]. Mining operations release huge quantity of sulphate, while the industries and domestic waste also contribute a significant quality to our lake and streams. Sulphate is also main part of hard and it exists with the combination of calcium and magnesium. Sulfate corrodes the concrete and metallic pipe lines through the formation of sulphuric acid. High sulphate level supports the growth of sulphur bacteria in water which results in foul smell and bad test into the water [67]. Comparing two sources, the concentration of sulphate (mg/l) was highest (135mg/l) in the evening at S_2. At lake, maximum concentration (ave.) of sulphate was 78 in the morning at $S_{4.}$

Electrical conductivity E.C or specific conductance is the type of that ability of material that can conduct an electric current [68]. Dissolved salts ionize in aqueous medium. An inorganic substance shows better conductance than organic compounds because they do not dissociate easily. Electric conductivity (μS/cm) average was specifically higher at S_2 (643.33) than S_1 (502) (Fig. 3.1.5). A gradual incline in E.C (ave.) (393 to 406) was observed from morning to evening in the lake. Maximum EC (407, 412 & 418) was observed in the all the 3 samples collected at spillway (S_4) during the day. It means that mixing of contaminants took place during the course of water from sources to spillway, and EC value became stable and maximum when water reached at spillway.

CONCLUSIONS AND SUGGESTIONS

Conclusions and Suggestions:

- Water quality of Rawal lake was good with respect to most of the parameters, except;
    - Bacteria count (total and coliform).
    - TSS
- The water quality of two main source nullahs showed comparatively high levels (some contaminants even higher than WHO standards) of contaminants than the water of lake
- Mallpur and Bari Imam Nullah, the two main sources of water proved to be the main reason of contamination in Rawal lake.
- Comparatively, the water of Bari Imam nullah was more contaminated than Mallpur nullah.
- Water quality was more deteriorated with reference to total bacterial count as water moved from sources towards spill way of lake.
- Stabilization of water help removing TSS, however, TDS increased on the other hand in lake.
- The water quality of lake continuously deteriorated from morning till evening suggested input of contaminants from residential areas in source nullahs.
- Contaminants in water sources should be stopped before they enter in lake
- Residential areas should stop pouring their sewage disposal practices in the freshwater nullah (streams); otherwise, Govt. should plan proper sewage disposal practices and should take stringent actions that violate them.

- Disinfection practices for lake water are must otherwise associated population will be at risk with reference to infectious diseases.
- Considering high TSS, filtration practices should be practiced before water of lake is distributed to associated residential areas for consumption.
- Presence of objectionable levels of TSS and bacteria in lake water ultimate reduce dissolve O_2 levels thereby creating BOD issues.

REFERENCES

References:

1 Kahlown, M. A., Tahir, M. A., and Rasheed, H. (2008) Fifth Water Quality Monitoring Report 2005-2006. Islamabad: Pakistan Council of Research in Water Resources. 133-2007, vii-3.

2 Meybeck, M., Chapman, D., and Helmer, R. (1989) Global Freshwater Quality: A First Assessment. Blackwell Reference, Oxford, 306.

3 Meybeck, M., Chapman, D., and Helmer, R. (1989) Global Freshwater Quality: A First Assessment. Blackwell Reference, Oxford, 306.

4 Naik, I. U. (1986) Inland fisheries and aquaculture in Pakistan: review of the progress and new activities. Paper presented at FAO/IPFC Workshop on Strategies for the Management of Fisheries and Aquaculture in Mangrove Ecosystems, Bangkok, Thailand, 23-25.

5 Ahmed, I. (2002) Biotechnology for Sustainable water use. *Water and new Technologies*: Global Change Impact Studies Center, Islamabad, (113 pp).

6 Ali, S. S. (2003) Pollution definition and effects. *Basic concepts of Ecology*. 2nd Edition: Naseem Book Depot, Hyderabad, (262-263 pp).

7 Sinha, S., Shukla, M., and Shukla, R. (2005) Environmental pollution. *A text book of Environmental Studies*.1st Edition: AITBS Publishers and Distributers, New Delhi, (152 pp).

8 Ali, S. S. (2003) Pollution definition and effects. *Basic concepts of Ecology*. 2nd Edition: Naseem Book Depot, Hyderabad, (262-263 pp).

9 Akhtar, N., Jamil, M., Noureen, H., Imran, M., Iqbal, I., and Alam. A. (2005) Impact of Water Pollution on Human Health in Faisalabad City (Pakistan); *J. of Agriculture & Social Sciences.* Department of Rural Sociology, University of Agriculture, Pakistan. 1813–2235, 43-44.

10 Ahmed, I. (2002) Surface water resources. *Water and new Technologies*: Global Change Impact Studies Center, Islamabad, 21

11 Strategic Plan of the Pakistan council of Research in Water resources (2008). Pakistan Council of Research in Water Resources, Islamabad, 1-2

12 Report on Pakistan's Water at Risk. (2007) WWF- Pakistan, Frozepur Road, Lahore, 1-5

13 Waheed, T., and Kausar, T. (1987) Quality of drinking water in Lahore; *J.of Medical Research. Pakistan.* 26, 162-165.

14 Lars, F., Gunnar, F. N., and Velimir, B. V. (1986) *Handbook on the Toxicology of Metals*. Elsevier, Amsterdam, the Netherlands.

15 Gleick, P. H. (1996) Basic water requirements for human activities: meeting basic needs, Water International. 21, 83-92.

16 Ahmed, I. (2002) The Way forward. *Water and new Technologies*: Global Change Impact Studies Center, Islamabad, (15 pp).

17 Quality Drinking Water: Guidelines and Standards for Pakistan. (2005) Government of Pakistan, Ministry of Health, Health Service Academy, Islamabad, 1.

18 Gantidis, N., Pervolarakis, M., and Fytianos, K. (2007) Assessment of the quality characteristics of two lakes (Koronia and Volvi) of N. Greece Environmental Monitoring and Assessment. 125, 175-181.

19 Gray, N. F. (1994) Drinking Water Quality: Problems and Solutions: John Wiley and Sons Chichester, UK.

20 Guler, C., Thyne, G. D., McCray J, E., and Turner, A. K. (2002) Evaluation of graphical and multivariate statistical methods for classification of water chemistry data: *J. of Hydrogeology*. 10, 455-474.

21 Yayyntas, O. T., Yylmaz, Z., Turkoglu, M., and Dilgin, Y. (2007) Determination of heavy metal pollution with environmental physicochemical parameters in waste water of Kocabas stream, Biga, Canakkale, Turkey: ICP-AES. Environmental Monitoring and Assessment. 27, 389-397.

22 George, B., Arhonditsis, M., Winder, M., Brett, T., and Daniel, E. S. (2004) Patterns and mechanisms of phytoplankton variability in Lake Washington (USA). Water Research. 38, 4013-4027.

23 Likens, G. E., Borman, F. H., and Johnson, N. M. (1969) Nitrification: Importance to nutrient losses from a cutover-forested ecosystem, Science. 163, 1205-1206.

24 Vinçon-Leite, B., Tassin, B., and Druart, J. C. (2002) Phytoplankton variability in Lake Bourget: Phytoplankton dynamics and meteorology. Lakes and Reservoirs, Research and Management. 7, 93-102.

25 Sharpley, A. N., Chapra, S. C., Wedepohl. R., Sims, J. T., Daniel, T.C., and Reddy, K.R. (1994) Managing agricultural phosphorus for protection of surface

waters: issues and options: *J. of Environmental Quality*. 23, 437-451.

26 Meybeck, M., Chapman, D., and Helmer, R. (1989) Global Freshwater Quality: A First Assessment. Blackwell Reference, Oxford, 306.

27 Kannel, P. R., Lee, S., Kanel, S. R., Khan, S. P., and Lee, Y. (2007) Spatial-temporal variation and comparative assessment of water qualities of urban river system: a case study of the river Bagmati (Nepal). Environmental Monitoring Assessment. 129, 433-459.

28 Mastoi, G. M., Shah, G. S., and Khuhawar, M. Y. (2008) Assessment of water quality of Manchar Lake in Sindh, Pakistan. Environmental Monitoring Assessment. 141, 287-296.

29 Duman, F., Sezen, G., and Nilhantug, G. (2007) Seasonal Changes of Some Heavy Metal Concentrations in Sapanca Lake Water, Turkey: *International Journal of Natural and Engineering Sciences*. 1, 25-28.

30 Kazi, T.G., Arain, M. B., Jamali, M. K., Jalbani, N., Afridi, H. I., Sarfraz, R. A., Baig, J. A., and Shah, A. Q. (2008) Assessment of water quality of polluted lake using multivariate statistical techniques: A case study of Ecotoxicology and Environmental Safety. 72, 301-309.

31 Gupta, G., Abd-el-Hamid, Z., and El-Hamid, Z. A. (2003) Water quality of lake Qarun, Egypt: *International J. of Environmental Studies*. 60, 651-657.

32 Laws, E. A. (2000) Aquatic pollution. John Wiley and Sons, New York.

33 De-Jonge, V. N., Elliott, M., and Orive, E. (2002) Causes, historical development, effects and future challenges of a common environmental problem: Eutrophication. Hydrobiologia. 475/476, 1-19.

34 Kouimtizs, T. H., Samara, C., Voutsa, D., and Zachariadis, G. (1994) Evaluation of chemical parameters in Aliakmon River, N. Greece. *J. of Environmental Science and Health.* A29, 2115-2126.

35 Meybeck, M., Chapman, D., and Helmer, R. (1989) Global Freshwater Quality: A First Assessment. Blackwell Reference, Oxford, 306.

36 Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., and Smith, V. H. (1998) Nonpoint Pollution of surface waters with phosphorus and nitrogen. Ecological Applications. 8, 559-568.

37 De-Anda, J., Shear, H., Maniak, U., and Riedel, G. (2001). Phosphates in Lake Chapala, Mexico. Lakes and Reservoirs: Research and Management. 6, 313-321.

38 Ahad, K., Mohammad, A., Mehboob, F., Sattar, A., and Ahmed, I. (2006) Pesticide Residues in Rawal Lake, Islamabad. Pakistan Ecotoxicology Research Programme Institute: Institute of Plants and Environmental Protection, NARC, Islamabad, Pakistan. 76, 463-464.

39 Report on Rawal Lake Catchment Area Monitoring Operation. (2004) Pak-EPA, Ministry of Environment, Islamabad, 1-4.

40 Mohamed, A. E., Awadallah, R. M., and Gaber, S. A. (1990) Chemical and ecological studies on Tilapia nilotica: *Journal of Water South Africa*. 16, 131-134.

41 http://en.wikipedia.org/wiki/rawal_lake [Retrieved on 18.3.2009]

42 Ali, Z., and Akhtar, M. (2006) Decreases in size of lakes and numbers of birds in selected wetlands in Pakistan. Water birds around the world. Eds. Boere G.C., Galbraith. C.A. and Stroud. D.A: The Stationery Office, Edinburgh, UK. 294-295.

43 Report on Rawal lake Catchment Area Monitoring Operation. (2004) Pak-EPA, Ministry of Environment, Islamabad, 2.

44 Ahmed, A. (1998) Impact of environmental pollution in Rawalpindi-Islamabad. 24th WEDC Conference, Water and sanitation for all, 157.

45 Mastoi, G. M., Shah, G. S., and Khuhawar, M. Y. (2008) Assessment of water quality of Manchar Lake in Sindh, Pakistan. Environmental Monitoring Assessment. 141, 288.

46 Habteselassie, M., Bischoff, M., Blume, E., Applegate, B., Reuhs, B., Brouder, S., and Turco, R. F. (2007) Environmental Controls on the Fate of Escherichia coli in Soil. 190, 143.

47 Sadeghi, Gh., Mohammadian, M., Nourani, M., Peyda, M., and Eslami, A. (2007) Microbiological Quality Assessment of Rural Drinking Water Supplies in Iran: Journal of Agriculture and Health Sciences. Department of Environmental Health and Public Health, School of Public Health, Zanjan University of Medical Sciences, Zanjan, Iran. 3, 32.

48 Djuikom, E., Njine, T., Nola, M., Sikati, V., and Jugnia, B. (2005) Microbiological water quality of the mfoundi river watershed at yaounde, Cameroon, as inferred from indicator bacteria or fecal contamination: National Research Council of Canada, Boitechnology Research Institute, Canada. 122, 170.

49 Ambasht, R. S., and Ambasht, P. K. (2004) Total Solids. *Environment and Pollution.* 4th Edition: CBS Publishers and Distributers, New Delhi, (58 pp).

50 Ambasht, R. S., and Ambasht, P. K. (2004) pH. *Environment and Pollution.* 4th Edition: CBS Publishers and Distributers, New Delhi, (66 pp).

51 Ambasht, R. S., and Ambasht, P. K. (2004) Dissolved Oxygen. *Environment and Pollution.* 4th Edition: CBS Publishers and Distributers, New Delhi, (59 pp).

52 http://en.wikipedia.org/wiki/Dissolved_Solids [Retrieved on 2.6.2009]

53 Voutsa, D., Manoli, E., Samara, C., Sofoniou, M., and Stratis, I. (2001) A study of surface water quality in Macedonia, Greece: Speciation of nitrogen and phosphorus. Water Air and Soil Pollution, 13-32.

54 Ambasht, R. S., and Ambasht, P. K. (2004) Phosphorus. *Environment and Pollution.* 4th Edition: CBS Publishers and Distributers, New Delhi, (102 pp).

55 Herlihy, A. T., Stoddard, J. L., and Johnson, C. B. (1998) The relationship between stream chemistry and watershed land cover data in the Mid-Atlantic region, U.S. Water Air and Soil Pollution. 105, 377-386.

56 Ahmad, I. (2004) Final report on Analysis of Drinking water of Palas Valley. Palas Conservation and Development Project, NWFP, 17.

57 Ambasht, R. S. and Ambasht, P. K. (2004) Hardness. *Environment and Pollution.* 4th Edition: CBS Publishers and Distributers, New Delhi, (61 pp).

58 Bosnic, M., Buljan, J., and Daniels, R. P. (2000) Pollutants in tannery effluents: Definitions and environmental impact limits for discharge into water bodies and sewers, Regional Programme for Pollution Control in the Tanning Industry in South-East Asia, United Nations Industrial Development Organization, 1-26.

59 Ahmad, I. (2004) Final report on Analysis of Drinking water of Palas Valley. Palas Conservation and Development Project, NWFP, 16.

60 Sauvant, M-P., and Pepin, D. (2002) Drinking water and cardiovascular disease: Faculte de Farmacie, BP38, 28 place Henri Daunant, F63001 Clermout-Ferrand Cedex, France. 40, 1311.

61 Ahmad, I. (2004) Final report on Analysis of Drinking water of Palas Valley. Palas Conservation and Development Project, NWFP, 14.

62 http://en.wikipedia.org/wiki/Calcium [Retrieved on 2.6.2009]

63 Ambasht, R. S., and Ambasht, P. K. (2004) Calcium. *Environment and Pollution*. 4th Edition: CBS Publishers and Distributers, New Delhi, (98 pp).

64 Kahlown, M. A., Tahir, M. A., and Rasheed, H. (2008) Fifth Water Quality Monitoring Report 2005-2006. Islamabad: Pakistan Council of Research in Water Resources. 133-2007, 28.

65 Kahlown, M. A., Tahir, M. A., and Rasheed, H. (2008) Fifth Water Quality Monitoring Report 2005-2006. Pakistan Council of Research in Water Resources. Islamabad. 133-2007, 26.

66 Kahlown, M. A., Tahir, M. A., and Rasheed, H. (2008) Fifth Water Quality Monitoring Report 2005-2006. Islamabad: Pakistan Council of Research in Water Resources. 133-2007, 30.

67 Ambasht, R. S., and Ambasht, P. K. (2004) Sulpher, Sulphate, Sulphite and Sulphide. *Environment and Pollution*. 4th Edition: CBS Publishers and Distributers, New Delhi, (106-108 pp).

68 http://en.wikipedia.org/wiki/Electrical_conductivity [Retrieved on 2.6.2009]

APPENDIX

Appendix

Table. 3.1.1: Characterization of water samples of source nullahs and different sites of Lake in the morning (9:00 am).

Parameters	Units	WHO SWQ	NEQS	Water Quality of Sources		Water quality of Lake						
				S_1 (Mallpur)	S_2 (Bari Imam)	S_3 (Pushta)	S_4 (Spillway)	S_5 (Center)	Ave.	S.E (+/-)	Minimum	Maximum
pH	-	6.5-9.20	6.5-8.5	7.06	7.17	7.2	7.16	7.08	7.15	0.035	7.08	7.2
Electric Conductivity	µS/cm	NGV	NGV	476	632	403	407	370	393.33	11.72	370	407
Total Dissolved Solids	ml/l	1000	1000	303	410	220	218	241	226.33	7.35	218	241
Total Suspended Solids	mg/l	5	NGV	110	15	10	4	5	6.33	1.85	4	10
Total Hardness as $CaCO_3$	mg/l	500	NGV	164	218	120	114	108	114	3.46	108	120
Calcium as $CaCO_3$	mg/l	250	NGV	118	137	85	81	64	76.66	6.43	64	85
Magnesium as $CaCO_3$	mg/l	150	NGV	70	76	56	47	43	48.66	3.84	43	56
Total Alkalinity as $CaCO_3$	mg/l	500	NGV	156	178	108	110	38	85.33	23.67	38	110
Chloride as $CaCO_3$	mg/l	250	250-400	24	29	20	15	13.5	16.16	1.96	13.5	20
Sulphate as $CaCO_3$	mg/l	250	NGV	98	114	75	70	56	67	5.68	56	75
Sodium as $CaCO_3$	mg/l	200	NGV	28	35	17	21.5	20.2	19.56	1.34	17	21.5
Potassium as $CaCO_3$	mg/l	75	NGV	2.9	3.1	2.1	2.3	1.7	2.033	0.176	1.7	2.3
Total Bacterial Count	CFU/ml	< 100	NGV	1640	1932	1672	3245	556	1824.33	779.97	556	3245
Coliform Count	MPN/ ml	< 1.1	NGV	>1600	>1600	>1600	212	17			17	>1600

Abbreviation:
WHO = World Health Organization, NEQS = National Environmental Quality Standard, CFU/ml = Colony forming unit per milli liter, MPN/ml = Most Probable Number, µS/cm = Micro Siemens per centimeter, S.E = Standard Error, mgl/l = Milligram per liter, pH = Power of Hydrogen and NGV = No guideline values.

Table. 3.1.2: Characterization of water samples of source nullahs and different sites of Lake in the noon (2:00 pm)

Parameters	Units	WHO WQS	NEQS	Water Quality of Sources		Water quality of Lake						
				S_1 (Mallpur)	S_2 (Bari Imam)	S_3 (Pushta)	S_4 (Spillway)	S_5 (Center)	Ave.	S.E (+/-)	Minimum	Maximum
Ph	-	6.5-9.20	6.5-8.5	7.13	7.51	7.25	7.38	7.09	7.24	0.08	7.09	7.38
Electric Conductivity	µS/cm	NGV	NGV	510	650	403	412	395	403.33	4.91	395	412
Total Dissolved Solids	ml/l	1000	1000	326	416	260	264	250	258	4.16	250	264
Total Suspended Solids	mg/l	5	NGV	12	16	7	6	8	7	0.57	6	8
Total Hardness as $CaCO_3$	mg/l	500	NGV	184	224	140	144	128	137.33	4.80	128	144
Calcium as $CaCO_3$	mg/l	250	NGV	116	140	84	92	76	84	4.61	76	92
Magnesium as $CaCO_3$	mg/l	150	NGV	68	84	56	52	52	53.33	1.33	52	56
Total Alkalinity as $CaCO_3$	mg/l	500	NGV	160	204	120	128	52	100	1.33	52	128
Chloride as $CaCO_3$	mg/l	250	250-400	26	32	20	18	16.5	18.16	1.013	16.5	20
Sulphate as $CaCO_3$	mg/l	250	NGV	105	128	75	78	60	71	5.56	60	78
Sodium as $CaCO_3$	mg/l	200	NGV	35	40	25	26.5	22.2	24.56	1.260	22.2	26.5
Potassium as $CaCO_3$	mg/l	75	NGV	2.9	3.3	2.1	2.3	1.7	2.033	0.17	1.7	2.3
Total Bacterial Count	CFU/ml	‹ 100	NGV	1950	2120	1800	4600	600	2333.33	1185.09	600	4600
Coliform Count	MPN/ml	‹ 1.1	NGV	>1600	>1600	>1600	240	23			23	>1600

Abbreviation:

WHO = World Health Organizatión, NEQS = National Environmental Quality Standard, CFU/ml = Colony forming unit per milli liter, MPN/ml = Most Probable Number, µS/cm = Micro Siemens per centimeter, S.E = Standard Error, mgl/l = Milligram per liter, pH = Power of Hydrogen and NGV = No guideline values.

Table. 3.1.3: Characterization of water samples of source nullahs and different sites of Lake in the evening (7:00 pm)

Parameters	Units	WHO WQS	NEQS	Water Quality of Sources		Water quality of Lake						
				S_1 (Mallpur)	S_2 (Bari Imam)	S_3 (Pushta)	S_4 (Spillway)	S_5 (Center)	Ave.	S.E (+/-)	Minimum	Maximum
Ph	-	6.5-9.20	6.5-8.5	7.15	7.61	7.18	7.14	7.11	7.14	0.02	7.11	7.18
Electric Conductivity	µS/cm	NGV	NGV	520	648	397	418	403	406	6.24	397	418
Total Dissolved Solids	ml/l	1000	1000	326	431	260	264	250	258	4.16	250	264
Total Suspended Solids	mg/l	5	NGV	18	17	10	8	8	8.66	0.66	8	10
Total Hardness as $CaCO_3$	mg/l	500	NGV	174	232	161	131	134	142	9.54	131	161
Calcium as $CaCO_3$	mg/l	250	NGV	119	152	85	88	79	84	2.64	79	88
Magnesium as $CaCO_3$	mg/l	150	NGV	72	90	48	57	58	54.33	3.17	48	58
Total Alkalinity as $CaCO_3$	mg/l	500	NGV	176	218	125	131	56	104	24.06	56	131
Chloride as CaCO3	mg/l	250	250-400	28	37	27	21	16.8	21.6	2.95	16.8	27
Sulphate as $CaCO_3$	mg/l	250	NGV	115	135	71	69	67	69	1.15	67	71
Sodium as CaCO3	mg/l	200	NGV	40	39	27	27.1	23.4	25.83	1.21	23.4	27.1
Potassium as $CaCO_3$	mg/l	75	NGV	3.1	3.9	2.9	2	1.2	2.033	0.49	1.2	2.9
Total Bacterial Count	CFU/ml	‹ 100	NGV	2013	2317	1943	4519	610	2357.33	1147.29	610	4519
Coliform Count	MPN/ml	‹ 1.1	NGV	>1600	>1600	>1600	310	44		-	44	>1600

Abbreviation:
WHO = World Health Organization, NEQS = National Environmental Quality Standard, CFU/ml = Colony forming unit per milli liter, MPN/ml = Most Probable Number, µS/cm = Micro Siemens per centimeter, S.E = Standard Error, mgl/l = Milligram per liter, pH = Power of Hydrogen and NGV = No guideline values.