Yerevan State University
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Hydro-Ecology and Self-purification in Taleghan River (Iran)

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Thesis for Ph.D. Degree

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Actuality

The need for water in all life forms , from micro-organisms to man, is a serious problem today because many water resources have reached to the point of crisis due to unplanned urbanization and industrialization (Singh et al., 2002[1]; Dixit and Tiwari , 2008[2]).

They deliver a range of ecosystem functions and services that sustain biodiversity and human well-being. Rivers underpin biodiversity and deliver various socio-economic benefits to human (Hajkowicz, 2006[3]; Aura et al., 2017[4]; Singh, 2019[5]).

Water quality plays an important role in the health of humans, animals and plants. The quality of surface water within a region is governed by both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban, industrial and agricultural activities and the human exploitation of water resources) (Jarvie et al., 1998[6]; Liao et al., 2007[7]; Mahavi et al., 2005[8]).

The access to “closer and cleaner drinking water” is still a distant dream for about one-sixth of humanity on this planet (Smedley and Kinniburgh, 2002[9]). It is predicted that this increasing s carcity, and competition over water resources in the first quarter of the 21st century will dramatically change the way we value and use water (Mroczek , 2005[10]; Maqbool et al., 2011[11]). Assessment of surface water quality can be a complex process undertaking multiple parameters capable of causing various stresses on overall water quality.

As a major source for supply and transmission of consumptive water, the rivers are of particular importance. Increasingly development in agricultural and industrial activities as well as noticeable increase in the civil sewage have caused the rivers pollution, water quality reduction, and the biological death of rivers in some regions.

Quality of river water, in each region, is influenced by a number of parameters including catchments areas’ geology, atmospheric entries, water condition as well as man-made factors (Bricker and Jones, 1995 [12]Shrestha and Kazama, 2007[13]). Evacuation of man-made wastewater is a pollutant fixed source; meanwhile, surface water is a seasonal phenomenon, which is seriously influenced by the atmospheric condition in catchments (Najafpour et. al, 2008[14]; Singh et. al, 2004[15]; Karbassi et al., 2007[16]). Seasonal changes influence the precipitation rate, surface water, ground water streams and prevent the increase in density of pollutants proceeding from discharge flow changes of the river (Khaka and Khanal, 2008[17]; Monavari and Guieysse, 2007[18]; Mtethiwa et al., 2008[19]; Vega et al., 1998[20]).

Natural and artificial Estrogens, drug compositions and some other pathogenic bacteria can influence the rivers through wastewater treatment plant and leaky septic tanks (Gross et al., 2004[21]; Kinzelman, et al., 2003[22]; Williams et al., 2003[23]). One of the most common of these, E.coli (Escherichia coli), is the only member of the total coli form, group of bacteria that is found only in the intestines of mainly in mammals including humans (Divya and Solomon ,2016[24]) .
In this part you can say shortly (several sentensis) about created models as a ways to solve water problems and pollution ... some suggestions. In this content it actuality this will emphasize the relevance of your research.
Many tools can be used for planning studies. One of these tools is mathematical modeling. In recent years, mathematical simulation models have been consulted to solve the water pollution problem in a basin. A simulation models indicate the values of water quality variable given the flow, the quantity and quality of the waste loadings, and waste discharges or to increase the

waste assimilation capacity of the receiving systems. However, the applicability of models for different climate conditions needs to be tested to have accurate prediction by the model. Thus a model needs to be calibrated and validated before putting into use for accurate water quality simulation. QUAL2K is a one-dimensional river and stream water quality model that is an upgraded version of the QUAL2E model. The QUAL2K framework, which was developed by the US Environmental Protection Agency, can simulate the migration and transformation of conventional pollutants.

Objectives

The aim of this study was to analyze the ecological evaluations based on physical, chemical and biological parameters in Taleghan River (Iran) according to the use of this water for drinking, agricultural purposes, and to determine the interaction between physico- chemical and biological parameters changes.

Therefore, in this study, we measured the water parameters including important quality parameters as: the monthly temperature, dissolved oxygen, pH, BOD_5, COD, electro conductivity, N, NO_3^{2-}, NO_2^-, NH_4^+, PO_4^{3-} and the biological parameters were determined seasonally in 6 stations at the estuary (~51 km) of the Taleghan River.

To achieve this goal, the following tasks were formulated:

- The ecological analysis of the fecal coliform of Taleghan River.
- Physical-chemical analysis of the Taleghan River (such as temperature, dissolved oxygen, pH, BOD_5, COD, Conductivity, N, NO_3^-, NO_2^-, NH_4^+, PO_4^{3-}).
- Analyze and dynamics of the physicochemical parameters (temperature, dissolved oxygen, pH, BOD5, COD, Conductivity, N, NO3-, NO2-, NH4+, PO43-)Taleghan River.
- Evaluating the suitability of river water for drinking and agricultural uses.
- Evaluation of water quality according to National Sanitation Foundation (NSF) water quality index.
- Taleghan River water quality modeling based on Qual2k model.
- Investigation of phisico-chemical parameters changes during the years, 2009 and 2016.

Scientific novelty

The research includes the following novelties:

- Based on research data it provides information for the first time about the Self-purification process of the Taleghan River, Iran.
- Systematization of pollution control, determination and identification of the biological patterns in the studied rivers were carried out for the first time.
- Identification and systematization of pollution control, determination and revealed of the biological indicators in the studied rivers were carried out for the first time.
- Pioneered determination of the parameters affecting the Taleghan River at different seasons.
- For the first time, environmental parameters were identified and determined that affect the water quality of the Taleghan River, in different seasons
- To improve the ecological state and indicators of water quality, the quality model of Taleghan River was prepared for the first time.

Practical suggestions

Based on the received results of this research, the following recommendations are made:

- Results of cluster analysis should be considered in optimizing the number of monitoring stations. It is proposed to consider one station in the non-polluted zone (reference condition), one in low polluted zone and two in the polluted zone.
- Given the importance Taleghan River ecosystem or Taleghan River basin water resource (drinking water supply of Tehran city) and also the seasonal variations of different parameters, it is proposed that a kind of on line monitoring system be considered at selected stations for BOD_5, NO_3 and EC.
- Implementation of pretreatment units at local sand and gravel mines, villages and restaurants.
- Water withdrawal from the river and its tributaries for irrigation purposes should be strictly controlled by authorities.
- Increase the level of awareness and knowledge of local farmers, citizens and tourists about water quality concerns within the study area. This may be implemented through instructions in mosques, schools, restaurants and even road signs.
- The set up and activities of large and medium industries (with a potential to pollute) should be strictly controlled by environmental authorities within the area.
- Because of the low distance of point source pollution (Taleghan city) with river, some limitations such as wastewater inflow should be considered.

Practical importance

Talegan's river is one of the important rivers of the country (Iran). Overall, the river is located in the tourism region and attracts many travelers during one half of the year. The numerous restaurants, and aquaculture ponds, as well as the application of the river water for irrigation of the agricultural fields constitute the main consumers in the river's catchment basin.

The practical significance of this work is defined as the impact assessment of chemical and physical parameters of the Taleghan River, which can be an important criterion for further organization of drinking water and agriculture in the region.

Results of the research on biological pollution from sewage in water should be considered, and can be applied to evaluate and increase the self-purification capacity of the River.

The results obtained to identify the most contaminated sites in Taleghan River and its major tributaries will be revealed and presented to the municipal authorities for the development of measures to prevent further pollution of the river.

Presentation and Discussion of the findings:

Conferences and seminar;

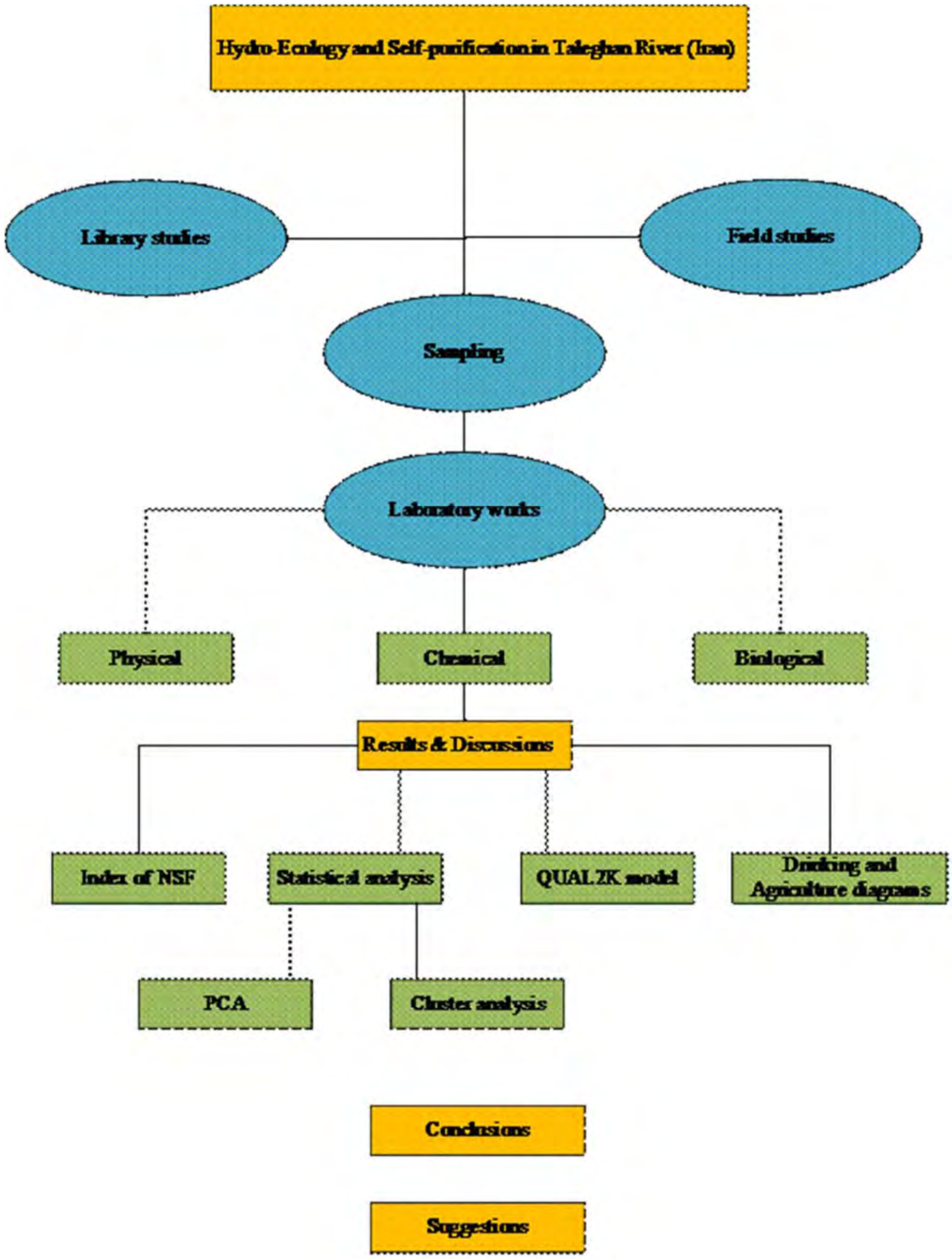
- The 2nd scientific-Research conference of Iranian students, Yerevan – Armenia 24, 25 June 2013- ISSN: 1829-3832
- (Index No. AB-299), ICGTCS-2012, Rajasthan in India.
- 7th national conference on water resources management,23oct 2018

Journals;

- ISSN 1829 – 0043 ՀԱՅԱՍՏԱՆԻ ՃԱՐՏԱՐԱԳԻՏԱԿԱՆ ԱԿԱԴԵՄԻԱՅԻ ԼՐԱԲԵՐ (ՀՃԱԼ). 2013
- AACL Bioflux, 2012, Volume 5, Issue 5. http://www.bioflux.com.ro/aacl
- Life Science Journal 2012;9(4) http://www.lifesciencesite.com
- National Academy of Sciences of RA Electronic Journal of Natural Sciences, 1(20), 2013

Volume and structure:

In chapter one, a general review of the research terminology was taken into consideration. Chapter two is dedicated to introduction of the study area as well as details such as the specifications of sampling stations, the sampling campaign, the analytical procedures and the model's descriptions. In chapter three results and discussions about the temporal and spatial variations in river water quality (NSF WQI), water suitability for drinking and irrigation uses as well as water quality modeling (Qual2k) are discussed. In the end, a conclusion on different parts about water quality and modeling is presented and practical solutions are recommended.



Procedure of doing study

Publications:

- Evaluation of river water quality by Canadian water quality index, Case study of Taleghan River, Iran, The 2nd scientific-Research conference of Iranian students, Yerevan – Armenia 24, 25 June 2013- ISSN: 1829-3832
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- ISSN 1829 – 0043 ՀԱՅԱՍՏԱՆԻ ՃԱՐՏԱՐԱԳԻՏԱԿԱՆ ԱԿԱԴԵՄԻԱՅԻ ԼՐԱԲԵՐ (ՀՃԱԼ). 2013

- Evaluation of seasonal variations in physicochemical parameters of Taleghan River, northern Iran, AACL Bioflux, 2012, Volume 5, Issue 5. http://www.bioflux.com.ro/aacl
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- Water Quality Assessment of Taleghan River, Life Science Journal 2012;9(4) http://www.lifesciencesite.com
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- Environmental effect for Nitrogen and Phosphorus Rates in Water of Taleghan River During 2008-2009, National Academy of Sciences of RA Electronic Journal of Natural Sciences , 1(20), 2013
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- Effects of Chemical Wastes on Drinking Water Quality, Case Study of Taleghan River, Iran, (Index No. AB-299), ICGTCS-2012, Rajasthan in India.
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- Modeling of river water quality using qual2k case study of Taleghan river, 7th national conference on water resources management, 23oct 2018, hamid reza sharif Vaghefi,L.Hambarian

1 Literature Review

- **Introduction**

Water quality has an important impact on human health, animals and plants.

Surface water quality in a region is affected by natural factors such as the rate of precipitation, atmospheric erosion, soil erosion; man-made factors such as Urban, industrial and agricultural activities as well as the exploration of water resources (Jarvie et al., 1998[6]; Leao et al., 2007[7]; Mahavi et. al., 20058; Singh and Singh 20195).

As one of the most important sources of water, rivers have a significant role to play. Surface runoff of pollutants is still very much a seasonal phenomenon and occurs in a basin under atmospheric conditions (Karbassi et al., 2007[16]; Najafpour et al. 2008[14]; Singh et al., 2004[15]).
Water quality models have been used extensively in water resources management to improve understanding of the system and support decision making (Hoang et al., 2019[25]).

Taleghan River is one of the major rivers in the northern parts of the country from economic and social points of view.

Generally, the river is considered as a regional tourist attraction drawing many travelers, from all over the country.

Accumulation of restaurants and farms around the banks of the river and the withdrawal of river water for irrigation in the basin pose major threats to the water quality.

1.1 Research objectives:

Research objectives is include the study of water quality and the self-purification process of Taleghan River, identification of the sources of pollution, and recommendation of necessary decisionsand solutions to the river. The main objectives of this dissertation are:

- Survey of Taleghan region, Taleghan River and identification of the of the pollutants' sources.
- Sampling from six determined stations in the main channel and conducting the biological and physical, chemical analyses.
- Determining the quality of river by application of NSFWQI (National Sanitation Foundation water quality index).
- Determining the water quality of river for different consumptions.
- Compiling the purification schedule in the scope of studies and information of this dissertation.
- Eventual Conclusion and Suggestions

1.2 A review of the research background

An experimental study on surface water of Chalakudy River was conducted during Jan2013-Dec 2013 by Divya and Solomon (2016)[24] to assess the pollution load in the river due to the presence of Coliform bacteria in Chalakudy River. In this study the presence of Coliform Bacteria in MPN/l was surveyed. The study intended to find the effect of pollution by analyzing the water quality parameters like pH, EC, TDS, TC and FC in Chalakudy River. Physicochemical parameters of river water like pH, EC and TDS were analyzed along with this microbiological analysis. It was revealed that increase in TC and might cause increase in Bacterial Count those results in water borne diseases, and can affect water quality in future. Also, microbial contamination was detected as very high in the form of Total Coliform bacteria.

Following the self-purification study of Babolrood River using the Qual2E software, which was undertaken by Nasrollahi, this software was used for modeling the quality of river after identification of the pollutant unit in the river. In addition, the pollutant sources of the river were identified by using the graphic outputs of the model. Finally, some alternatives and resolutions were suggested for removing the pollution (Nasrollahi 2005[26]).

In winter 2011, (Noshadi and Hatamizadeh)[27] and in September 2003, Ataei[28] undertook a research under the title of Nitrogen Changes in the Kor River and its Effects on the River Solution Oxygen Balance. Kor River is one of the major sources of water supply in the province of Fars.

Development of various agricultural, industrial and residential units in the river margin has intensified the discharge of more sewage and different pollutants to it. Among these polluting substances, Nitrogen is one of the main sources of the river pollution.

Among processes of Nitrogen cycle, Nitrification process reduces the quality of the water of these environments by decrease in density of oxygen solution in the water environments. Therefore, the objectives of the research are around the question of whether Nitrification occurs in the Kor River or not and if the answer is yes, its intensity (gravity) index (km) will be calculated. Accompanying these considerations is the study of Kor River condition including its Nitrogen compositions.

Different measurements conducted during the period of sampling showed that density of different Nitrogen compositions in the scope of this study is, dominantly, more than the allowed densities. In this case, sewage of Fars petrochemical complex was determined as the main source of pollution of the Kor River, as far as Nitrogen compositions are concerned.

Industrialization and urbanization have caused water pollution and ecosystem degradation, especially in urban canals and rivers in China. Accordingly, effective water quality improvement programs are needed. In a related study, the Tianlai River in Jiangsu, China was taken as a research site, and a combination of ecological purification technologies consisting of biological rope, phytoremediation, and activated carbon were applied in a laboratory-scale study to examine degradation coefficients under dynamic water conditions. Coefficients were then input into the QUAL2K model to simulate various hypothetical scenarios and to determine the minimum density of ecological purification combination and hydraulic retention time (HRT) to meet Grade V or IV of the China standard for surface water (Zhu et al.,2015).[29]

In a research, Rahimabadi,[30]tried to consider the effect of pollutant sources on the quality of Zayandehrood River. To do this, he used the computerized model of Qual2E for assimilation of Zayandehrood water quality. In this study, the results of Qual2E model in the periods of August and February were calibrated with the actual results and a comparison was drawn between them.

They showed some differences due to parameters with little information about, as well as the shortage of data to create the river's hydrological model and the ambiguity in the heaviness and the error indices of the experimental results (Rahimabadi 2000[30]).

Hernandez-Ramirez et al., 2019[31] did a research about Atoyac water river quality in Mexico. Atoyac River is considered to be one of the most polluted rivers in Mexico due to the discharges of untreated or partially treated wastewater from industrial and municipal activities. In order to improve the river water quality, it was obligatory to identify the possible contaminant sources for upholding a well-balanced ecosystem. Henceforth, the present study incorporates the application of a continuous real-time monitoring system to identify the provenance of pollutants of the river mainly from anomaly events. Four monitoring stations were installed all along the River Atoyac in the State of Puebla, Central Mexico. The real-time monitoring systems had an ability to measure various water quality parameters for every 15 minutes such as Temperature (T), pH, Conductivity (EC), turbidity (TURB), Dissolved Oxygen (DO), Oxidation Reduction Potential (ORP) and Spectral Absorption Coefficient (SAC). In total, eight water samples of anomaly events (i.e.) 2 per monitoring station during rainy (August–September) and winter seasons (November–December), that were detected using the parameters previously mentioned were procured and also analyzed in the laboratory for evaluating almost 54 physicochemical, inorganic and organic characteristics. Statistical results of factorial analysis explained that 30% of the total variance corresponded to textile effluents, 23% related to discharges produced by automobile and petrochemical industries, and 18% of the total variance defined the agricultural activities. Additionally, indices like Overall Index Pollution, Heavy Metal Evaluation Index, Screening Quick Reference Table and Molecular ratios of hydrocarbons for PAH sources was also calculated to estimate the grade of pollution and associated ecotoxicological risks. The results were definitely provided valuable information for the management of river water quality by developing stringent public policies by governmental agencies for the sustainable conservation of Atoyac River.

Jafarzadeh et al., 2008[32], did a research under the title of "Consideration of Quality of the Karon River Water by use of Qual2E Program". The research studies the quality of water in the project of Karun River water management with the aim of considering the water quality condition in the existing situation as well as in development conditions. It also tries to the issues and problems of increasing and irregular water exploitation from this river compared with the performance quality. In this study, while considering the statistics of the measured data in the previous years, the results of the previous performed consideration were also evaluated. In addition, given the role and importance of the new data resulting from quality parameters of the river water and their time, in this study, one year sampling was carried out from the important sites for civil, industrial, and agricultural sewage as well as from the stations on the river and the experiments results were applied to analyze the project. Moreover, these results were used in a specific mathematic model for predicting the water quality (Qual2E). The condition of river water quality in the existing situation and development condition were assessed after calibration of the above-mentioned model. Eventually, the studies' results and application of the model express the pollutant condition of the river in the existing and future conditions without refinement of influents.

In a research in 2007, PoorKarimi[33]tried to identify the pollution sources of Qareh Aghaj River and their effects on the quality of river's water by use of Qual2E model. He reported that the quality of Qareh Aghaj River water is adequate for agriculture but it needs primary treatment and chlorination to be fit for drinking. At the river's estuary, the electric conductivity of the river water increased due to the different geological formations, salty dome, and the confluence of the joining the salty river of Jahrom and Qareh Bagh River. The region's agricultural lands are the real source of the river pollution.

Kuo et al., 2019[34] studied water quality variability of Han River in China. The middle and down streams of Han River are complex river systems influenced by hydrologic variations, population distributions, and the engineering projects. The Middle Route of China's South-to-North Water Transfer (MSNW) project planned to transfer 95 billion m^3 annually from Han River to north China. The operation of the MSNW project may alter the flow rate and further influence the water quality of Han River. This study used min/max autocorrelation factor analysis (MAFA) and dynamic factor analysis (DFA) to analyze spatio-temporal variations of the water quality variables in three typical tributary-mainstream intersection zones in Han River from June 2014 to April 2017. MAFA results showed that chlorophyll-a (Chl-a), chemical oxygen demand (COD), suspend solid (SS) and phosphate (PO_4^{3-}) (represented as trophic dynamics) were main concerned water quality variables in densely populated zones (Zones 1 and 3), and total nitrogen (TN), nitrate nitrogen(NO^{3-}), COD, and PO_4^{3-} (regarded as nutrient formations dynamics) represent the underlying water quality variations in agricultural cultivation zone (Zone 2). DFA results indicated that domestic and municipal effluent pollutants influence the organic concentrations and nutrient formations in the mainstream in Zones 1 and 2.
The non-point source nitrogen and phosphorus discharged from the tributaries Tangbai and Hanbei Rivers elevate the nutrient concentrations and increase Chl-a concentration (i.e. promote the algal growth) in densely populated zones. In addition, controlling the flow rates in low and middle flow rate conditions can avoid degrading water quality. The flow rate should be elevated to more than 700 cms (cubic meters3per second) in the middle stream and to more than 800 cms in the downstream of Han River for preventing water quality deterioration from high loadings of organic pollutants and nutrients. The integrated MAFA and DFA method establishes an efficient analysis distinguishing spatio-temporal variation of water quality variables and provides useful site-specific management to control water quality in various flow conditions.

(Karamoz et al,1997) conducted a research in 1997[35] under the title of "Mathematical Model of Exploitation from Zayandehrood Dam" in which they studied Zayandehrood River from the two aspects of quality and quantity. thequality study dealt with collection of self-straining model and quality of Zayandehrood River. In this part, the impacts of various water quality parameters of Zayandehrood included in the scope of the study (from Tanzimi dam to Gavkhoni swamp) were analyzed by using the results of tests conducted by of Isfahan Environment Administration. In thi project, a computer model was used for assimilation of two parameters of BOD and DO as quality indicators of water pollution.

Park et al., used Qual2k and Qual2E models to model quality of Nakdong River water in Korea. For doing so, they gave parameters including: DO, BOD, Nitrate, and coliform as the input to the two mentioned models. The result of this study showed that Qual2k software shows a closer correlation with the samples taken from the river as well as a higher ability in comparison with Qual2E for modeling quality of water (Park et al., 2001[36]).

For modeling the quality of Yamona River in India, Paliwal et al., used Qual2E model. The result clearly identified the scope of pollution (Paliwal et al., 2006[37]).

In their study on Balatuin River in Philippine, Mcavoy et al., used Qual2E model to evaluate the effect of unrefined material in the river water. The result showed the adequacy of the model in error evaluation of unrefined sewage in the receptive water (McAvoy et al., 2003[38]).

Van Orden and Uchrin used Qual2E model to consider water quality of Whippany River in New Jersey in which quality parameters of DO, BOD, photosynthesis, hydrologic and morphologic conditions of the river were assimilated (Van Orden and Uchrin, 1993[39]).

Angola is one of the countries with a high rate of waterborne diseases, due to the scarcity and poor quality of water for human consumption. The watercourses are receptors of many effluents, mainly domestic sewage, due to a precarious or inexistent sanitation system and a small number of wastewater treatment plants. In 2019, Paca et al.[40], have studied quality assessment of water intended for human consumption from Kwanza, Dande and Bengo rivers.
The aims of this study were, (i) to evaluate the water quality (physicochemical and microbiological parameters) of three Angolan rivers (Kwanza, Bengo and Dande) in locations where water is used as drinking water or abstracted for human consumption; (ii) to develop a new water quality index able to quantitatively express the water quality in those sites; and (iii) to assess the spatial distribution of water pollution through principal component analysis (PCA).
Water quality assessment was performed by conducting four field surveys (campaigns I to IV); the first two campaigns took place in the dry season, while the last two ones took place in the rainy season. In the first two campaigns, the water quality was suitable to be treated for the production of drinking water, while in the last two campaigns, the water was unsuitable for that purpose (high levels of fecal coliforms were detected). The water quality index allowed to classify the water as generally excellent (campaigns I and II) and poor (campaigns III and IV). The rudimentary disinfection usually performed by individual water suppliers may improve the water quality, but it was not enough to achieve the parametric values required for human consumption in the rainy season (campaigns III and IV) except for Bengo sites. PCA identified sampling sites with the same water quality patterns, grouping into four groups (Kwanza sites) and two groups (Dande and Bengo sites). Therefore, the results of this study can support decision-makers as regards water supply management in the river stretches under study.

In 1999, Drolc et al. performed a project under the title of Calibration of Qual2E Model for Sava River in Slovenia. In this project, QUAL2E model, which was provided by the Environment Protection Organization of United State, was applied to evaluate the effect of sewage discharges to the Sawa River. To do it, sewage and soluble organic materials thrown into the Sawa River were considered. Based on the model's results, it was concluded that the sewage discharged to the river should be treated during the low flow conditions in summers to ensure a BOD_5 less than 30 mil-gr/lit. In this condition the water quality standards of Slovenia will be utilized namely and the concentration of dissolved oxygen will remain higher than 5 mil-gr/lit (Drolc et al., 1999[41]).

In 2019, multivariate statistical analysis and water quality index were used for health risk assessment by domestic use of Tana River in Kenya by Njuguna et al[42].
Tana River basin covers approximately 21% of Kenya's total land area. The basin produces about 33.5 % of the country's surface water and 23.8% of underground water that supports about seven million people. To assess metal and nutrient concentration of Tana River surface water, 57 and 53 water samples were collected in wet (May) and dry (August) seasons of 2018, respectively.
Cadmium, chromium, nickel, lead, mercury, arsenic, manganese, zinc, copper, aluminum, boron, selenium, fluoride, chloride, total phosphorus and nitrate were analyzed. Water quality index (WQI) was used to classify water quality into four categories based on pollution level while hazard quotient (HQ) and hazard index (HI) were used to assess non-carcinogenic risk posed to human health since majority of people in the lower reach use Tana River water without any form of treatment. Multivariate statistical analysis was applied to deduce associations and identify

pollution sources. Arsenic, cadmium, lead, nickel, selenium and mercury were not detected while manganese, chloride and aluminum were the principal pollutants in the two seasons. 26.3% of all studied sites recorded HQ >1 due to high Mn contamination. WQI was noted to be unreliable risk assessment tool since it did not correlate well with HQ and HI besides portraying all sampling sites as bearing suitable water for drinking. Tana River is at risk of eutrophication since total phosphorus concentration detected exceeded recommended threshold. Leached fertilizer from encroached riparian zone, fuel from leaking irrigation pumps and cleaning of motor bikes on water ways was the main source of anthropogenic pollution. Pollution processes and practices observed can be remedied to curb detrimental effects on human health.

In 1996, Melching et al. conducted a research under the title of Uncertainty of the Key and Important Sources in Qual2E for Passaic River in New Jersey. The study explains the methods used to calculate the necessary data for the model that resulted in the reduction of uncertainty in prediction. In this research, the effect of reduction of uncertainty in aeration speed and special maximum speed of alga on uncertainty of DO prediction and chlorophyll A respectively have been shown; consequently, it was recognized that re-aeration speed and special maximum growth of alga play an important role in the uncertainty of prediction (Melching et al., 1996[43]).

In 1997, Dussailant executed a project under the title of “Modeling Quality of Mapuchu River Water by Use of Qual2E Model”. The project aimed at predicting the effects of pollutant, resulting from the future projects on quality of the river water and proposing some adequate solutions and programs in the beginning of 1999. In this research, the river was defined by hydraulic and environmental indicators as well as the indicators of sewage discharge points and water exploitation from the river for assimilation by Qual2E- UNCAS model. The assimilation results for different projects show a noticeable improvement in BOD and fecal Coliform, but they do not match with those of standards quantity (Dussailant, 2007[44]).

Hoang et al., 2019[25] integrated SWAT and Qual2K for water quality modeling in a data scarce basin of Cau River basin in Vietnam.

The important inputs to the water quality model are pollution concentrations and discharge from river tributaries, lateral inflows and related pollution load from different sources along the river. In general, such an extensive data set is rarely available, especially for data scarce basins. This makes water quality modeling more challenging. However, integration of models may be able to fill this data gap.
Selection of models should be made based on the data that is available for the river basin. For the case of Cau River basin, the SWAT and Qual2K models were selected. The outputs of SWAT model for lateral inflows and discharges of ungagged tributaries, and the observed pollutant concentrations data and estimated pollution loads of sub-watersheds were used as inputs to the water quality model Qual2K. The resulting Qual2K model was calibrated and validated using recent water quality data for two periods in 2014. In this study four model performance ratings PBIAS, NSE, RSR and R2 were used to evaluate the model results. PBIAS index was chosen for water quality model evaluation because it more adequately accounted for the large uncertainty inherent in water quality data. In term of PBIAS, the calibration and validation results for Cau River water quality model were in the ‘‘very good’’ performance range with |PBIAS| < 15%. The obtained results could be used to support water quality management and control in the Cau River basin.

In 2004, Thomas et al. conducted a research under the title of "Importance of the Field Data in Quality Modeling of Water of Surface Flow by Use of QUAL2E- UNCAS". In this research, they studied the QUAL2E- UNCAS model for dissolved oxygen assimilation of rivers in the condition of sustainable stream flow. In this article, some applications of this model are reviewed. Moreover, the capability of analyzing uncertainty as well as the importance of field data in the model prediction (Thomas et al., 2004[45]) are explained.

In 2017, Rezaei Tavabe et al. [46] had used biological index for pollution assessment of Dammghanroud River in the Semnan province. This river supplies some parts of drinking water of Damghan city and some vicinity villages. The aim of this study was biological index assessment of the Damghanroud River. At this study, seven sampling stations were determined based on limnological standard method along the river. Sampling of invertebrates and water were performed respectively to calculate biological index and biochemical oxygen demand (BOD_5) seasonally during the study period. The results showed that the first station (Cheshmeh-Ali) was free of pollution while the fourth sampling stations (Doab) were the most polluted region at the river because the first station had no pollutant resource but the fourth station directly received wastewater of the agricultural activities and rural wastewaters. According to biomonitoring and water BOD_5 measurement findings, Damghanroud River had relatively polluted situation and was classified in β-mezosaprobe class and benthos biological index has been deteriorated at this river.

In order to consider the outputs of MIK11, QUAL2E, SIMCAT, TOMCAT, and ISIS models, Cox et al. have conducted the assimilation of quality parameters of dissolved oxygen by the above-mentioned models. The result showed the good output and the accuracy of the model in river system (Cox, 2003[47]).

Qinggai Wang etc. in 2013 reviewed the development of surface water quality models at three stages and analyzed the suitability, precisions, and methods among different models. Standardization of water quality models can help environmental management agencies guarantee the consistency in application of water quality models for regulatory purposes. They concluded the status of standardization of these models in developed countries and put forward available measures for the standardization of these surface water quality models, especially in developing countries (Qinggai Wang etc., 2013[48])

In 2019, Semenov et al.,[49] evaluated the Self-Purification Capacity of surface waters in Lake Baikal Watershed. In this study removal of trace metals (TM), dissolved organic carbon (DOC), mineral nitrogen (N_{min}), and polycyclic aromatic hydrocarbons (PAH_s) from the water of Lake Baikal and its tributaries was evaluated. The contaminant removal rate (CRR) and the contaminant removal capacity (CRC) were used as water self-purification parameters. The CRR was calculated as the deference between contaminant mass flow rates at downstream and upstream gauging stations. The CRC was calculated as the quotient of the CRR and the change in water discharge between downstream and upstream gauging stations. Whether the CRR and CRC have positive or negative values depends on whether contaminant release or removal occurs in the water body. The CRR depends on the size of the water body. The lowest and the highest CRRs observed for Baikal were equal to -15 mg/s (PAHs) to -7327 g/s (DOC), whereas the highest PAH and DOC removal rates observed for Selenga River (the major Baikal tributary) in summer were equal to -9 mg/s and -3190 g/s correspondingly. The highest PAH and DOC removal rates observed for small tributaries were equal to 0.0004 mg/s and -0.7 g/s respectively.

The amplitude of annual CRR oscillations depends on contaminant abundance. The highest amplitude was typical for most abundant contaminants such as N_{min} and DOC. In unpolluted

sections of the Selenga River the highest rates of N and C removal (-85 g/s and -3190 g/s, respectively) were observed in summer and the lowest rates (4 g/s and 3869 g/s, respectively) were observed in the spring. The lowest amplitude was typical for PAHs and some low-abundance TM such as V and Ni.
The highest summer rates of V and Ni removal were equal to -378 mg/s and -155 mg/s respectively, whereas lowest spring rates are equal to 296 mg/s and 220 mg/s. The intermediate CRR amplitudes were typical for most abundant TM such as Sr, Al, and Fe. The spatial CRR variability depends on water chemistry and the presence of pollution sources. The lowest (up to 38 g/s) rates of N_{min} removal was observed for polluted lower Selenga sections characterized by low water mineralization and high DOC concentrations. The highest rates (-85 g/s) were observed for unpolluted upper sections. Seepage loss from the river to groundwater was also recognized as an important means of contaminant removal. The CRC values depend mostly on water residence time. The DOC removing capacity value of Baikal (-26 g/m^3) were lower than those of Selenga in summer (-35 g/m^3) but higher than the CRCs of all tributaries during the other seasons (from 30 mg/m^3 to -10 g/m^3).

Drak and Koncan applied Qual2E to consider the reason of change in dissolved oxygen concentration in SAVA River in Slovenia (Drole and Koncan, 1996[50]).

Chaudhury et al., also, applied this model for assimilation of dissolved oxygen in Blackstone River, located in America (Chaudhury et al., 1998[51]).

2 Material and methods

2.1 Taleghan region

Taleghan is a city of Iran's Alborz Province. Located at a distance of 150 kilometers North West of Tehran, Taleghan region is a picturesque and high area in the heart of the Alborz mountain chain.

The city of Taleghan is located in the Alborz mountain range. In the middle of summer, the weather is pleasant and the population reaches to above 50,000 including 26,976 local residents

Naturally, more than twenty small and big rivers and their tributaries form the surface water in Taleghan region and their vicinity tp join to the main channel. Taleghan River is one of the main tributaries of Shahrood River and a source of agricultural water for Qazvin's plains. Despite increased awareness of the potential threats to the environment, there are many areas around the world where pollution from wastewater and agricultural activities, still take place. The impacts of agricultural pesticides and chemical fertilizers, the expansion of cities, towns and villages have increased the volume of generated, undermining the environmental quality.

The geographical location of the sampling stations of Taleghan River in Iran is shown in Fig 2.1 and Table 2.1.

The objective of this study is to investigate the possibility of adverse effects of wastewater around the mentioned study area on the surface water quality on example Taleghan River and its catchment basin.

FIGURE 2-1: LOCATION MAP OF TALEGHAN IN IRAN

TABLE 2-1 : LOCATION OF THE SAMPLING STATIONS

Station Number	Station Name	UTM		Elevation (m)	Distance from Upstream(Km)
		X	Y		
S1	Gatedeh	51° 4'6.04"E	36°10'20.31"N	2858	51
S2	Bayzan	50°55'59.77"E	36°10'3.17"N	2394	33
S3	Joyestan	50°53'28.65"E	36°11'17.64"N	2261	22
S4	Mangolan	50 51' 24.7"E	36 10' 29"N	2142	17
S5	Befor Shahrak	50°46'29.26"E	36°10'14.82"N	1910	4
S6	Glinak After shahrak	50 44' 59.2"E	36 10' 3.5"N	1780	0

2.2 General geological issues

Geological studies of Taleghan region shows that it is a mountainous region, formed by a series of folds and Eastern-western outcrops, which have been driven from South to Northerly direction over one another. Geological developments of the region show that the extension of Taleghan Mountain chains to the south, the Alborz chains and later erosive yields have created deep valleys and sloppy hillside. According to the stratigraphy and petrology of the region, these developments have led to geological processes such as landslide, avalanche, flood and ice yield all over the region, among which floods and landslides greatly affect the lives of inhabitants.

Generally, we can distinguish three geological periods in Taleghan region including Paleozoic, and Mesozoic periods in the southern parts, Tertiary period in the central area and southern heights, which is related to the Paleozoic, and Mesozoic periods.

2.3 Climate

Observations show that the average daily temperature of the studied region is about 9º Celsius, the average of maximum temperature reaches to about 18º C., and the average of minimum temperature is about 1º C. Moreover, the maximum absolute temperature is 38º C. Numbers of freezing days are between 151 to 246 days and the annual relative humidity is 51%. However, these numbers are variable and uncertain.

2.3.1 Climatic and topographic specifications

Located at a distance of 150 kilometers North West of Tehran, Taleghan region is a picturesque and high area in the heart of the Alborz mountain chain. Given the fact that Taleghan dam divides the region under study in two parts and the studies undertaken in the upstream projects have been dominantly provided in the frame of the upstream-downstream lands, the results of the observations show that the altitude of catchments area of dams upstream vary between 1700 meters to 4400 meters from sea level and the altitudes of catchments area of downstream dams vary between 1800 to 3200 meter from the sea level. The eastern part of the region, which makes up catchments area of dams upstream, is surrounded by northern and southern mountain chains which are linked to one another at the end of eastern side. The western part however, is widespread and has a lower altitude. Given the western- eastern direction of nimbus systems movement, such situation helps construction of rainfall height gradient in the area. Also, regarding its width and permanency, the northern mountainous rim of the area is higher than southern part; therefore, given its topographic profile, Taleghan climatic conditions is dominantly influenced by aerology regime of or pre-mountain Alborz (southern Alborz) and high Caspian climate regime is a bit tangible only in the northern heights.

2.3.2 Summarization of climatic parameters

To present a special picture of climatic condition in the scope of study, climatic parameters were discussed and analyzed. Therefore, the following methods were used to determine the climate type and its properties:

2.3.3 Ambrose method:

In the Ambrose method, two factors are used to determine the climate type of a region, i.e. the average of annual rainfall and the mean of minimum and maximum temperature of the coldest and warmest months of the year. In the above-mentioned catchment basins the mean annual rainfall is 76.2 mm, the average temperature in the hottest month of the year namely July is 27.5 º, and the average minimum temperature in the coldest month of year namely February is 0.6 º. In addition, the mean annual rainfall recorded by Koreh Sang station is 70.8 mm, the mean maximum temperature was 27.9º in the warmest month of year and the mean minimum temperature was 1.2º in the coldest month of year.

Based on this division, the climate of Taleghan varies between semi-humid to moderate-humid. This method uses two factors to determine the climate type of the region, which is the average of annual rainfall and the average of annual temperature. Based on this method, the average of annual rainfall in the area is 915.4 mm and the average of annually temperature is 14.1º C. Based on the Marathon run method, the dry index is always a positive number and its amount varies from less than 10 for arid-desert to more than 35 for very humid forest regions. Therefore, according to this division, the area of the project is located in the moderate humid climate to very humid climate.

2.3.4 Air mass that influences the region:

In winter, the Mediterranean air mass comes from the west; the northern continental polar air mass from the northern sector and sea polar air mass come from northwest. In addition, in the winter, that is the continentally tropical dominant air mass, which influences all Iran plateau and its origin, is Saudi Arabia's Sahara that has even changed the central Europe (from west to North West). The origin of rainfall at Taleghan region is the nimbus systems, which come to the country from the west and cause the rainfall of Iran plateau. They are completely active in these limits and their activity has been reported from September to the mid- May. Also, a part of the rainfall in Alborz southern heights where the studied region is located, is is the consequence air mass slip on the Caspian area and moisture nutrition proceeding from related organic phenomena. This phenomenon is observable in the northern rim heights of the region in the form of cloudy rims in a way that it sometimes causes rainfall. Also, through broad valley of Sefidrood, the influence the Caspian air mass on Taleghan area is the dominant phenomenon.

2.4 Forests and pasture

The study of vegetation coverage of Taleghan region shows that the area under study lacks forests and its plant coverage consists of pasture with the following specification:

The area of Taleghan region is, approximately, 100,000 hectares. It is a mountainous region with harsh slopes that have limited both agricultural and animal husbandry.

The vegetation of the studied region is diverse and variable because of favorable climate, suitable topography, mother stone and height difference. In spite of the region's favorable climate, the irregular intervention and animal graze have caused the decline of desirable varieties in the regional pasture and the growth of undesirable and aggressive varieties. However, there are desirable varieties, in particular, of astragal among which we can find palatable astragals as the dominant variety in most part of the region.

Different kinds of high value can be found in the middle and lower heights. Moreover, there are valuable varieties, belonging to Umbelliferates, such as Prongos, Ferula Persica and other varieties as well as different kind of Labiatae containing pastoral values such as Teuerium Polium, Mentha Longifolia and Thymus spp.

Generally, due to their location in the heights and the consequent decline of temperature and snowfall, pastures used by local and traditional animal husbandry; have a short plant growth life limited to three to four months per year.

In addition to the uncontrolled and excessive grazing which has fundamentally changed the density and composition of the region vegetation coverage, the plowing of the pastures has caused their destruction over a vast area. Shallow soil, skeleton soils and stony revelation are the other factors in limiting the plant coverage of the region. The observation of the various pasture varieties shows that there are 18 species of pasture plants in the study area.

2.5 Water resources

More than twenty small and big rivers and their tributaries form the natural surface water bodies in Taleghan region, which join the main Taleghan River to make up one of the main tributaries of Shahrood River and to supply agricultural water for Qazvin’s plain lands. The most important rivers of the region are Taleghan River, Harang River, Akorkan, Orazan, Hable Rood, Khasban, Khodkavand, Danblid, Dizan, Zaluchan, Sagran, Suhan, Alizal, Feshendak, Korkabud, Kuein, Naryan, and Hardorud.

2.5.1 Surface water

Surface water of Taleghan region, originating from southern, northern and eastern heights, joins the Shahrood River through Taleghan River; then, it gets directed to the Caspian Sea through Sefidrood River. Taleghan River, which is the main river of the region and one of the major and important tributaries of Shahrood River, has mountainous and high areas. It originates from the Great Kahar mount, located at 34 kilometers north of Karaj. Various tributaries of the river collect the water from the vast area of Alborz heights, including the Takht Soleiman heights, the Kahar and Taleghan mountain chains, to transfer this water to Shahrood River through Taleghan's deep valley.

The primary tributaries of the river are linked to one another in a village called Garap; then, the river moves in an east to- westerly direction way to supply villages such as: Darapi, Getedeh, Dehdar, Marjan, Nesa, and Avang and ends up in the lake of Taleghan dam.

Before reaching the dam, Taleghanrood receives various tributaries from the right (north) and left (south) banks including Nariamrood, Deizan, Alizan, Zaluchal, Khosban among others. After its exit from the dam, Taleghan River moves through a roundabout way to northwest and after passing villages including Kalarood, Asfaran, Amrodek, Deinehkooh, Zadrood it receives other tributaries in Shirkooh and joins up with Alamut River to make up the Shahrood River.

The river length is 105 km and its catchment basin is about 2000 km^2. This area is located in the Alborz mounts. It dominantly contains the hilly regions, with the only plain being the Taleghan plain. The river has permanent water and it has an important role in the supplying Shahrood River. Water regime of the river is snowy- rainy and its catchment is mainly located in Taleghan.

2.5.2 Ground water

Accompanying the smaller fractions are big faults, which have caused breakage in stones with many cracks, and fissures thereby creating barriers for the passage of ground water. The Carbonate stones have also cracks and fissures caused by infiltrative water, resulting in many vertical and horizontal channels that act as barriers and reservoirs for ground water. Hypogene stones, in this region, have many springs because of breaks but their water yield is few and negligible l (some with less than 1lit water yield). However, there are springs with high water yield in the calcic stones which are the source of big rivers such as Taleghan.

However, the development of alluvium deposits in the region is not in a way that would allow the adequate development of groundwater tables.

This means that due to the lack of groundwater tables in the area, which is situated in a mountainous region, the exploration of ground waters can only be realized through springs. Moreover, exploration of ground water cannot be made through wells and aqueducts.

2.6 Plant, animal and aquatic cover:

Given the mountainous location of Taleghan, it is filled with the various kinds of plants, animals, birds and fishes, among which we can mention:

- **Plants**

Taleghan area has 510 plant species including 30 medicinal species and 29 types of rangelands and different tree and shrub communities due to high altitude differences and diverse topography such as: Aras, Beech, Oak, Benneryl Sumac, Hawthorn etc. Therefore, in terms of vegetation and medicinal plants, it is a natural and unique laboratory. We can find some plants in this area such as:

Thyme, sagebrush, yarrow, wild leeks, rhubarb, Jvshyr, yellow salsify, chicory, milk, poppies, trees: peanuts, willow, sycamore, barberry, hawthorn, olive, apple, walnut, pear, cherry as vegetation.

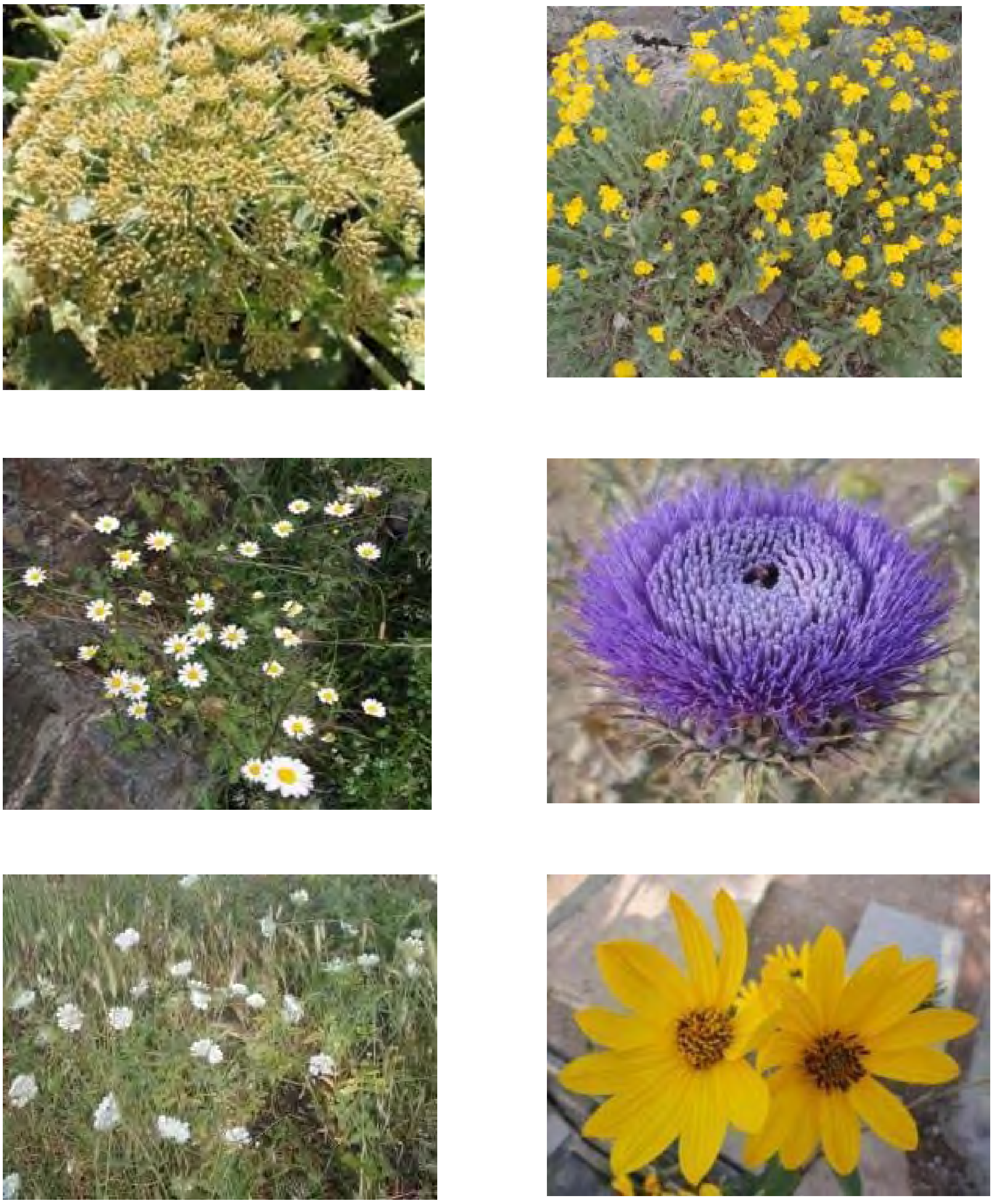

FIGURE 2-2: FLOWERS OF STUDY AREA

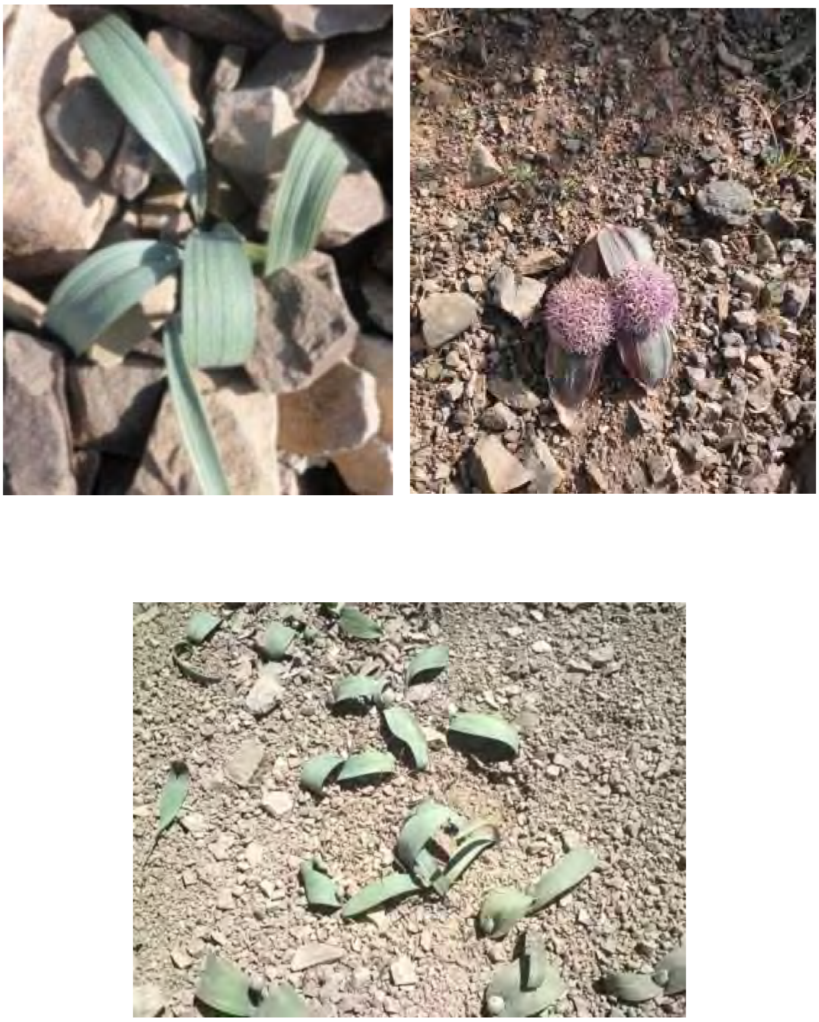

FIGURE 2-3: MEDICAL PLANTS OF STUDY AREA

- **Species**

Study area has diversity of animal species. We can find some species in this area such as:

Species of mammals: antelope, bear, rabbit, fox, otter,lynx, jackal, hyena,wild goat, wild boar and wolf.

Species of birds: jackdaw, Wagtail, hawks, eagles, falcons, Quebec Derry, vulture .

Aquaculture: V. Dapoeta, Whitefish River, rainbow trout, C. Carpio as the species fish.

FIGURE 2-4: LYNX IN STUDY AREA

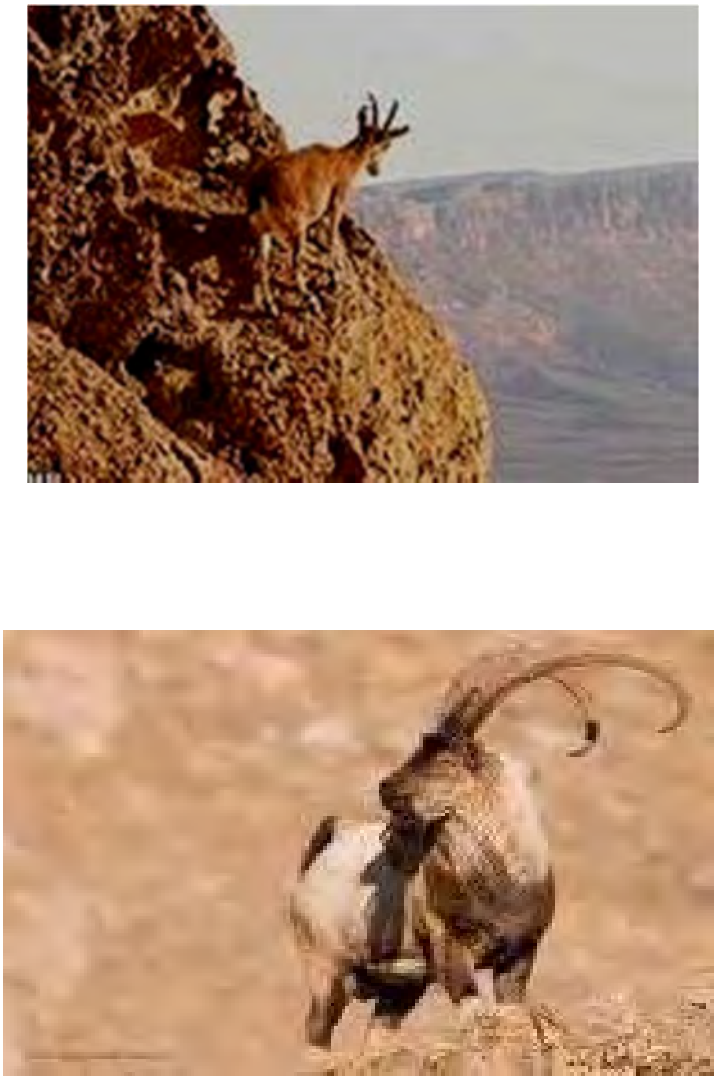

FIGURE 2-5: WILD GOAT IN STUDY AREA

FIGURE 2-6: BIRDS IN STUDY AREA

2.7 Time of sampling

This study was undertaken during the period 2008-2010, and by monthly sampling of physio-chemical parameters at each station of Taleghan River. In autumn 2016, we continued our study in Taleghan River to evaluate changes in parameters of the river's ecosystem.

To achieve their objectives, the researcher determined 6 sampling stations along the main channel of Taleghan River.

The first station was located at the upstream of the river and is more under the influence of natural conditions (reference conditions).

In fact, there are no agricultural and industrial activities in this region. Stations 2, 3, 4 are often under the influence of farming, aquaculture and sand and gravel mining.

Stations 5 and 6 are often exposed to pollution activities including agricultural, rural, eco-tourism and civil works.

The catchment basis of Taleghan River is shown in Figure 2-.

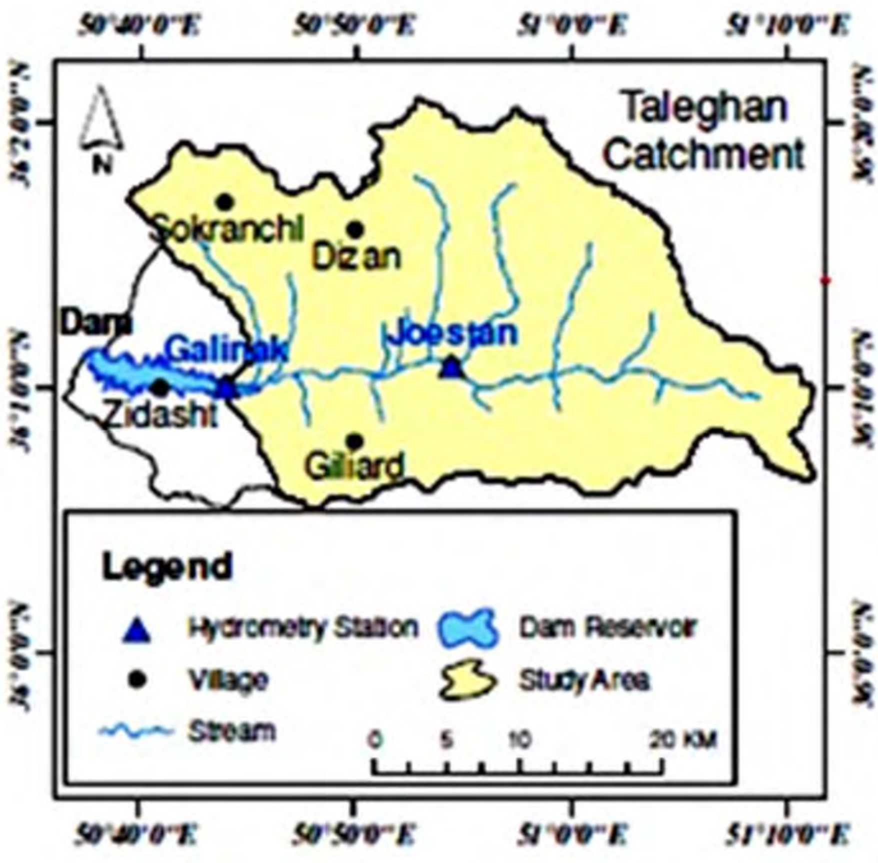

FIGURE 2-7: TALEGHAN CATCHMENT

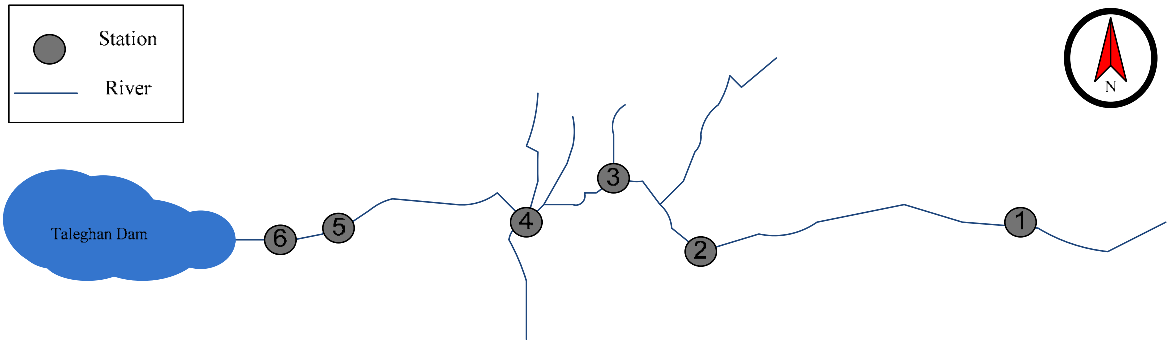

FIGURE 2-8: LOCATION OF STATION IN TALEGHAN RIVERS

The chosen parameters are the followings: Dissolved Oxygen (DO) , Fecal coliform (FC), pH, water temperature (T), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Nitrogen (N), Nitrate (NO_3), Nitrite (NO_2), Ammoniac (NH_4), Total phosphate (Po_4), Turbidity (TU), Total solids, river flow, (Q), Electric Conductivity (EC).

These ten parameters have been sampled and analyzed monthly (since summer 2008 to summer 2010). Furthermore, in 2016 parameters like temperature, nitrate, pH, EC, and BOD_5 were sampled to create a view over temporal changes. The measurement methods are often based on APHA standard.

2.8 Method of sampling

Temperature, pH and DO in the region were measured respectively by thermometer, pH and DO meters. Solid materials were measured by gravimetric method at the temperatures of 110-105°C.

Density of nitrate and total phosphate was determined by spectrophotometer. Turbidity was also measured by application of the Nephelometic method with a turbidity meter and the river flow was measured by the use of a flow meter. Fecal coliform was determined by the use of membrane filter and based on the number of colony in 100 milliliters in the laboratory. Table 9 shows the parameters' measuring methods of in summer.

Parameters of electro conductivity in the region, was measured by EC. Moreover, all the samples taken to the lab were filtered by strainer paper of 0.45 µm in mesh, and then the cations were measured by the atomic absorption device, the bicarbonates by the method of Acid Titration, the sulfates by turbidity metric method and color was measured by it ratio and silver nitrate.

Water samples were collected in 1litter plastic vessels and transferred to laboratory. The BOD_5 (incubation of samples in 20°C and dark condition over 5 days) and the COD (sulfuric acid and potassium dichromate method) were analyzed using the standard methods (Wetzell and Gene 1992)[52].

TABLE 2-2: THE ABBREVIATED LETTERS OF PARAMETERS WITH ASSESSMENT AND MEASUREMENT METHOD

Parameters	Abbreviation	Units	Analytical methods
Dissolved oxygen	DO	mg/L	DO meter
Fecal coliform	FC	cfu/100ml	Membrane filtration
pH	pH	pH unit	pH-meter
Temperature	T	°C	Mercury thermometer
Biochemical oxygen demand	BOD_5	mg/L	Five days incubation at 20ºC
Nitrate	NO_3	mg/L	Spectrophotometric
Nitrite	NO_2	mg/L	Spectrophotometric
Total Phosphate	$T\text{-}PO_4$	mg/L	Spectrophotometric
Turbidity	Turbidity	NTU	Nephelometric method
Total solids	TS	mg/L	Gravimetric
Discharge	Q	m^3/s	Current-meter

2.9 Picture of sampling sites

Images and location of sampling stations in Taleghan River.

FIGURE 2-9 : STATION NO. 1

FIGURE 2-10 : STATION NO. 2

FIGURE 2-11 : STATION NO. 3

FIGURE 2-12: STATION NO. 4

FIGURE 2-13: STATION NO. 5

FIGURE 2-14: STATION NO. 6

2.10 Methods for analysis of physical and chemical parameters

All the data were transformed to logarithm scale and then analyzed using split-plot where the seasons were assumed as the main factor and the stations as plots. Duncan's test was applied to determine the significant differences between all stations and season as well as their interaction. The data was presented as mean ±SD. All analyses were performed in MSTATC software environment.

2.11 Data analyses

- **Physical parameters**

2.11.1 Temperature (T)

Temperature is a measure of how much heat is present in the water.

- Water temperature tells many things about the health of a river. Temperature affects:
- Dissolved oxygen levels in water – Cold water holds more oxygen than warm water.
- Photosynthesis – As temperature goes up, the rate of photosynthesis and plant growth goes up. More plants grow and more plants die. When plants die, decomposers eat them and use oxygen. So when the rate of photosynthesis increases, the amount of oxygen needed by aquatic organisms increases.
- Animal survival – Many animals need certain temperatures to live. For example, stonefly nymphs and trout need cool temperatures. Dragonfly nymphs and carp can live in warmer water. If water temperatures change too much, many organisms can no longer survive.
- Sensitivity to toxic wastes and disease – Wastes often raise water temperatures. This leads to lower oxygen levels and weakens many fish and insects. Weakened animals get sick and die more easily.

Chemical parameters

2.11.2 pH

pH is a measurement of the acidity or basic quality of water. For example, lemons, oranges and vinegar are high in acid ("very acidic"). The pH scale ranges from a value of 0 (very acidic) to 14 (very basic), with 7 being neutral. The pH of natural water is usually between 6.5 and 8.2

At extremely high or low pH levels (for example 9.6 or 4.5), the water becomes unsuitable for most organisms. Young fish and insects are also very sensitive to changes in pH. Most aquatic organisms adapt to a specific pH level and may die if the pH of the water changes even slightly.

pH can vary from its normal levels (6.5 to 8.2) due to pollution from automobiles and coal-burning power plants. These sources of pollution help form acid rain. Acid forms when chemicals in the air combine with moisture in the atmosphere. It falls to earth as acid rain or snow. Many lakes in eastern Canada, the northeastern US, and northern Europe are becoming acidic because they are downwind of polluting industrial plants. Drainage from mines can seep into streams and ground water and make the water more acidic as well.

2.11.3 Dissolved oxygen (DO)

Like people, aquatic organisms need oxygen to survive and stay healthy. In areas with waves, or where water tumbles over rocks, falling water traps oxygen and mixes it into the water.

Unlike people, aquatic organisms breathe oxygen that is dissolved in water. To breathe underwater, fish and other aquatic organisms use gills instead of lungs. These gills breathe the oxygen dissolved in the water.

The content of dissolved oxygen in water is affected by many factors such as the state of sea surface, hydrodynamic and biochemical processes, and thus its distribution is very complicated .

Clean, healthy water has plenty of DO. When water quality decreases, DO levels drop and become impossible for many animals to survive. Some fish such as trout require lots of dissolved oxygen. Others such as carp can live in water with lower levels of DO.

Warmer water holds less oxygen than cold water. Also, the time of year and many other factors affect the amount of DO in water.

The main reason DO levels might fall is the presence of organic waste. Organic waste comes from something living or that was once living. It comes from raw or poorly treated sewage; runoff from farms and animal feedlots; and natural sources like decaying aquatic plants and animals and fallen leaves in water.

Microscopic organisms, called decomposers, break down the organic waste and use oxygen in the process. Two common types of decomposers are bacteria and protozoa. More waste means more decomposers and more oxygen being used. DO levels can also fall due to any human activity that heats the water.

2.11.4Nitrogen (N)

Nitrogen is one of the most common elements in the world. All living plants and animals need it to build proteins. Nitrogen and phosphorus are both nutrients.

High levels of nitrogen may make some people sick, especially young babies. This happens to people who drink directly from groundwater wells where the water has too much nitrogen.

Because nitrogen is a nutrient like phosphorus, the effects of this nutrient on water are almost the same. Like phosphorus, extra nitrogen in water leads to rapid plant growth.

Too many plants living in the water can lead to some bad results. When these plants die (which, in the case of tiny plants or algae, is very often), they sink to the bottom. There, bacteria decompose the dead plant parts. They use up most of the oxygen in the water.

They actually use more oxygen than the amount added by the plants through photosynthesis. Therefore, too many plants in the water from too much phosphorus lead to less oxygen. This is what happens when too much nitrogen enters the water:

- Nitrogen enters the water.Water ecosystems have an internal quantity of nitrogen.
- Plants take up the nitrogen and grow very dramatically.
- Plants (algae) die and sink to the bottom
- Bacteria at the bottom decompose the dead plants, using up oxygen in the process
- Oxygen levels drop, killing fish or aquatic insects
- Nitrogen continues to enter the water

- The cycle continues

Nitrogen can be found in fertilizers and in human or farm animals' wastes. In some cases, home septic systems in rural areas leak waste into the ground. This waste should be filtered by the soil around the septic system. However, this does not always happen. Therefore, groundwater can be polluted by nitrogen in the wastewater.

The results showed that the I. Wilsonii and M. Verticillatum units had excellent nitrogen removal. This is attributed to direct purification by I. Wilsonii via absorption and enrichment, which directly removed pollutants, as well as indirect purification through the large surface area provided by the roots. The mechanisms of N and P removal by plants may include plant uptake, microbial uptake, and volatilization.

2.11.5 Phosphate (PO_4)

Plant uptake has a direct contribution to nutrient content. This contribution to N and P has been reported in the range of 25%– 47%(Chen et al., 2013[53]). Moreover, the entire underwater surface of plants helps maintain an aerobic environment in the riverbed through oxygen transfer via roots and rhizome systems, and controls the growth of algae by restricting sunlight penetration (Tanner et al.,1999)[54].The biological rope unit showed excellent TP removal. The removal of phosphorus from this unit was primarily dependent on physical adsorption and deposition. Biological rope has a high filtering capacity for organic particles, while the microorganisms attached to the rope can facilitate hydrolysis and transformation. The results clearly demonstrate that vegetation and biological contact purification materials should be applied at the same time throughout the system, which supports previous findings [Sun et al., 2009 [55]; Chou et al., 2007[56]].

Phosphorus is a nutrient found in all living things. It is also a mineral in nature. Both plants and animals have phosphorus in their bodies. It is in most of the foods we eat. When people buy fertilizer for their gardens, they use nutrients such as phosphorus to help plants grow.

Scientists believe that when too much phosphorus enters a river or lake, plants grow more. Tiny plants like algae use the phosphorus to grow. Other plants that live on the surface and bottom of a river or lake use phosphorus also. When plant growth increases, the water turns pea-green and becomes cloudy. The green color comes from the chlorophyll content of the tiny floating plants.

Too many plants living in the water can lead to some bad results. When these plants die (which, in the case of tiny plants or algae, is very often), they sink to the bottom. There, bacteria decompose the dead plant parts. They use up most of the oxygen in the water. They actually use more oxygen than the amount added by the plants through photosynthesis. Therefore, too many plants in the water from too much phosphorus lead to less oxygen. This is what happens when too much phosphorus enters the water:

- Phosphorus enters the water
- Plants take up the phosphorus and grow too much
- Plants (algae) die and sink to the bottom
- Bacteria at the bottom decompose the dead plants, using up oxygen in the process
- Oxygen levels drop, killing fish or aquatic insects
- Phosphorus continues to enter the water
- The cycle continues

Phosphorus enters the water from a number of places. It is found when human and animal wastes are flushed into waterways, either from poorly treated sewage, broken pipes or runoff. Some industrial wastes also carry phosphorus into the water. Whenever trees and grass are removed from an area, soil erodes into waterways, carrying the phosphorus that sticks to soil. Fertilizers used at homes on lawns and on farm fields carry much of the phosphorus in the fertilizer into streams when it rains. Since rivers flow, the phosphorus carried downstream. Lakes do not flow like rivers but trap nutrients instead. Therefore, high levels of phosphorus are more serious in lakes and ponds.

In the catchment of the rivers, containing a noticeable agricultural and domestic lands, increase in various compositions of organic matters always occurs in the river water (Sickman et al., 2007[57]) and it is followed by boosted concentration of phosphorous and some other nutritive substances, which are the products of manure application (Easton et al., 2007[58]).

2.11.6 Electro conductivity (EC)

Conductivity is a measure of a water bodies' ability to carry an electric current. While conductivity has little biological significance, it does give an idea of dissolved salt concentration. Exceedingly high conductivity levels are often associated with heavy irrigation, mining, or industrial effluents. Freshwater conductivity is highly variable, ranging from less than 50 µS/cm to 1000 µS/cm (Dojlido 1993)[59].

- **Biological parameters**

2.11.7 Biological oxygen demand (BOD_5):

When organic matter decomposes, microorganisms (such as bacteria and fungi) feed upon this decaying material and eventually the matter becomes oxidized. Biochemical oxygen demand, or BOD_5, measures the amount of oxygen consumed by microorganisms in the process of decomposing organic matter in stream water. The harder the microorganisms work, the more oxygen they use, and the higher the measure of BOD_5, leaving less oxygen for other life in the water.

BOD_5 directly affects the amount of dissolved oxygen in rivers and streams. The more rapidly oxygen is depleted in the stream, the greater the BOD_5. This means less oxygen is available for other aquatic life, such as insects and fish. A high BOD_5 measure harms stream health in the same ways as low dissolved oxygen: aquatic organisms get stressed, suffocate, and die. The few organisms that can survive with less oxygen, like carp and sewage worms, will increase in number.

As more organic matters that are enter a stream, the BOD_5 will rise. Organic matter may include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff.

2.11.8 Chemical oxygen demand (COD):

COD is the amount of oxygen required for the chemical oxidation of organic or inorganic compounds in water and is usually an important sink of DO in rivers that receive industrial effluents such as iron sulfite and aldehyde, which are readily oxidized (Cox, 2003a)[60]. In the presence of DO, oxidation takes place rapidly, so the oxygen demand is observed close to the pollutant source and can be quite significant. COD is generally not an important parameter in rivers or streams that do not receive industrial effluents. But because COD measurements are easier to conduct and often more repeatable than BOD_5 measurements, some regulatory agencies allow measurement of COD as a surrogate for BOD_5 provided that a linear relationship between the two can be developed for the stream in question.

2.11.9 Fecal coliform (Fc):

Fecal coliform bacteria are found in the feces of human beings and other warm-blooded animals. By themselves, fecal coliform bacteria do not usually cause disease. In fact, they are already inside you. They occur naturally in the human digestive tract and aid in the digestion of food.

However, when a human being or other warm-blooded animal is infected with disease, pathogenic (disease causing) organisms are found along with fecal coliform bacteria.

Think of high levels of fecal coliform bacteria as a warning sign that water can make you sick, rather than as a cause of illness. If fecal coliform counts are high (over 200 colonies/100 ml of a water sample) in a body of water, there is a greater chance that disease causing organisms are also present. If you are swimming in waters with high levels of fecal coliform, you have a greater chance of developing a fever, nausea or stomach cramps from swallowing disease-causing organisms, or from pathogens entering the body through cuts in the skin, the nose, mouth, or ears. Some examples of diseases and illnesses that can be contracted in water with high fecal coliform counts include typhoid fever, hepatitis, gastroenteritis, and dysentery and ear infections.

Fecal coliform bacteria are living organisms, unlike the other conventional water quality parameters. The fecal coliform bacteria multiply rapidly when conditions are good for growth and die in large quantities when they are not.

Untreated sewage, poorly maintained septic systems, un-scooped pet waste, and farm animals with access to streams can cause high levels of fecal coliform bacteria to appear in a water body.

2.12 Statistical analysis

Application of multi variable statistic techniques such as: cluster analysis, factor analysis and principle analysis (PCA) are effective to interpret the data and to better understand the status of water quality and ecology of the systems under study. It also serves to identify the effective parameters in the water quality.

This application is a valuable instrument in management of water resources as well as presentation of a quake resolution about problems of pollutions (Reghunath et al., 2002[61]; Wunderlin et al., 2001[62], lee et al., 2001[63]).

Multi- variable statistic water techniques are used to describe and assess quality of surface water and they are useful in considering the space and time variations by natural and man-made factors related to different seasons (Singh et al, 2004[64], 2005[65]).

In the recent years the PCA and FA methods have been used for the different environmental applications, among which the following cases will be mentioned as assessments and supervision of quality of groundwater, well, experiment of space and time models of surface waters quality, identification of chemical species related to the Hydrological condition and assessment of environment qualitative indexes (Bengraine and Marhaba, 2003[66]).

The aim of this discussion is to assess the relationship between different region of catchment basin of Taleghan River as well as the differences and similarities between the location of sampling stations in terms of water quality by use of statistic techniques as CA, PCA, PCA, FA and the analysis 10 of measured parameters from 6 sampling stations for two years and at different seasons.

Cluster analysis is group of multi-variable techniques, the aim of which is to pile the different components or agents based on their features (Shrestha and Kazama, 2007[67]).

Method of Euclidean distance usually produces the similarity between two samples and displays a distance, which is the result of difference between the amounts under analysis (Otto, 1998[68]).

In this study, the condensed hierarchical method of CA was applied on the normalized data by ward method. Using the squared distances Euclidean techniques as a similarity measurement.

The Space variability of water quality in the total catchment of river was determined by CA.

Moreover, it was also reported by the use of linkage distance and in the form of Dlink / Dmax, the result of which shows submultiple linkage distances for a particular station was divided to minimum linkage distances. The resulting submultiple has been multiplied by 100 for standardization of linkage distances (Wunderline et al., 2001[69], Simeonov et al., 2003[70]).

In this study, the cluster analysis was used to present a usual summary in the relation between variations of parameters, which resulted in the better understanding of the ruling factors.

PCA changed the main variables into the new uncorrelated variables, called the main components, which are in the form of linear mixtures of main variables (Shrestha and Kazama, 2007[67]).

PCA provides information based on the most significant parameters by which we are able to express the interpretation of total data, decline of data and summarizing the statistic correlation between compounds in water, with of course the least damage to the information's (Helena et al., 2000[71]). FA was derived from PCA. PCA expresses a linear compound of measured variables of water quality, while FA contains invisible, pathetic, and unobservable variables (Helena et al, 2000[71]; Vegaet al,. 1998[72]).

Normalized variables of PCA were applied to extract the main significant components as well as the decrease in the variables of less-significance. The main items present conditions of varimax rotation of product factors. (Love et al., 2004[73]; Shrestha and Kazama, 2007[67]; Singh et al., 2004[64], Abdul-Wahab et al., 2005[74])

2.13 Quality properties of water

Information about quality condition of surface water provides the possibility of its application in different cases as well as in choice of the ways to reduce the vulnerability of this source to possible minimum amount. Different techniques have been studied and considered to measure the quality of surface water in the world, among which water quality indexes is one of the most applicable and simple method in the world.

With regard to the copious amount of the information resulting from water quality refinery, it is suitable to reduce this copious amount of information into a summarized one in a way that reports water quality condition.

Index method of water quality copious amount of water quality information was changed into a single number, which, as far as the scale of each method is concerned, denotes the performed classification to which water quality status belongs, as well as how its status will change in other places and times.

The characteristics techniques of water quality are mostly experimental; therefore, their application is based on specific conditions.

Water quality index, in general, is divided into two groups. First group are indexes whose values decreased by increase in the pollution and the second group are the indexes whose values increased by increase in pollution. There are also four general stages for making indexes as follow:

2.13.1 Choice of parameters

The different units of each parameter were transfigured into a common scale to produce sub-indexes. Allocation of weights to each parameter was based on their importance. The formula for producing the general index was presented using sub-indexes. Three stages (1, 2, and 4) are necessary to make an index; while, some indexes can be defined without the stage 3.

2.13.2 Index of NSF (national sanitation foundation)

In 1970, supported by the American Hygiene National Organization, Brown et al. presented an index, which was collected from 142 experts in American Water Sources Administration, and which had a share in water pollution on 35 parameters. Based on the amount of their share in the pollution, a score of 1 to 5 was given to them: 1 for the most share and 5 for the least share in the pollution. After analyzing the questionnaires, 9 parameters were chosen and again they were requested to draw the determining curve of each parameter sub-index. The mean of the drawn curves was computed and the results presented in the form of graph for each parameter (figure 2-15 to 2-23). The parameters are:

- Dissolve oxygen (DO)
- pH
- Temperature
- Biochemical Oxygen Demand
- Fecal Coliform
- Turbidity
- Total Phosphate
- Nitrate
- Total Solid

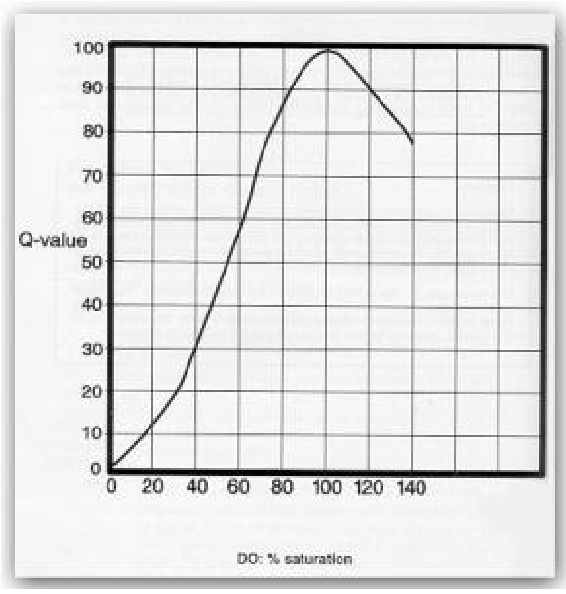

FIGURE 2-2 : GRAPH OF DISSOLVE OXYGEN DEMAND

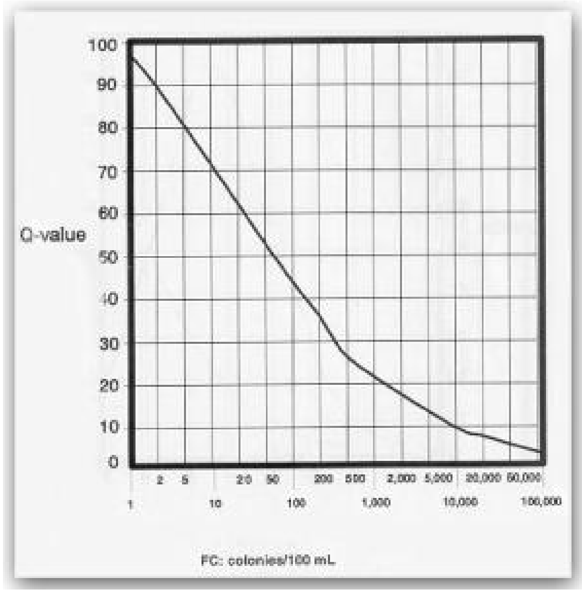

FIGURE 2-3 : GRAPH OF FECAL OF COLIFORM

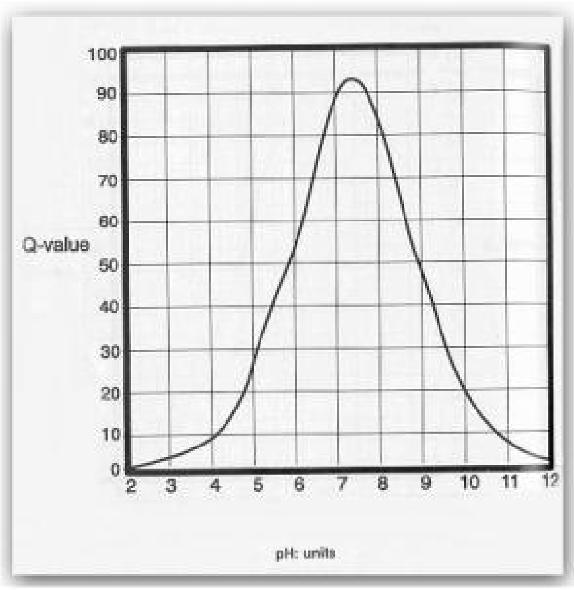

FIGURE 2-4 : GRAPH OF THE PH

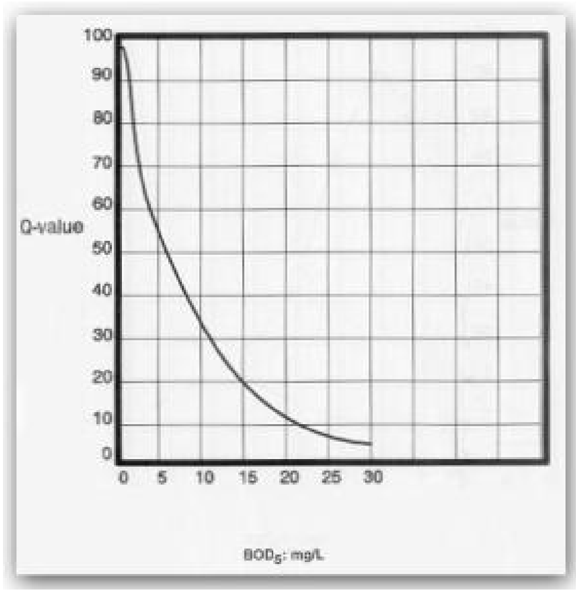

FIGURE 2-5: BOD5 INDEX GRAPH

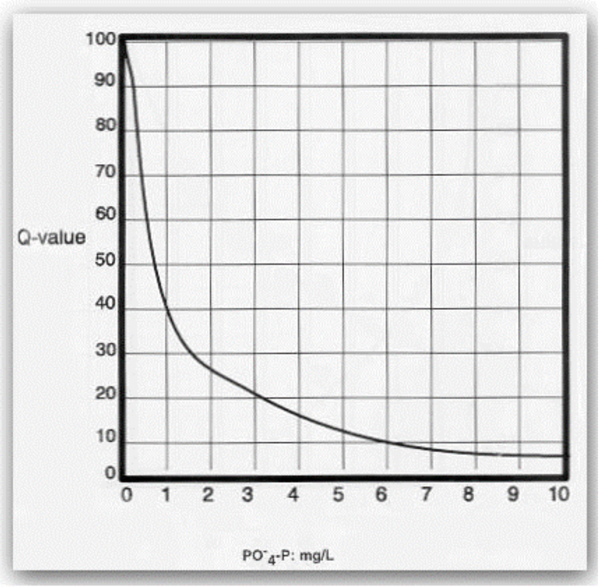

FIGURE 2-6: GRAPH OF THE PHOSPHATE

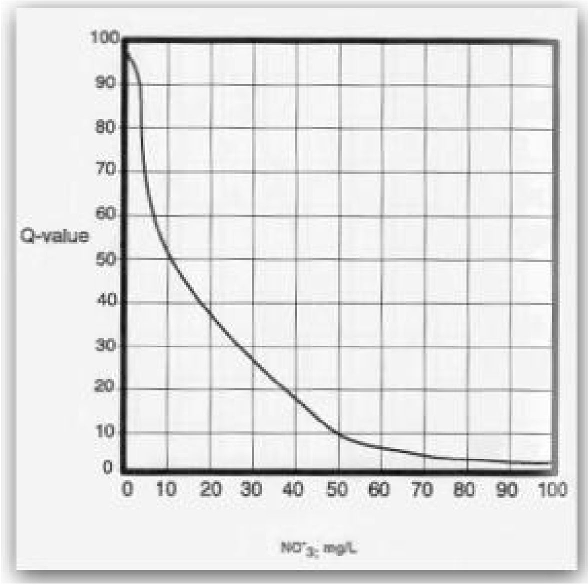

FIGURE 2-20 : GRAPH OF THE NITRATE

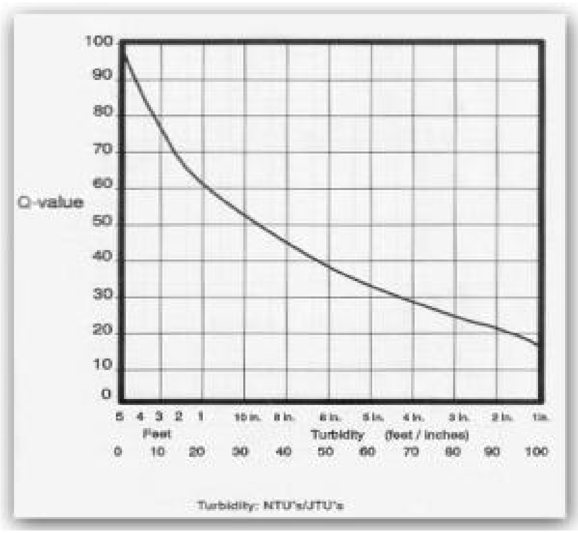

FIGURE 2-21 : GRAPH OF TURBIDITY INDEX

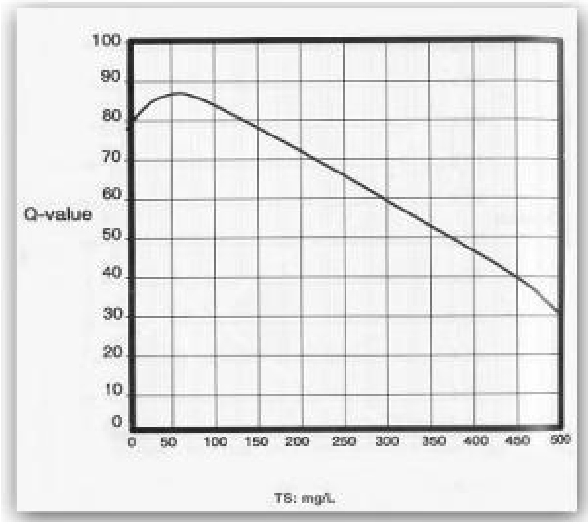

FIGURE 2-22 : GRAPH OF THE TOTAL SOLIDS

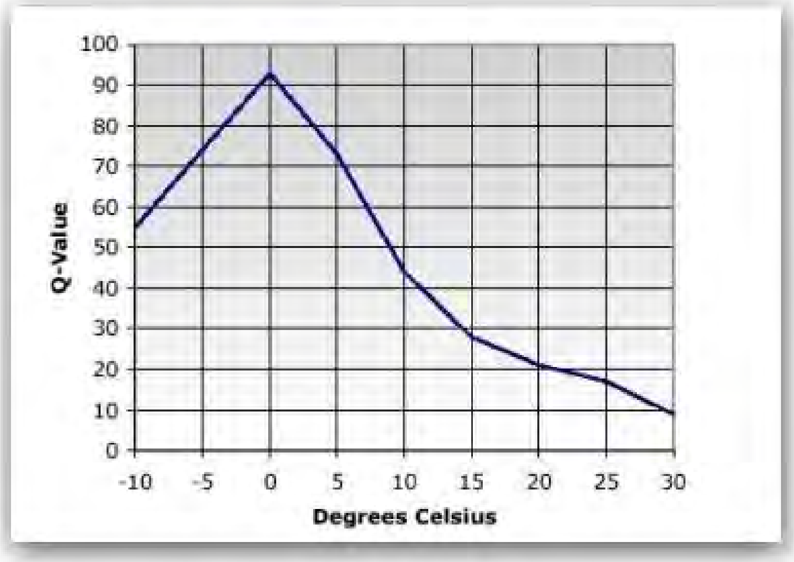

FIGURE 2-23 : GRAPH OF TEMPERATURE INDICATORS

2.14 Drinking and agriculture usage:

Chemical parameters play an important role in classification and determination of water quality for different consumptions. The discussion aims to classify the water quality of Taleghan River in its region for irrigation and drinking purposes as well as determination of water type or in other words the identification of Ion domination Anion and Cation in the Taleghan River.

To achieve this goal, 7 main Ions and the 2 parameters of temperature and electrical conduction (EC) of the water were considered.

It was observed that the concentration of Anions and Cations, in general, in seasons with low water level were more than seasons with high level water, because the flow was increased in the river resulting in more dilution and a decrease in the trend of Anion and Cation concentration.

The chemical specification of the river water in different stations was evaluated in piper diagram. By using the diagram, we can specify the type of the river water. The triangle shape diagrams express the density of Cations and Anions (triangle on the left shows the concentration of Cations and on the right the concentration of Anion) while the oval shape diagram contains both Anions and Cations.

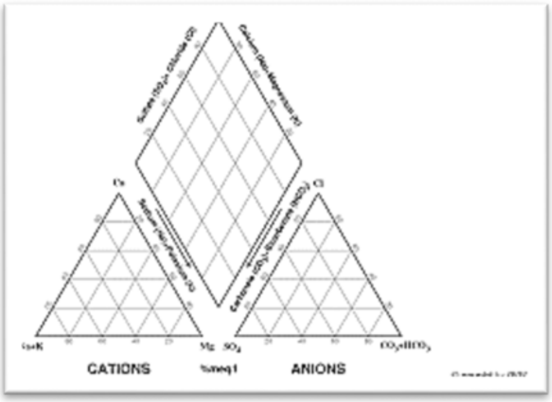

FIGURE 2-24 : DIAGRAM PIPER GROUPED ACCORDING TO THE CLASSIFICATION OF WATER BASED ON THE CONCENTRATIONS OF MAJOR IONS

Schoeller is a semi-logarithm diagram, on which the main Ions have been drawn based on (mg/l). Thus, the diagram is used to determine the degree of water quality for drinking. The chemical classification of drinking water according to the Schoeller diagram is shown in figure 2-25.

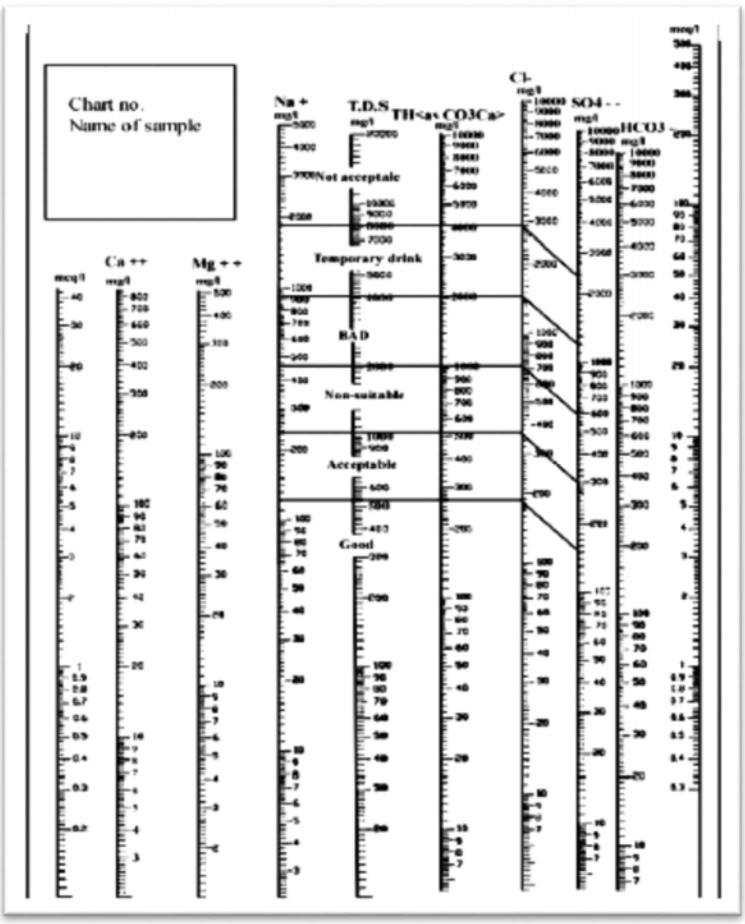

FIGURE 2-25 : SCHULER DIAGRAM GROUPED ACCORDING TO THE CLASSIFICATION OF WATER BASED ON THE CONCENTRATIONS OF MAJOR IONS

The chemical integration of surface water is very important in determining its quality for agricultural consumption because it has not had a harmful and unfavorable effect on the fertilized land. Therefore, the adequacy of the river water was considered by application of Ion density and EC parameter for irrigation of agricultural lands.

The high concentration of Sodium in soil has influenced the physical condition of the soil as well as it structure and has caused a change in the soil layers and its saturation. Consequently, soils ventilation and penetration is reduced. Also, the high concentration of Sodium in soil can increase toxicity in some products (Sundaray et al. 2006[75]).

In the past, the danger of sodium for agricultural soil was expressed in the form of Sodium percentage and the adequacy of water for irrigation was measured using this parameter. Na percentage is computed by the following formula:

In the formula, Na, K, Ca and Mg are based on mg/l. If Na% is less than 60, the water quality is good, between 60 to 75 it is harmful and more than 75 it is inadequate for agricultural irrigation.

There are other parameters in the soil related to the danger of Sodium. They are referred to as Sodium Absorption Ratio (SAR) and are computed by the following formula.

2.14.1 Formula

In the formula, the Sodium, Calcium and Manganese are also based on mg/l. The parameter SAR presents a more trustable assessment of danger of Sodium in quality of water; therefore, it has more accuracy in assessment of Sodium in soil in comparison to Na percentage (Tiwari and Manzoor, 1988[76]). Sodium replacement is absorbed instead of Ca and Magnesium. This is considered as a danger and causes soil damage, condensation and penetration in soil (Sundaray et al. 2006[75]).

When parameters SAR and EC are present in a water sample, its classification for agricultural irrigation can be determined by drawing a diagram. The United State Salinity Laboratory (USSL) Diagram can use for rapid determination of water classification for irrigation. In this diagram, the danger of Sodium or in other words parameter SAR is shown on Y axis and the danger of salinity, which is measured by EC, is shown on X axis (Schoeller is a semi-logarithm diagram, on which the main Ions have been drawn based on (mg/l). Thus, the diagram is used to determine the degree of water quality for drinking. The chemical classification of drinking water according to the Schoeller diagram is shown in figure 2-25.

Figure 2-).

Water types, are divided into the four classes: S1, S2, S3 and S4 based on the danger of Sodium (SAR) and C1, C2, C3 and C4 based on the danger of salinity (EC).

Water with low Sodium (S1) can be applied for irrigation on almost any soil. Water with average Sodium (S2) causes a tangible danger over soft soils with high capacity of conversion of Cation and under treatment of low soil (water washing). This water can be used for the soil with sever structures or organic soil which has a high penetration. Water with high Sodium (S3) can be harmful in most of soils and it needs an especial management in this case. Water with very high Sodium (S4), in general, is inadequate for agricultural irrigation unless special measures are taken on soil.

Water with low salt (C1) can be used for irrigation of most soils and agricultural products. A little treatment of soil is necessary, which is realized by normal irrigation. However, the soil with very high penetration is exception. Water with low salinity (C2) can be used if we do a little treatment of soil. Water with high salinity (C3) cannot be used for the soils with limited drainage. Water with very high salinity (C4) is inadequate in normal conditions. (US Salinity Laboratory, 1954).

In water with high concentration of Bicarbonate, there is a tendency for settlement of Calcium and Magnesium on soil. This results in higher density of water in soil; consequently, increase in the Sodium ratio in the form of Sodium Carbonate. This phenomenon is defined as residual Sodium Carbonate (RSC). Water with high RSC will have a high pH and appears in the form of a black color from soil (Eaton, 1950).

$$RSC = (CO_3 + HCO_3) - (Ca + Mg) \quad \text{Equation 1}$$

In this formula, all Ions are based on mg/l. If RSC<1.25 mg/l, water is not dangerous and it is inadequate for agricultural irrigation. In other hand, if RSC is between 2/5 or more than 2/5 mg/l then water is adequate for irrigation (US Salinity Laboratory, 1954).

2.15 Mathematical Model of River Water Quality (QUAL2K)

2.15.1 Mathematical models of the river water quality nowadays

There are many models for analysis of solution and oxygen changes in the rivers allowing the study and determination of the load of extra materials. The models have been designed from the beginning or they are a modified form of the other models, but their mathematical forms are the same and they have a set of differential equation as well as equations for each matter or existing creature, which should be clearly inserted in the model framework.

Choice of an adequate model depends on the aim of the choice of the simplest model, which is considerably applicable in the assumed problem. Methods of model selection are classified into two general groups of technical and practical. The technical methods in terms of model capability are by definition the significant physical and chemical processes of the real system. The processes include determining the mechanism and important processes in the real system, considering the existing models and their capabilities and finally comparing the significant specification and properties of the real system with the model capabilities.

By exercising the technical solutions, some models are identified for selection. Then, by applying the practical one among others, the best model is selected based on simplicity of its application and cost. In determining the costs, the cost of creating and running the model, availability of data and the cost of supplying the data are provided for calibration and acknowledgement of the model.

2.15.2 Comparison of the computerized models

The QUAL2K model, which has been provided by EPA (American Environmental Protection Agency), is the outcome of years of doing serious research. It has been applied as an appropriate tool for designing and programming the quality of river water for a long time and it still has maintained its status in some organizations. The model can be used to study the effects of the changes in daily parameters of aerology on the water quality (essential solution oxygen and temperature).

Moreover, the QUAL2E-UNCAS or QUAL2EU model has been presented to market. It is similar to QUAL2E, and has the capability to analyze uncertainty. The MOD FLOW, like QUAL2E, is able to assimilate the parameters as solution oxygen, the need of biochemical oxygen demand, temperature, phosphate, organic phosphorous, nitrate, organic nitrogen and coliform.

The QUAL2K is the last model of the QUAL models, which is, nowadays, used to assimilate the quality of rivers water. In terms of the model capability, in definition of the various processes of the real system and taking into consideration the various parameters and existing creatures in the model, model QUAL2K and QUAL2E are similar in the following items:

- Mono-dimensionality: both models only assimilate the changes along the length of the river and the conditions in the vertical and side direction are assumed in a mind form.
- Both models are able to do the qualities assimilation of the rivers with the secondary tributaries.
- Hydraulically, the conduct of both models acts in the condition of permanent and irregular conduct.
- Both models are able to do the assimilation, with regard to aerology data's, by use of the daily temperature degree.
- Both models can assimilate the qualities parameters of water daily.
- Both models assimilate the pollution point and non-point resource and heat.

Moreover, model QUAL2K contains the following parts:

- Model QUAL 2K has been performed in the windows Microsoft environment and the language of its program is BASIC. It uses the excel environment as a graphic environment for data output.
- QUAL2K model divides the river into unequal Part for balance and heat whereas the model was divided into equal part in the previous edition.
- QUAL2K model uses two forms of BOD_5 to show the organic carbon. These forms include slow oxidation and quick oxidation. Moreover, the tiny organic materials also are assimilated in the model.
- This model takes into consideration the shortage of oxygen when the density of solution oxygen reaches to zero. Also, process of denitrification is influential in assimilation in the low oxygen concentrations.
- Oxygen need by the floor sediment and nutritive materials between floor sediment is also taken into consideration in assimilation in this model.
- The model, evidently, assimilates algae
- Decrease in the light, with regard to the amount of algae's, non-organic materials and suspense resulting from land erosion, are computed.
- pH assimilation, alkalinity and total non- organic carbon are assimilated, and then the pH is computed and assimilated in relation to the amount of the other two parameters.
- The common pathogens, also, are assimilated in this model. Pathogen removal is determined in relation to the degree of light, heat and sediment.

2.15.3 Introducing QUAL2K

QUAL2K is the latest version of QUAL models capable of uncertainty analysis. The model is able to solve the equations of the river in both static and pseudo-dynamic state (here, we mean that the model for assimilation of qualitative variables in the river acts in the dynamic conditions, but the river pollution point and non-point source, are static- without any change). The program is able to assimilate the parameters including Solution oxygen, need of biochemical oxygen demand, temperature, acidity, suspense materials, total phosphorous, organic phosphorous, total nitrogen, organic nitrogen and algae.

The program is able to take into account the linear distribution of necessary oxygen materials for sediments, sedimentation of carbonic matters, nitrification and denitrification in the assimilation of water qualitative parameters.

2.15.3.1 Geometric parameters of the model

QUAL2K divides the river into the different duration in which they have the equal hydraulic conditions (as linear slope, width of floor, slope of walls …) the durations are numbered respectively from up to down and both point and non-point resources can enter into or exit from each part of the river.

2.15.3.2 Manning equation

It is possible to determine the speed and depth of the water in each section of the river by determining the geometric specification of the river including bottom width, linear slope and slope of the walls and use of Manning. As rivers lack regular forms, we should assume sections as a Trapezium in which each duration determines its geometric parameter.

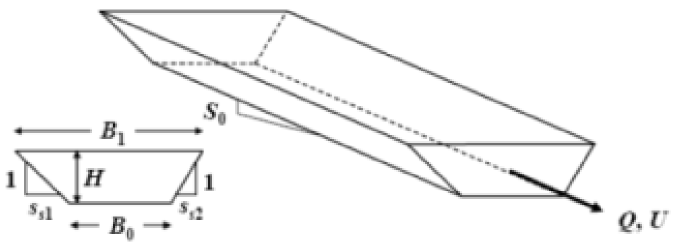

FIGURE 2-7 : GEOMETRIC PARAMETERS OF THE TRAPEZOIDAL CHANNEL

By replacement the questions and solving the equation based on depth we will have, (Canale and Chapra, 2002[77]).

$$Q = \frac{S_0^{1/2}}{n}\frac{A_c^{5/3}}{P^{2/3}}$$ Equation 2

$$A_c = [B_0 + = 0.5(s_{s1} + s_{s2})H]H$$ Equation 3

$$A_c = [B_0 + = 0.5(s_{s1} + s_{s2})H]H$$ Equation 4

Where:

P = Wet Perimeter

S = Slope

A = Section Area

A_c = Trapezoidal cross-sectional area

$$H_k = \frac{(Qn)^{5/3}\left(B_0 + H_k + \sqrt{s_{s1}^2 + 1} + H_{k-1}\sqrt{s_{s2}^2 + 1}\right)^{2/5}}{S^{3/10}[B_0 + 0.5(s_{s1} + s_{s2})H_{k-1}]} \qquad \text{Equation 5}$$

Roughness coefficient (n) is different for different sections and the proposed values for each section have been shown in 00. The coefficient's value varies with the changes in the flow and depth (Canale and Chapra, 2002[78]).

The coefficient varies from 0.015 for the smooth section to 0.15 for the natural section with the high roughness when the river is full .For assimilation of the river water quality in the critical conditions in which the depth of flow is too low, the coefficient is much higher than the mentioned values.

TABLE 2-3 : MANNING ROUGHNESS COEFFICIENT FOR OPEN CHANNEL[CHOW,1988[79]]

n	Material
Man-made Channels	
0.012	Concrete
	Carvel bottom with sides:
0.020	Concrete
0.023	Mortared Stone
0.033	Ripard
Natural stream channels	
0.025-0.040	Clean, Straight
0.030-0.050	Clean, winding and some weeds
0.050	Weeds and pools, winding
0.040-0.10	Mountain stream with boulders
0.050-0.20	Heavy brush, timber

2.15.3.3 Temperature models:

Temperature is one of the most important parameters in assimilation of the river water quality in each spot of the river. Temperature variations affect the river water quality, solution oxygen, rate decrease in BOD therefore, determining the temperature in each term of the river is very important. The factors, which are effective in determining the temperature, include early temperature of the river, weather temperature, temperature of the land surface and river content, temperature of the point and non-point resources entering to the river, intensity of the sun light, weather atmosphere condition, and day length

2.15.3.4 Assimilation of qualitative parameters

Qualitative parameters and balance of the total mass the parameters and qualitative items of the model are in Table 2-4.

TABLE 2-4 : COMPONENTS AND VARIABLES OF THE MODEL QUAL2K [CHAPRA ET AL., 2003[80]]

Variable	Symbol	Units
Conductivity	s	μMohs
Inorganic suspended solids	m_i	mg D/L
Dissolved oxygen	o	mg O_2/L
Slowly reacting CBOD	c_s	mg O_2/L
Fast reacting CBOD	c_f	mg O_2/L
Organic nitrogen	n_o	μg N/L
Ammonia nitrogen	n_a	μg N/L
Nitrate nitrogen	n_n	μg N/L
Organic phosphorus	p_o	μg N/L
Inorganic phosphorus	p_i	μg N/L
Phytoplankton	a_p	μg N/L
Detritus	m_o	mg D/L
Pathogen	X	Cfu/100L
Alkalinity	Alk	mg $CaCO_3$/L
Total inorganic carbon	c_T	mole/L
Bottom algae biomass	a_b	mg A/m^2
Bottom algae nitrogen	IN_b	mg N/m^2
Bottom algae phosphorus	IP_b	mg P/m^2

Except the bottom alga, a balance of total mass for each part is written in the following way:

$$\frac{dc_i}{dt} = \frac{Q_{i-1}}{V_i} c_{i-1} - \frac{Q_i}{V_i} c_i - \frac{Q_{ab,1}}{V_i} c_i + \frac{E'_i}{V_i}\left(c_{i-1} - c_i\right) + \frac{E'_i}{V_i}\left(c_{i+1} - c_i\right) + \frac{W_i}{V_i} + S_i \qquad \text{Equation 6}$$

The inlet mass flow rate to the system is compute d by this formula:

$$W_i = \sum_{j=1}^{psi} Q_{ps,i,j} c_{psi,j} \sum_{j=1}^{npsi} Q_{nps,i,j} c_{npsi,j} \qquad \text{Equation 7}$$

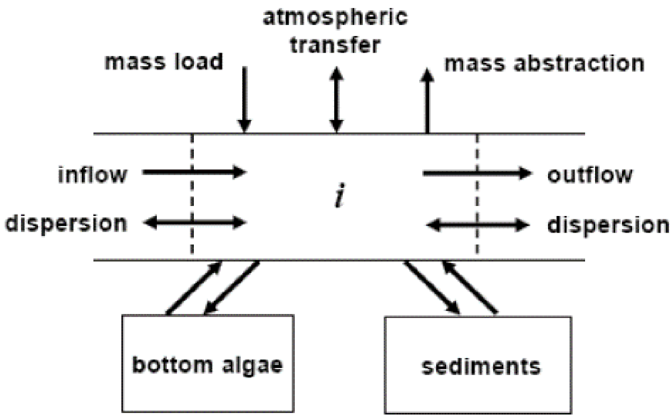

Figure 2-8: Mass Balance

For the bottom alga, the terms related to mass transfer and inflow mass to the system are deleted:

$$\frac{da_{b,i}}{dt} = S_{b,i}, \quad \frac{dIN_b}{dt} = S_{bN,i}, \quad \frac{dIP_b}{dt} = S_{bP,i} \qquad \text{Equation 8}$$

Production and consumption resources of each static variable have been shown in the figure Figure 2-9. It is not able that the existing nitrogen and phosphorous in the bottom alga have been shown in this figure.

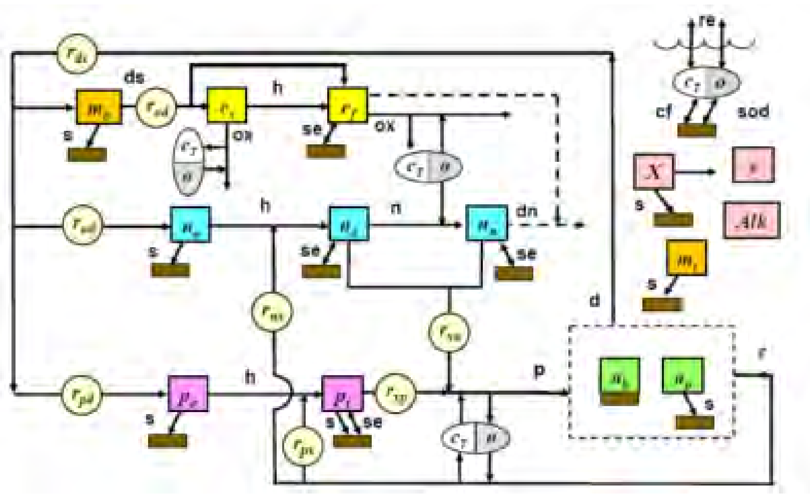

FIGURE 2-9 : KINETIC MODELING AND MASS TRANSFER PROCESSES [CHAPRA, SC ET AL., 2003[80]]

2.16 Basis and essence of reaction

2.16.1 Biochemical reactions

The following equations and formulas are used to show the chemical and biochemical reactions occurring in the modeling (Stumm and Morgan, 1996[81])

2.16.2 Photosynthesis and plant breathe

A. Ammonium ion as a food matter

$$106CO_2 + 16NH_4^+ + HPO_4^{2-} + 108H_2O \underset{R}{\overset{0}{\rightleftarrows}} C_{106}H_{110}N_{16}P_1 + 107O_2 + 14H^+$$

B. Nitrate as food matter

$$106CO_2 + 16NO_3^- + HPO_4^{2-} + 122H_2O + 18H^+ \underset{R}{\overset{0}{\rightleftarrows}} C_{106}H_{263}O_{110}N_{16}P_1 + 138O_2$$

C. Nitrification process

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$$

D. De nitrification process

$$5CH_2O + 4NO_3^- + 4H^+ \rightarrow 5CO_2 + 2N_2 + 7H_2O$$

E. Stoichiometry of organic matters

The Stoichiometry of organic matters should be given to the model. The following amounts are suggested for early estimation in the modeling (Redfield et al. 1953[82] and Chapra 1997[83])

$$100_g D : 40_g C : 7200_{mg} N : 1000_{mg} P : 1000_{mg} A$$

D,C,N,P,A respectively sit instead of dry weight, carbon, nitrogen, phosphorus and chlorophyll a. be careful that the amount of chlorophyll A is too variable and it can be between 500-2000 mgA (laws and Chalup 1990[84] and Chapra, 1997[83]).

2.16.3 Oxygen production and consumption

Amount of oxygen product and consumption should be determined for the model. The product and consumed oxygen is computed by the following statuses:

2.16.4 Ammoniac as an alimentary matter:

$$r_{oca} = \frac{107 moleO_2 (32_g O_2 \,|\, moleO_2)}{106 moleC (12_g C_2 \,|\, moleC)} = 2.69 \frac{gO_2}{gC}$$

2.16.5 Nitrate as an alimentary matter

$$r_{oca} = \frac{138 moleO_2 (32_g O_2 \,|\, moleO_2)}{106 moleC (12_g C_2 \,|\, moleC)} = 3.47 \frac{gO_2}{gC}$$

In the process of nitrification, the following formula is used to determine the consumed oxygen

$$r_{on} = \frac{2 moleO_2 (32_g O_2 \,|\, moleO_2)}{1 moleC (14_g C_2 \,|\, moleC)} = 4.57 \frac{gO_2}{gC}$$

Consumption of CBOD in the process of de nitrification the BOD that is used in the process of de nitrification will be in the following way:

$$R_{ondn} = 2.67 \frac{gO_2}{gC} \frac{5 moleC \times 12_g C \,|\, moleO}{4 moleN \times 14_g N \,|\, moleN} \times \frac{1gN}{1000 mgN} = 0.00286 \frac{gO_2}{mgN}$$

2.16.6 Effects of temperature on the reactions:

Effect of temperature for all reactions of degree one, which is used in the model, is based on the following equation:

$$k(T) = k(20)\theta^{T-20} \quad \text{Equation 9}$$

2.16.7 Complex variables:

Complex variables, which have been shown in QUAL2K, one:

$$TN = n_o + n_n + r_{na} a_p \quad \text{Equation 10}$$

$$TP = p_o + p_i + r_{pa} a_p \quad \text{Equation 11}$$

$$TKN = n_o + n_a + r_{na} a_p \quad \text{Equation 12}$$

$$TKN = n_o + n_a + r_{na} a_p \quad \text{Equation 13}$$

$$CBODu = c_s + c_f + r_{oc} r_{cd} m_o \qquad \text{Equation 14}$$

Reaction of the parameters the equations formulas of the reactions have been brought separately so:

2.16.8 Conservative matter:

By definition, conservative matter is the matter, which does not participate in the reactions. In other words:

$$S_s = 0 \qquad \text{Equation 15}$$

2.16.9 Phytoplankton:

$$S_{ap} = PhytoPhoto - Phyto\,Resp - Phyto\,Death - Phyto\,Settl \qquad \text{Equation 16}$$

2.16.10 Bottom alga:

Bottom algae are increased in the process of nitrification and decrease in the process of breathe and mortality:

$$S_{ap} = BotAlgPhoto - BotAlgResp - BotAlgDeath \qquad \text{Equation 17}$$

2.16.11 Detritus matters:

Detritus's are increased by death of plants and decreased by solving and sedimentation.

$$S_{mo} = r_{da} Phyto\ Death + Bota\ lg\ Death - DetrDiss - DetrSettl \qquad \text{Equation 18}$$

2.16.12 SCBOD:

SCBOD is increased by solving the organic ingredient and decreased by hydrolyze and oxidation.

$$S_{cs} = (1 - F_f)\, r_{od}\ det\ rDiss - SlowCHydr - SlowCOxid \qquad \text{Equation 19}$$

2.16.13 fCBOD (slow reacting):

FCBOD is increased by death of organic ingredients, hydrolyze of slow CBOD, and decreased by oxidation and denitrification.

$$S_{cf} = F_f r_{od} DetrDiss + SlowCHydr - FastCOxid - r_{ondn} Denitr \qquad \text{Equation 20}$$

2.16.14 Organic nitrogen:

Organic nitrogen is increased by death of plant and decreased by hydrolyze and sedimentation

$$S_{no} = R_{na} PhytoDeath + q_{ON} BotA\ lg\ Death - ONHydr - ONSettl \qquad \text{Equation 21}$$

2.16.15 Ammoniac nitrogen:

Ammoniac nitrogen is increased during the process of organic nitrogen hydrolyze and breathe of phytoplankton.

This parameter is decreased by process of nitrification and photosynthesis of plant

$$S_{na} = DONHydr + r_{na}PhytoResp + r_{nd}BotAlgResp - NH_4Nitrif - r_{na}P_{ap}PhytoPhoto - r_{nd}P_{ub}BotAlgPhoto \quad \text{Equation 22}$$

2.16.16 Nitrate nitrogen:

Nitrate nitrogen is increased by nitrification of ammoniac and decreased by process of denitrification and photosynthesis of plants.

$$S_{ni} = NH_4Nitrif - Denitr - r_{na}(1-p_{ap})PhytoPhoto - r_{nd}(1-P_{ab})BotAlg\,Photo \quad \text{Equation 23}$$

2.16.17 Organic phosphorous:

Organic phosphorous is increased during the process of plant death and decreased by hydrolyze and sediment from

$$S_{po} = r_{pa}PhytoDeath + q_{OP}BotAlgDeath - OPHydr - OPSettl \quad \text{Equation 24}$$

2.16.18 Inorganic phosphorous:

Inorganic phosphorous is increased in the processes of organic phosphorous hydrolyze and phytoplankton's breathe and decreased by plant photo synthesis

$$S_{pi} = DOPHydr + r_{pa}PhytoResp - R_{pa}PhtoPhoto - r_{pd}BotAlgUptakeP - IPSettl \quad \text{Equation 25}$$

2.16.19 Suspense in organic matters

Suspense inorganic matters are decreased be sedimentation

$$S_{mi} = -InorgSettl, \quad InorgSettl = \frac{v_i}{H}m_i \quad \text{Equation 26}$$

2.17 Calibration:

Genetic algorithm (GA) was used for calibration of the model; this algorithm is able to increase the correspondence of predicted results (computed by model) with the measured results up to its minimum. Fitness is necessary to use the genetic algorithm. The formula for computation of fitness is:

$$f(x) = \left[\sum_{i=1}^{n} w_i\right]\left[\sum_{i=1}^{n}\frac{1}{w_i}\left[\frac{\left(\frac{\sum_{j=1}^{m} O_{ij}}{m}\right)}{\left[\frac{\sum_{j=1}^{m}(P_{ij}-O_{ij})^2}{m}\right]^{1/2}}\right]\right] \quad \text{Equation 27}$$

In Which:

N=the parameters used in the formula

M=number of computed and measured pairs

W= weight factor

P= predicted amounts by model

O= amounts of the measured amounts

3 Results and discussion - Results

3.1 Seasonal investigation of physical and chemical parameters in Taleghan River on water quality

In summer, the sun heats up sidewalks, parking lots and streets. Rain falls on these areas, warms up, and runs into the river. Factories and stations that generate electricity to cool their processes also use water. Warm water enters the river, raises the temperature of the downstream area and changes oxygen levels. These are forms of thermal pollution. Thermal pollution is one of the most serious ways humans affect rivers. Cutting down trees along the bank of a river or pond also raises water temperature. Trees help shade the river from the sun. When they are cut down, the sun shines directly on the water and warms it up. Cutting down trees also leads to erosion. When soil from the riverbank washes into the river the water becomes muddy (turbid). The darker, turbid water captures more heat from the sun than clear water does. Even murky green water with lots of algae will be warmer than clear water.

3.1.1 Seasonal variation of temperature

Comparison of T during the two years of sampling showed significant difference between the two years(P-value>0.01) as far as this parameter is concerned, but comparison of T during the different seasons showed not a significant difference in the level 1% (P-value<0.01) in this parameter. Consequently, the summer showed the highest values for T during the two years and the winter shows the least values for T. Moreover, the spring and autumn seasons together did not show a significant difference in this parameter. In addition, there is no interaction between year and season (**Error! Not a valid bookmark self-reference.**, Figure 3-1, Figure 3-2). There is no significant difference between the sampling stations during the two years. According to what we observed, the temperature, in relation to the geographical condition of Taleghan River, increases from upstream to downstream which signifies an increase in the pollutant load of the river. In addition, the river originates from a mountainous region; therefore, as the weather temperature increases; it affects the water temperature. Moreover, the water temperature at the second station was the lowest recorded during the two years because of surface water streams of melted snow, which continues until summer. The highest temperature during the two years was in the fifth and sixth stations because the river enters the Taleghan plain and exits from the deep valleys. Furthermore there is also the entry of village pollutants.-

TABLE 3-1 : VARIANCE FOR T VALUES IN DIFFERENT YEARS AND SEASONS

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.253	0.253	0.017	0.000**
Season	3	4261.59	1420.53	97.966	0.895
Station	5	46.718	9.344	0.485	0.787
year*Season	3	47.2	15.733	1.085	0.358
Error	130	1885.02	14.5	-	-
Total	138	20020	-	-	-

Split-plot design.
***Significant level of %1*

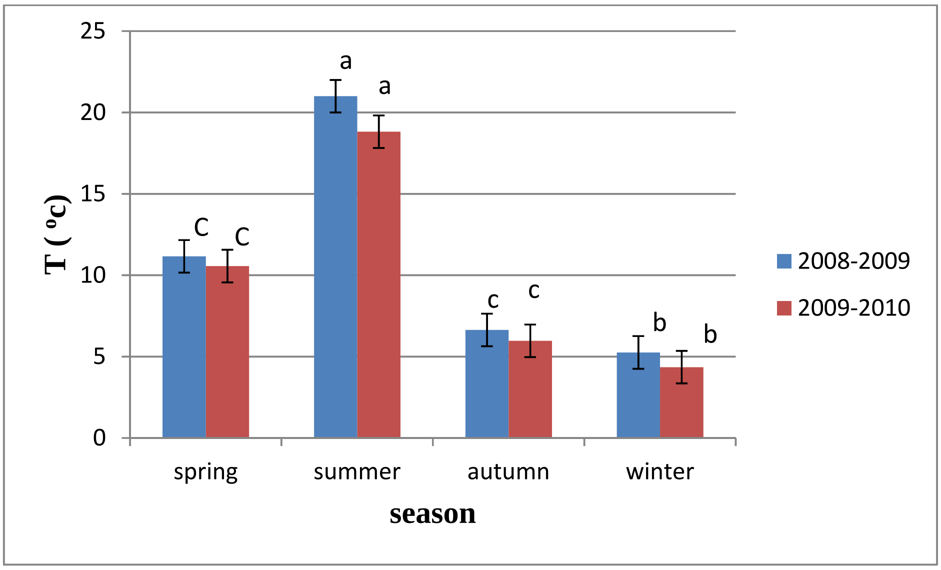

FIGURE 3-1 : SEASONAL CHANGES OF T VALUES

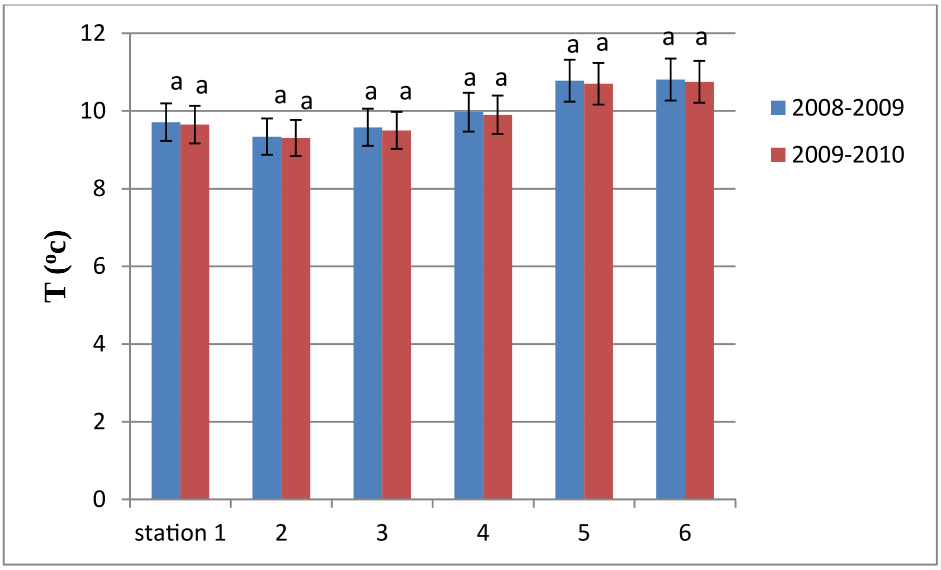

FIGURE 3-2 : STATIONS CHANGES OF T VALUES

3.1.2 Seasonal variation of pH

pH is a measurement of the acidity or basic quality of water. Acids can sting or burn, which is what you feel when you eat some kinds of fruit with a sore in your mouth. The pH scale ranges from a value of 0 (very acidic) to 14 (very basic), with 7 being neutral. The pH of natural water is usually between 6.5 and 8.2. At extremely high or low pH levels (for example 9.6 or 4.5), the water becomes unsuitable for most organisms. Young fish and insects are also very sensitive to changes in pH. Most aquatic organisms adapt to a specific pH level and may die if the pH of the water changes even slightly.

pH can vary from its normal levels (6.5 to 8.2) due to pollution from automobiles and coal-burning power plants. These sources of pollution help form acid rain. Acid forms when chemicals in the air combine with moisture in the atmosphere. It falls to earth as acid rain or snow. Many lakes in eastern Canada, the northeastern US, and northern Europe are becoming acidic because they are downwind of polluting industrial plants. Drainage from mines can seep into streams and ground water and make the water more acidic as well.

Comparison of pH in the two years of sampling shows that there is no significant difference between the two years as far as this parameter is concerned(P-value<0.01). Comparison of pH at different seasons shows that there is a significant difference in level %1 of this factor (P-value>0.01). Consequently during each of these two years the highest pH value was recorded in spring, while the least pH value was recorded in summer. Autumn and winter together do not show a meaningful difference in this parameter. Also, there is no observable interaction between year and season (**Error! Not a valid bookmark self-reference.**). There is no significant difference between the sampling stations in these two years.

Since, Taleghan River is not exposed to different type of soils from stations 1 to 6; it was predictable that pH would be stable between the stations. Also, this result might suggest that the wastewater and runoff that are introduced to the river are almost pH neutralized, or the tampon power of the river is high enough to neutralize the acidic or basic wastewater drainages.

The changes in pH during the different sessions are related to intensity of photosynthesis, if the effects of wastewater drainages are neglected. Figure 3-2 shows the pH variations at the different stations of Taleghan River for these two years. Overall, the river has the tendency toward alkalinity.

TABLE 3-2 : VARIANCE FOR PH VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.020	0.020	0.266	0.008
Season	3	10.869	3.623	47.784	0.094
Station	5	1.086	0.217	2.009	0.145
year*Season	3	0.004	0.001	0.018	0.997
Error	130	9.856	0.076	-	-
Total	138	9189.001	-	-	-

Split-plot design.

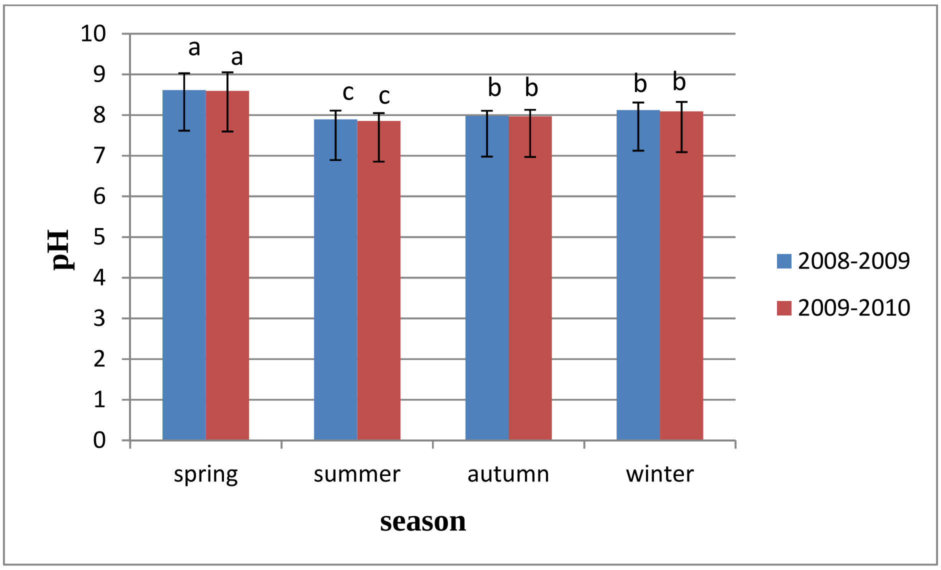

FIGURE 3-3 : SEASONAL CHANGES OF pH VALUES

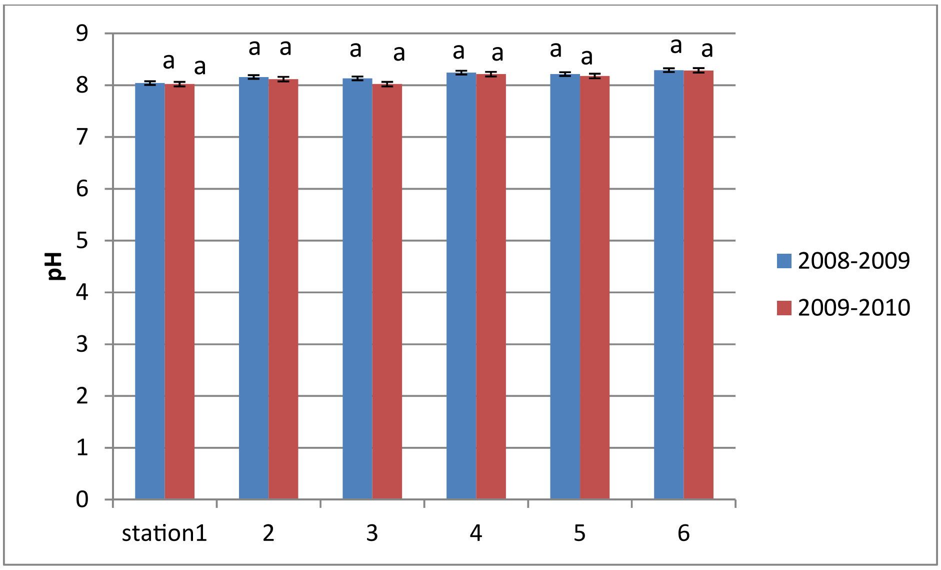

FIGURE 3-4: STATIONS CHANGES OF pH VALUES

3.1.3 Seasonal variation of Dissolved oxygen (DO)

Like people, aquatic organisms need oxygen to survive and stay healthy. In areas with waves, or where water tumbles over rocks, falling water traps oxygen and mixes it into the water.

Unlike people, aquatic organisms breathe oxygen that is dissolved in water. To breathe underwater, fish and other aquatic organisms use gills instead of lungs. These gills breathe the oxygen dissolved in the water.

The content of dissolved oxygen in water is affected by many factors such as the state of sea surface, hydrodynamic and biochemical processes, and thus its distribution is very complicated. Clean, healthy water has plenty of DO. When water quality decreases, DO levels drop and it becomes impossible for many animals to survive. Some fish such as trout require lots of dissolved oxygen. Others such as carp can live in water with lower levels of DO.

Warmer water holds less oxygen than cold water. Also, the time of year and many other factors affect the amount of DO in water. The main reason DO levels might fall is the presence of organic waste. Organic waste comes from something living or that was once living. It comes from raw or poorly treated sewage; runoff from farms and animal feedlots; and natural sources like decaying aquatic plants and animals and fallen leaves in water.

Microscopic organisms, called decomposers, break down the organic waste and use oxygen in the process. Two common types of decomposers are bacteria and protozoa. More waste means more decomposers and more oxygen being used. DO levels can also fall due to any human activity that heats the water.

Comparison of DO in the two years of sampling shows that there is a significant difference between the two years as far as this parameter is concerned($P\text{-value}>0.01$). Comparison of DO at different seasons shows a significant difference at level of %1 for this parameter ($P\text{-value}>0.01$). Consequently, spring had the highest DO in the two years and winter the least. There are no significant differences in this parameter during spring and summer. Moreover there is no observable mutual effect between year and season (**Error! Not a valid bookmark self-reference.**, Figure 3-5 and Figure 3-6). There is no significant difference between the sampling stations during these two years.

It is believed that DO level has negative correlation with temperature. Although temperature of spring was approximately two-fold higher than winter, DO values of these two seasons were similar in autumn and winter.

This is due to the up level flow in spring caused by greater flood currents during winter. DO level increased from station 1 to 4 and then decreased in station 5 and 6 and remained the same in the station 4. This is due to the fact that stations 4 and 5 are affected by local wastewaters and stations 1 to 3 are affected by estuarine currents and turbulences, which in turn lead to decrease in DO levels. Another reason might be related to slope of the river. Finally, DO level increase in station 6.

TABLE 3-3 : VARIANCE FOR DO VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.109	0.109	0.176	0.676
Season	3	23.171	7.724	12.414	0.741
Station	5	2.936	0.587	0.703	0.623
year*Season	3	0.126	0.042	0.067	0.977
Error	130	80.884	0.622	-	-
Total	138	4425.836	-	-	-

Split-plot design.

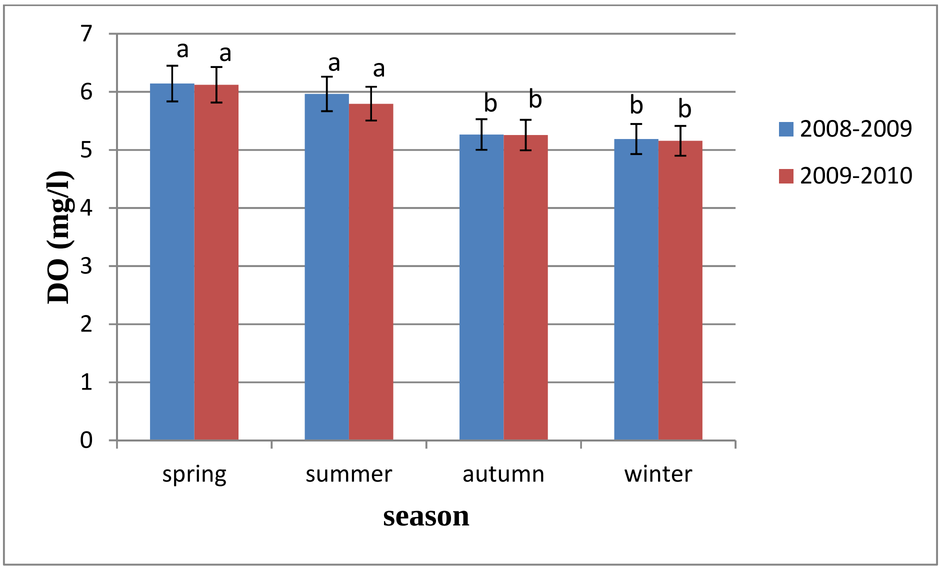

FIGURE 3-5: SEASONAL CHANGES OF DO VALUES

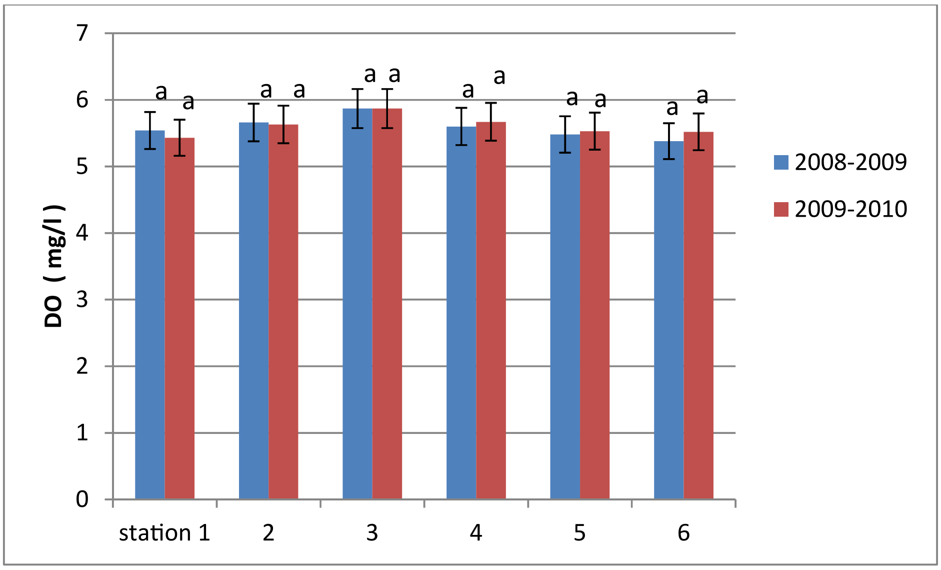

FIGURE 3-6: STATIONS CHANGES OF DO VALUES

3.1.4 Seasonal variation of Nitrogen (N)

Nitrogen is one of the most common elements in the world. All living plants and animals need it to build proteins. Nitrogen and phosphorus are both nutrients.

High levels of nitrogen may make some people sick, especially young babies. This happens to people who drink directly from groundwater wells where the water has too much nitrogen.

Because nitrogen is a nutrient like phosphorus, the effects of this nutrient on water are almost the same. Like phosphorus, extra nitrogen in water leads to rapid plant growth.

Too many plants living in the water can lead to some bad results. When these plants die (which, in the case of tiny plants or algae, is very often), they sink to the bottom. There, bacteria decompose the dead plant parts. They use up most of the oxygen in the water. Nitrogen can be found in fertilizers and in human or farm animal wastes. In some cases, home septic systems in rural areas leak waste into the ground. This waste should be filtered by the soil around the septic system. However, this does not always happen. Therefore, groundwater can become polluted by nitrogen in the wastewater.

Comparison of N concentration within the two years of sampling shows a significant difference in this parameter at level of 1% between these two years (P-value>0.01). Comparison of N at different seasons showed a significant difference between seasons in this parameter at level of 1%. Consequently, autumn shows the highest N value in both years and summer shows the least N value in the same period. Furthermore, there was no observable interaction between year and season (Table 3-4, Figure 3-7 and Figure 3-8). There is a significant difference between the sampling stations during the two years at level of 5%. Consequently, station 6 showed the highest N value during the two years and there was no significant difference between the other stations.

TABLE 3-4 : VARIANCE FOR N VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	**Degree of freedom(DF)**	**Sum of square (SS)**	**Mean sum of square(MS)**	**F- Statistics (F)**	**P-value**
year	1	19.56	19.56	23.177	0.050*
Season	3	20.67	6.89	8.164	0.043**
Station	5	3.97	0.795	0.942	0.050*
year*Season	3	49.39	16.465	19.510	0.957
Error	130	105.491	0.844	-	-
Total	138	1559.662	-	-	-

Split-plot design.
**Significant level of %5*
***Significant level of %1*

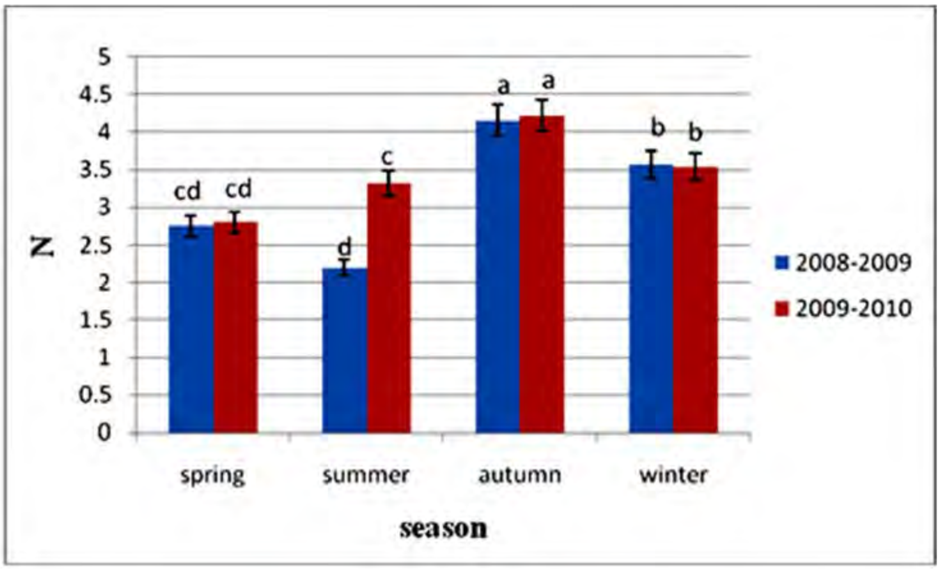

FIGURE 3-7 : SEASONAL CHANGES OF N VALUES

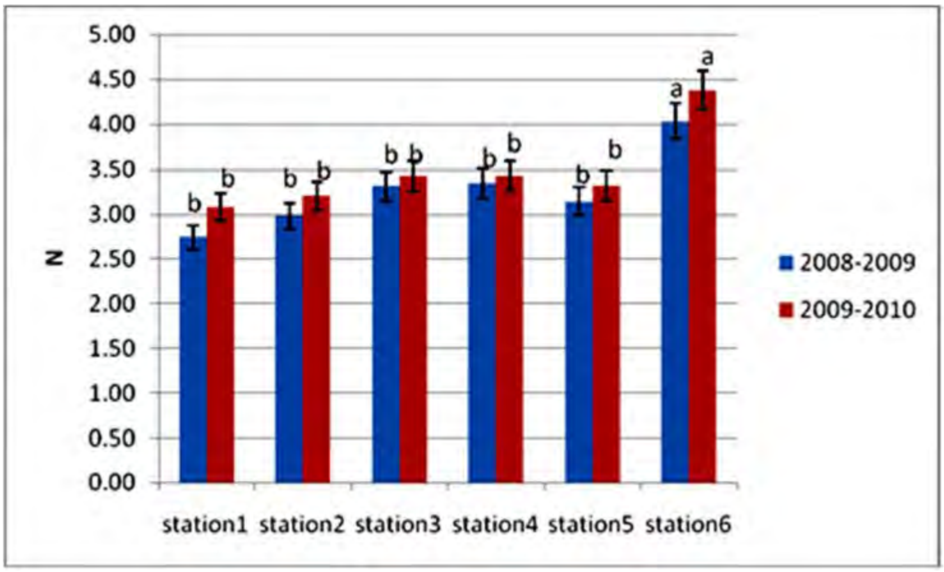

FIGURE 3-8: STATIONS CHANGES OF N VALUES

3.1.5 Seasonal variation of Nitrate (NO_3)

Comparison of N concentration (NO_3) during the two years of sampling showed significant difference in this parameter between the two years (P-value>0.01).

Comparison N concentration (NO_3) at different seasons showed that there is a significant difference in this parameter between seasons at level of 100%. Consequently during these two years (2008-2009) the highest N (NO_3) concentration was in autumn and the least N (NO_3) concentration was in summer.

Winter and spring together do not show a significant difference in term of this factor. Also, there is not an interaction between the year and season (**Error! Not a valid bookmark self-reference.**, Figure 3-9 and Figure 3-10).

There is a significance difference between the sampling stations during the two years at level of 5%. Consequently, station 6 showed the highest NO_3 value in 2009-2010.

Evidently, the Nitrate concentration, like other pollutants, has almost an increasing trend from upstream of the river to its downstream. This trend is because of entry of sewage of fishponds, runoff meadows and farms, waste of roadside restaurants from upstream of the river to its downstream causing increasing trend of Nitrate.

The highest Nitrate concentration was observed at the sixth station in autumn and winter. Like most of parameters, the first station, had the least Nitrate value in comparison to other stations.

TABLE 3-5 : VARIANCE FOR N[NO3-] VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	2.238	2.238	0.849	0.358
Season	3	54.101	18.034	6.843	0.020**
Station	5	39.497	7.899	2.415	0.042*
year*Season	3	6.981	2.327	0.883	0.452
Error	130	342.614	2.635	-	-
Total	138	1759.869	-	-	-

Split-plot design.
***Significant level of %1*
**Significant level of %5*

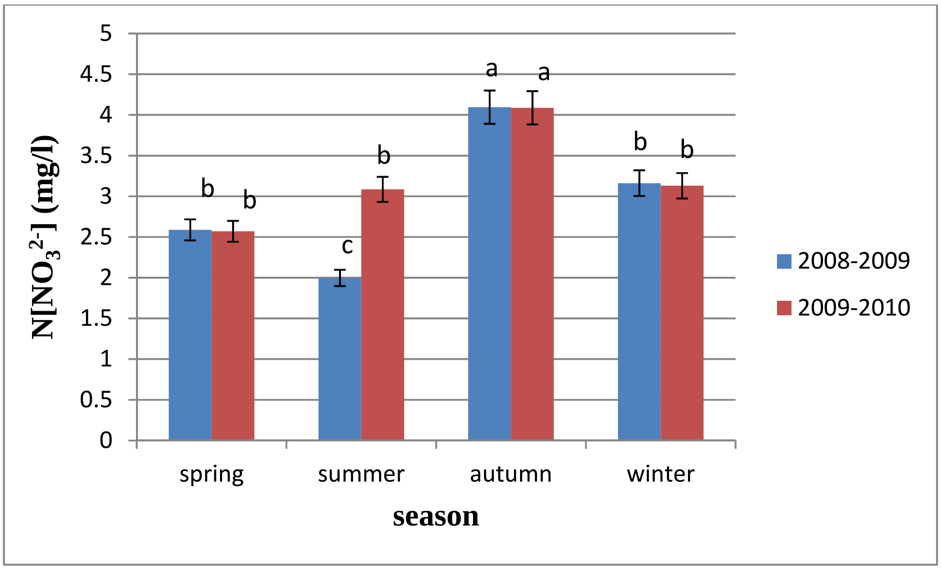

FIGURE 3-9 : SEASONAL CHANGES OF N[NO3] $^{2-}$ VALUES

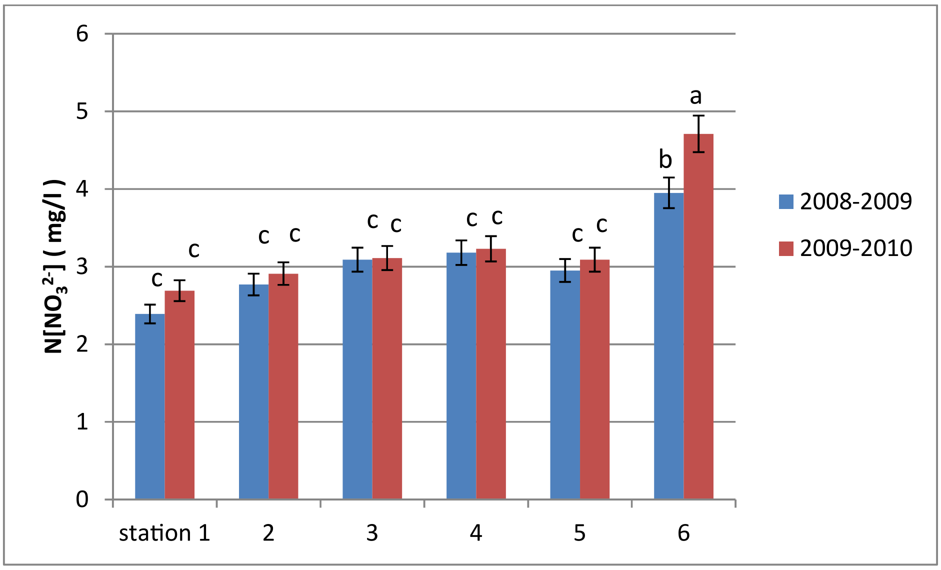

FIGURE 3-10 : STATIONS CHANGES OF N [NO3] $^{2-}$ VALUES

3.1.6 Seasonal variation of Nitrite (NO_2)

Comparison of NO_2 concentration in the two year of sampling showed significant difference in this parameter between the two years (P-value>0.01). Comparison of NO_2 concentration at different seasons showed a significant difference in this parameter between seasons at level of 5%. Consequently, spring and winter showed the highest NO_2 concentration in 2009-2010. Moreover, the least NO_2 concentration within 2008-2009 occurred in autumn. In addition, there was observable interaction between the year and season (**Error! Not a valid bookmark self-reference.**, Figure 3-11 and Figure 3-12). There is a significant difference between the sampling stations during the two years at level of 1%. Consequently, station 1 showed the highest NO_2 values during the two years.

TABLE 3-6 : VARIANCE FOR NO2- VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.005	0.005	0.195	0.659
Season	3	0.118	0.039	1.572	0.029*
Station	5	0.504	0.101	4.178	0.082**
year*Season	3	0.010	0.003	0.136	0.938
Error	130	3.242	0.025	-	-
Total	138	5.108	-	-	-

Split-plot design.
**Significant level of %5*
***Significant level of %1*

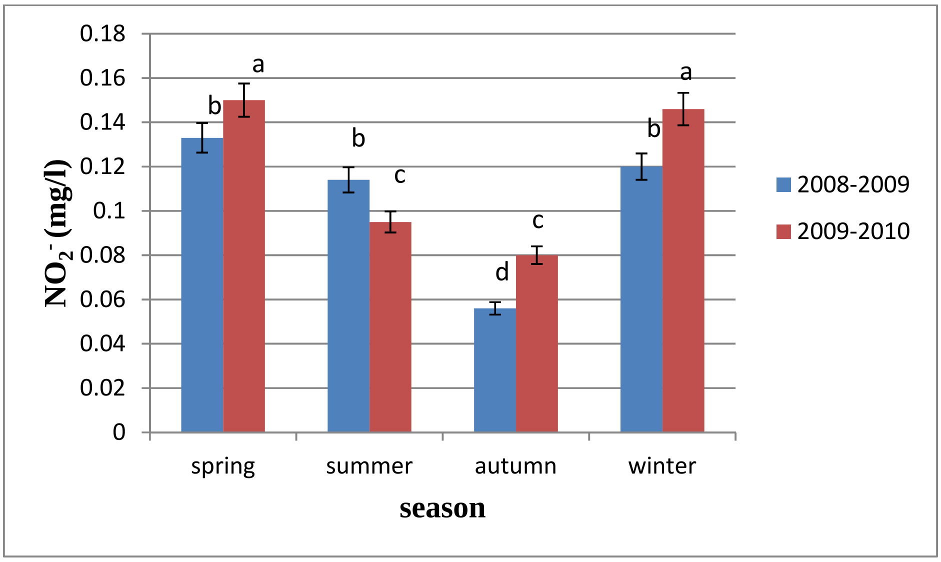

FIGURE 3-11 : SEASONAL CHANGES OF NO_2^- VALUES

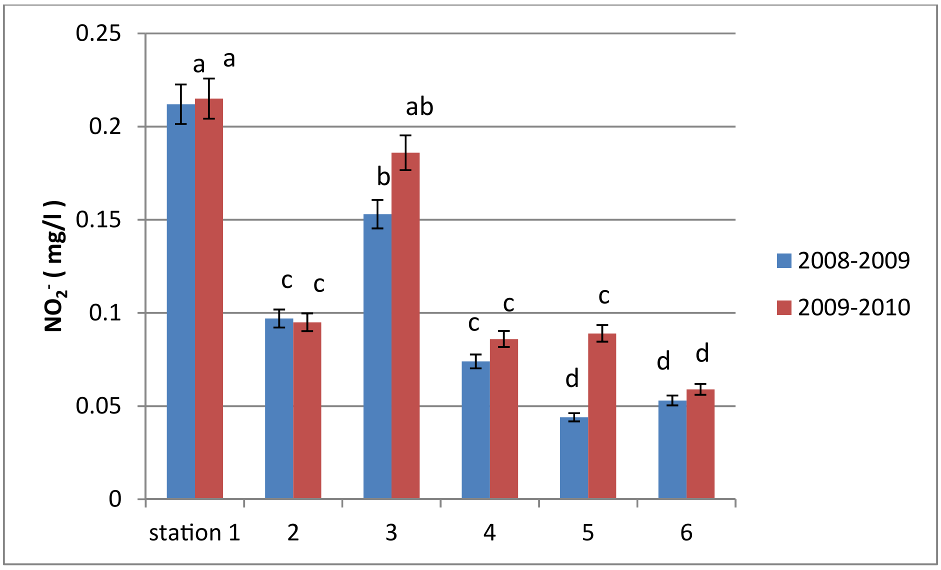

FIGURE 3-12 : STATIONS CHANGES OF NO_2^- VALUES

3.1.7 1.7. Seasonal variation of Ammonium (NH_4)

Comparison of NH_4 within the two year of sampling showed significant difference between the two years in this parameter (P-value>0.01). Comparison of NH_4 within the different seasons showed a significant difference in this parameter at level of 1%. Consequently, in both years the highest NH_4 concentration occurred in winter. During 2008-2009 autumn had the least NH_4 concentration. There is a little significant difference in NH_4 concentration between spring and autumn of 2008-2009. Moreover, there was observable interaction between the year and season. There was a significant difference between the sampling stations during the two years at level of

1%. Consequently, station 6 showed the highest NH4 value in 2009-2010.There is significant difference in winter and spring together as far as this parameter is concerned. Moreover, there was interaction between the year and season (**Error! Not a valid bookmark self-reference.**, Figure 3-13 and Figure 3-14).

TABLE 3-7 : VARIANCE FOR NH_4^+ VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.039	0.039	1.678	0.197
Season	3	1.354	0.451	19.442	0.064**
Station	5	0.116	0.023	0.498	0.027*
year*Season	3	0.028	0.009	0.397	0.755
Error	130	3.018	0.023	-	-
Total	138	6.529	-	-	-

Split-plot design.
***Significant level of %1*
**Significant level of %5*

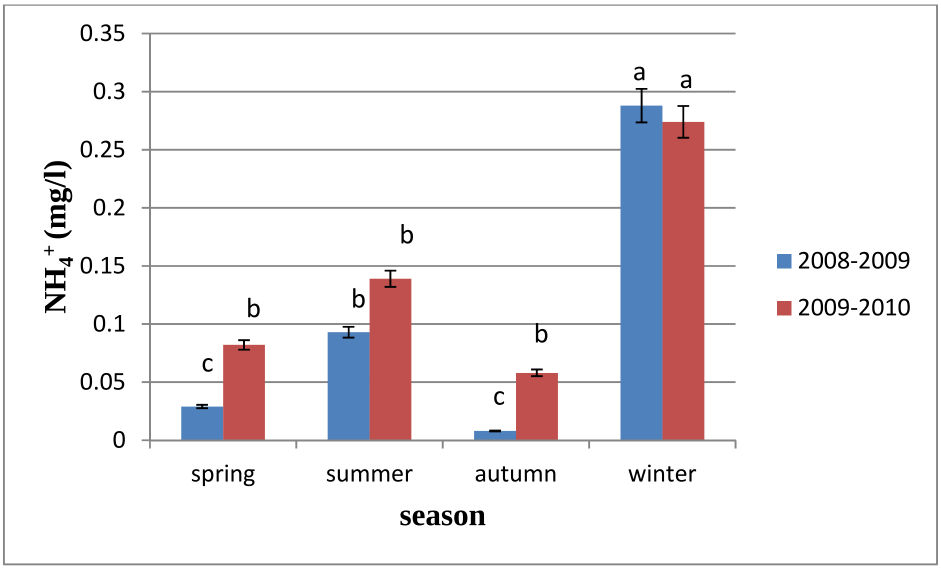

FIGURE 3-13: SEASONAL CHANGES OF NH_4^+ VALUES

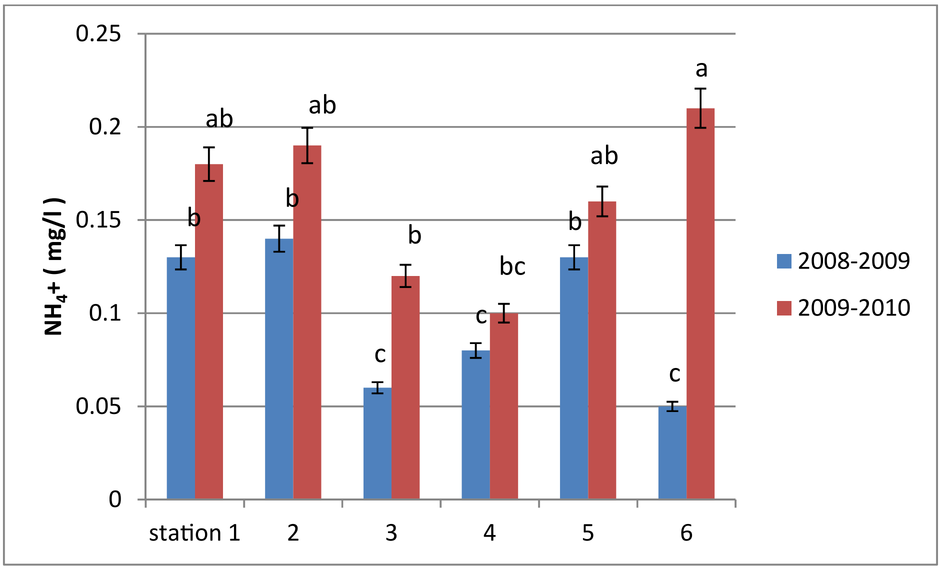

FIGURE 3-14 : STATIONAL CHANGES OF NH_4^+ VALUES

3.1.8 Seasonal variation of Phosphate (PO_4)

Phosphorus is a nutrient found in all living things. It is also a mineral in nature. Both plants and animals have phosphorus in their bodies. It is in most of the foods we eat. When people buy fertilizer for their gardens, they use nutrients such as phosphorus to help plants grow.

Scientists believe that when too much phosphorus enters a river or lake, plants grow more. Tiny plants like algae use the phosphorus to grow.

Other plants that live on the surface and bottom of a river or lake use phosphorus also. When plant growth increases, the water turns pea-green and becomes cloudy. The green color comes from the chlorophyll content of the tiny floating plants.

Comparison of PO_4 within the two years of sampling showed significant difference between the two years in this parameter.

Comparison of PO_4 concentration at different seasons showed a significant seasonal difference in this parameter at level of 1%. Consequently in 2008-2009, the highest PO_4 concentration occurred in summer. There was no significant difference between other seasons in both years.

Also, there was observable interaction between the year and season (Table 3-8, Figure 3-15and Figure 3-16).

There is a significant difference between the sampling stations during the two years at level of 1%. Consequently, station 1 showed the highest PO_4 value during the two years.

TABLE 3-8 : VARIANCE FOR PO_4^{3-} VALUES IN DIFFERENT YEARS AND SEASONS

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.000	0.000	0.080	0.778
Season	3	0.065	0.022	3.498	0.017*
Station	5	0.119	0.024	4.208	0.002**
year*Season	3	0.023	0.008	1.254	0.293
Error	130	0.802	0.006		
Total	138	2.342			

*Split-plot design. , *Significant level of %1 , **Significant level of %1*

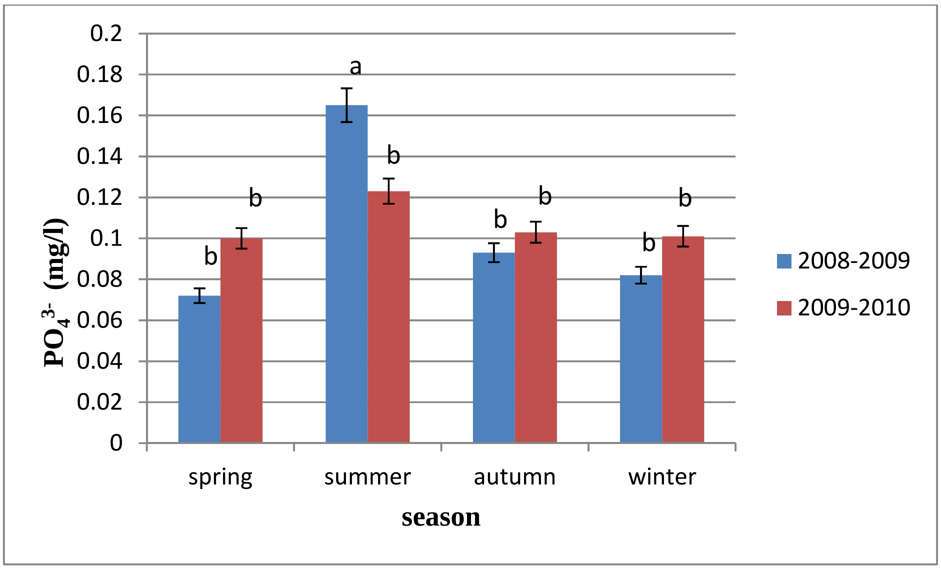

FIGURE 3-15 : SEASONAL CHANGES OF PO_4^{3-} VALUES

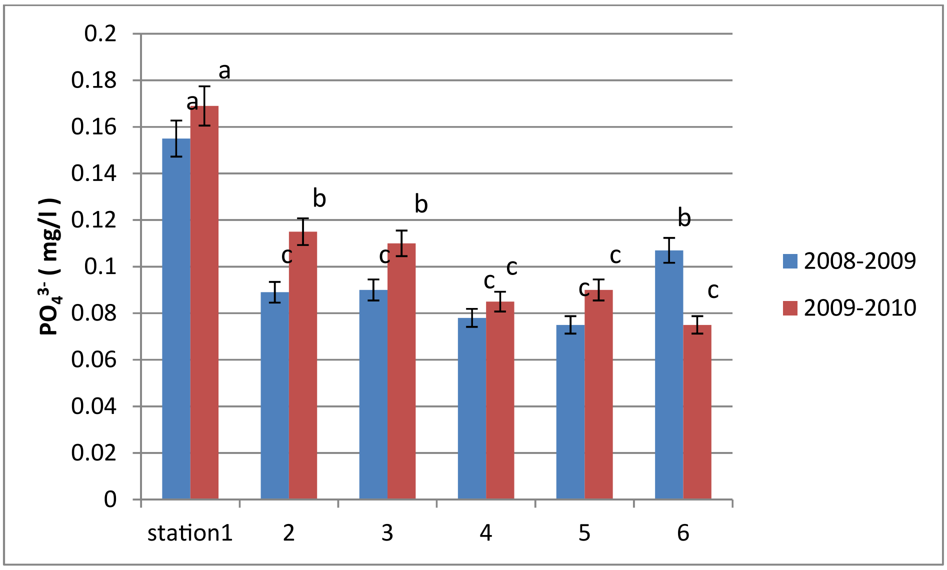

FIGURE 3-16 : STATIONS CHANGES OF PO_4^{3-} VALUES

3.1.9 Seasonal variation of Electro conductivity (EC)

Comparison of EC in the two sampling years showed no significant difference in this parameter in these two years. Comparison of EC at different seasons showed a significant difference at level of %1 of this parameter. Consequently, spring showed the highest EC value in the two years while winter showed the least EC value in both years. Winter showed the least EC value. Moreover, there was no observable interaction between the two years (**Error! Not a valid bookmark self-reference.**, Figure 3- and Figure 3-). There was no significant difference between the sampling stations during these two years.

Figure 3- shows changes in electrical conductivity as micro Siemens per centimeter at different stations during these two years. Station 5 had the highest electrical conductivity because the volumes of surface water and urban wastewater in the station 5 of Taleghan River were higher.

TABLE 3-9 : VARIANCE FOR EC VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	6667.320	6667.320	0.830	0.001
Season	3	2814201.439	938067.146	116.843	0.030**
Station	5	95961.962	19192.392	1.315	0.265
year*Season	3	17896.491	5965.497	0.743	0.528
Error	130	1043701.778	8028.475		
Total	138	5.657			

Split-plot design.
***Significant level of %1*

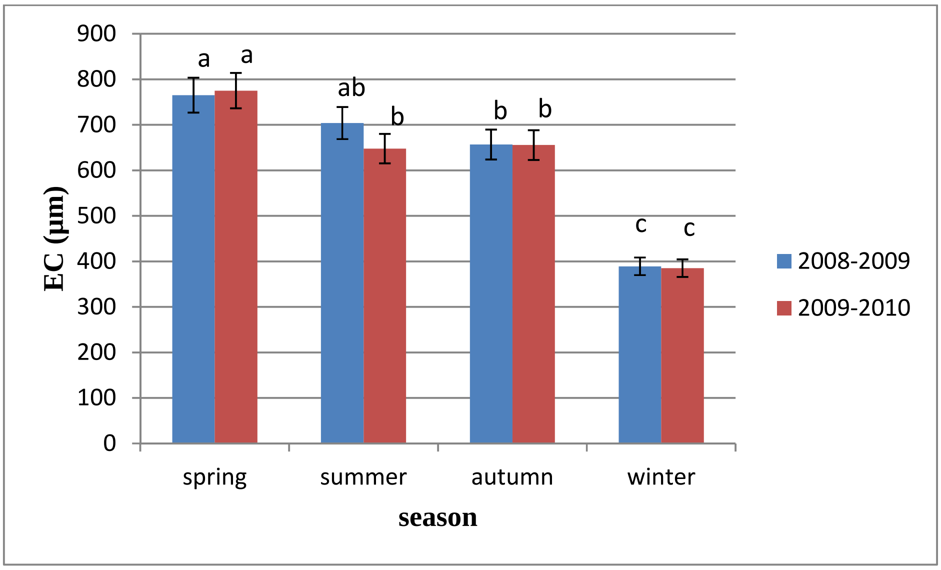

FIGURE 3-17 : STATIONS CHANGES OF EC VALUES

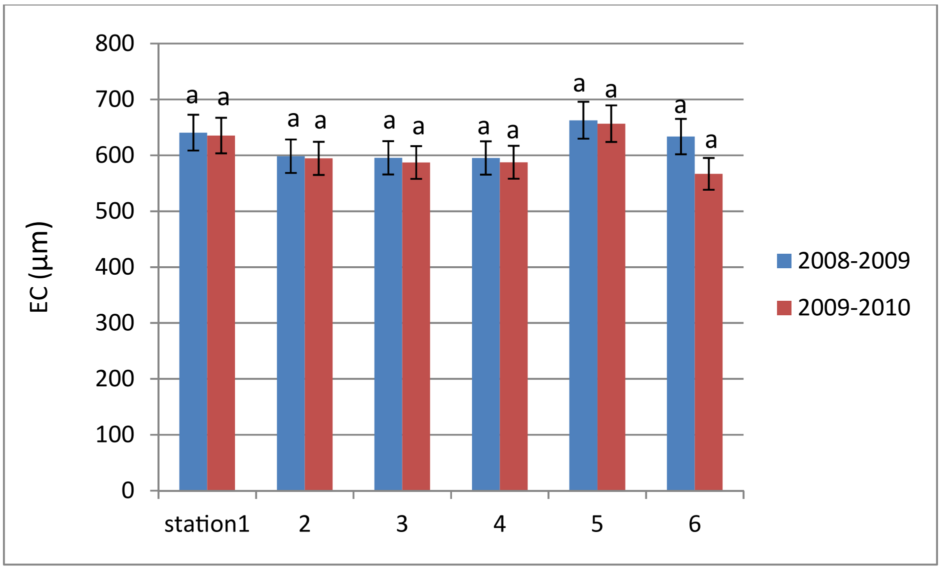

FIGURE 3-18 : STATIONS CHANGES OF EC VALUES

3.1.10 Seasonal variation of Flow (Q):

Comparison of Q value during the two years of sampling showed no significant difference in this parameter during these two years.

Comparison of Q at different seasons showed no significant difference between seasons for this parameter at level of 1%.

Consequently, winter had the least Q in 2008-2009. There was no significant difference between spring and summer in this parameter. Moreover there was no observable interaction between the year and season (Table 3-10, Figure 3- and Figure 3-).

There is a significant difference between the sampling stations during these two years at level of 1%.

Consequently, station 6 showed the highest value of Q during the two years. Moreover, there was no significant difference between stations 5 and 6. Flow in the station 1 was the lowest and in stations, 5 and 6 the highest in the Taleghan River.

More than agricultural drains and municipal sewage, wastewaters from the villages entered the Taleghan River due to the high slope of the land.

The effects of weather climate changes are evident in the region because the highest and lowest rate of rain occurred in the summer.

Moreover, the construction of Taleghan dam at the end of the river is the other reason for the climate change and change in the duration of rain.

TABLE 3-10 : VARIANCE FOR Q VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	0.706	0.706	0.085	0.002
Season	3	1695.036	565.012	67.771	0.005**
Station	5	146.738	29.348	3.179	0.011*
year*Season	3	2.467	0.822	0.099	0.961
Error	130	1083.826	8.337		
Total	138	6693.619			

Split-plot design.
***Significant level of %1*
**Significant level of %5*

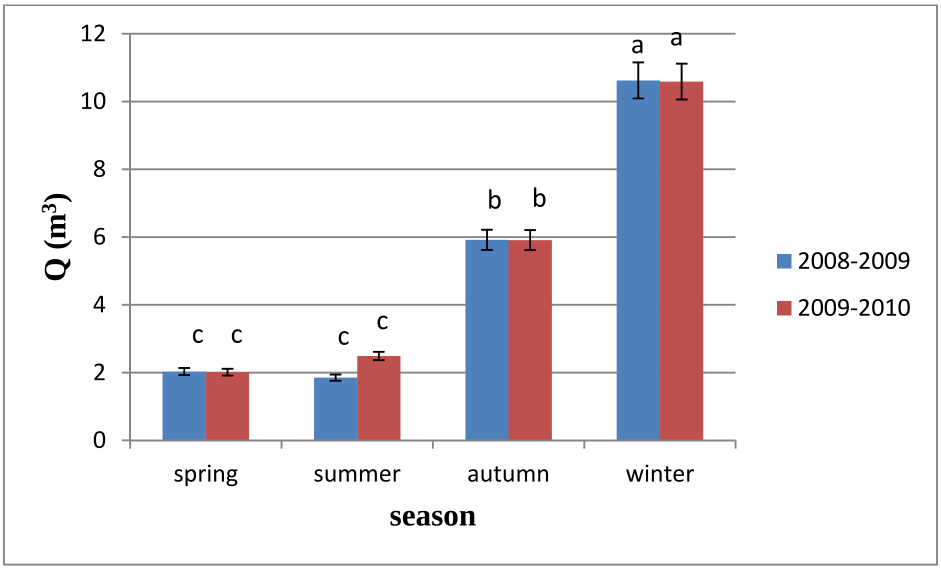

FIGURE 3-19: SEASONAL CHANGES OF Q VALUES

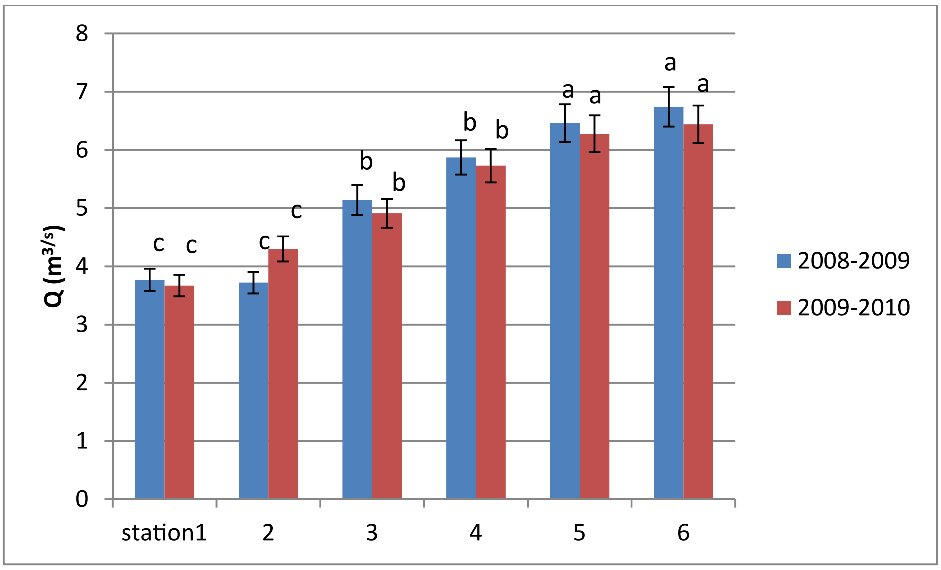

FIGURE 3-20: STATIONS CHANGES OF Q VALUES

3.2 Seasonal investigation of biological parameters in Taleghan River on water quality

3.2.1 Seasonal variation of Biological oxygen demand (BOD_5):

When organic matter decomposes, microorganisms (such as bacteria and fungi) feed upon this decaying material and eventually the matter becomes oxidized. Biochemical oxygen demand, or BOD_5, measures the amount of oxygen consumed by microorganisms in the process of decomposing organic matter in stream water. The harder the microorganisms work, the more oxygen they use, and the higher the measure of BOD_5, leaving less oxygen for other life in the water.

BOD_5 directly affects the amount of dissolved oxygen in rivers and streams. The more rapidly oxygen is depleted in the stream, the greater the BOD_5. This means less oxygen is available for other aquatic life, such as insects and fish. A high BOD_5 measure harms stream health in the same ways as low dissolved oxygen: aquatic organisms become stressed, suffocate, and die. The few organisms that can survive with less oxygen, like carp and sewage worms, will increase in number.

As more organic matter enters a stream, the BOD_5 will rise. Organic matter may include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban storm water runoff.

Comparison of BOD_5 in the two sampling years showed no significant difference in this parameter between these two years. Comparison of BOD_5 level at different seasons showed a very significant difference. Consequently, the highest BOD_5 level in these two years occurred in winter. The least BOD_5 level in the two years was recorded in summer had. There is no significant difference between spring and autumn. Moreover, there was no observable interaction effect between year and season (**Error! Not a valid bookmark self-reference.**, Figure 3- and Figure 3-). There was a significant difference between the sampling stations during the two years at level of 1%. Consequently, station 6 showed the highest BOD_5 level during these two years. There was no significant difference between stations 3 and 4.

It is believed that BOD_5level is related to planktonic colonies; it is not surprising that the BOD_5levels were similar in different sessions and stations, because Taleghan River has very limited planktonic colonies mainly due to high turbidity and speed of the river.

TABLE 3-11 : VARIANCE FOR BOD VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	1.512	1.512	0.020	0.005
Season	3	554.580	184.860	2.400	0.017*
Station	5	419.62	83.925	0.964	0.044*
year*Season	3	3.329	1.110	0.014	0.009
Error	130	10014.622	77.036	-	-
Total	138	65512.310	-	-	-

Split-plot design.
**Significant level of %5*

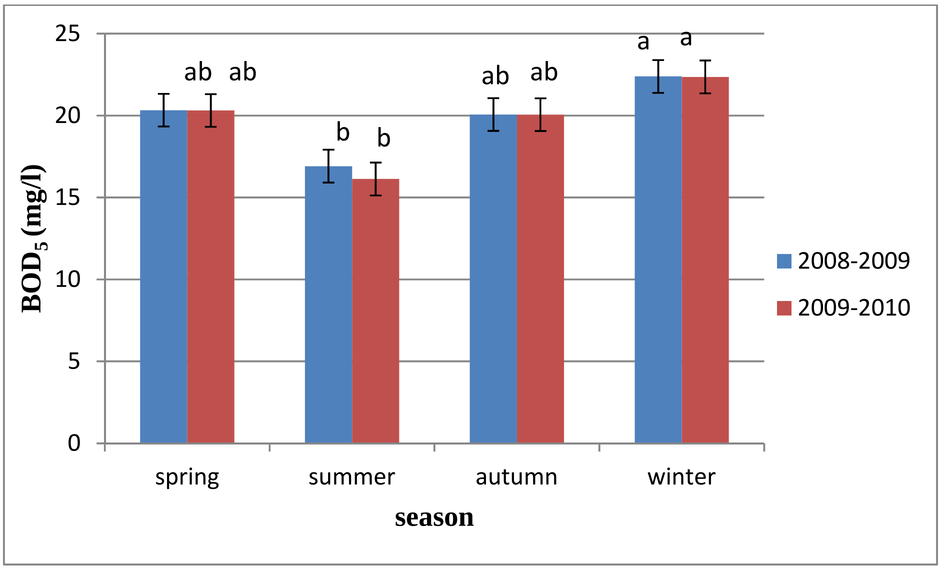

FIGURE 3-21: SEASONAL CHANGES OF BOD_5 VALUES

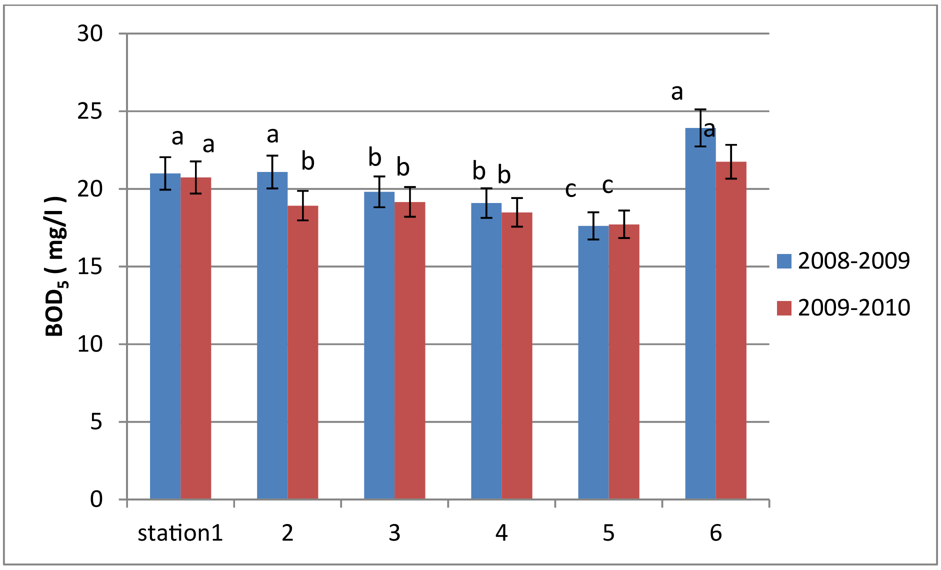

FIGURE 3-22 : STATIONS CHANGES OF BOD_5 VALUES

3.1.11 Seasonal variation of Chemical oxygen demand (COD)

Comparison of COD level during the two years of sampling showed no significant difference between the two years as far as this parameter is concerned. Comparison of COD level at different seasons showed a significant difference at level of %1 for this parameter. Consequently, winter had the highest COD level in these two years, while summer season had the least COD in the two years. Moreover, there is no interaction between year and season (**Error! Not a valid bookmark**

self-reference., Figure 3- and Figure 3-). There is a significant difference between the sampling stations during the two years at level of 1%. Consequently, station 6 showed the highest COD value in 2009-2010.

Furthermore the graph below shows that COD levels of spring, autumn and winter were similar for two years and significantly higher than the values of summer.

TABLE 3-12 : VARIANCE FOR COD VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	1.038	1.038	0.004	0.008
Season	3	5563.583	1854.528	7.008	0.090**
Station	5	11659.204	2331.841	2.132	0.050*
year*Season	3	3.674	1.225	0.005	1.000
Error	130	34404.070	264.647		
Total	138	225275.840			

Split-plot design.
***Significant level of %1*

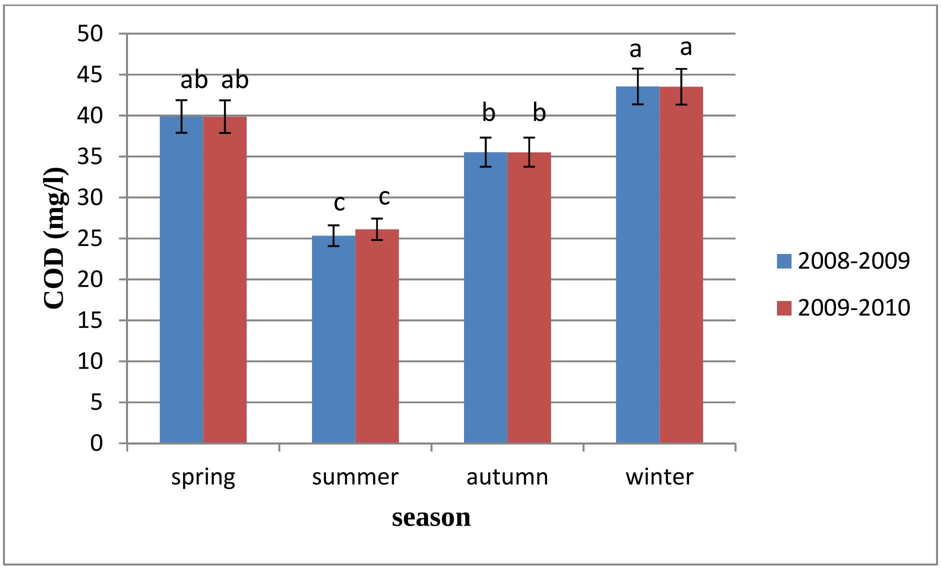

FIGURE 3-23 : CHANGES OF COD VALUES

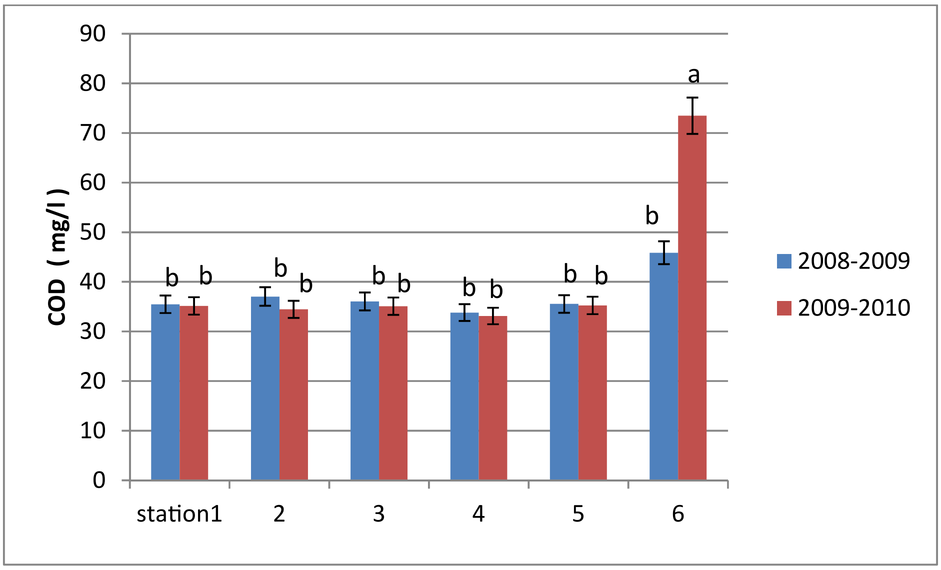

FIGURE 3-24 : STATIONS CHANGES OF COD VALUES

3.1.12 Seasonal variation of Fecal Coliform (FC)

Fecal coliform bacteria are found in the feces of human beings and other warm-blooded animals. By themselves, fecal coliform bacteria do not usually cause disease. In fact, they are already inside you. They occur naturally in the human digestive tract and aid in the digestion of food.

However, when a human being or other warm-blooded animal is infected with disease, pathogenic (disease causing) organisms are found along with fecal coliform bacteria.

Think of high levels of fecal coliform bacteria as a warning sign that water can make you sick, rather than as a cause of illness. If fecal coliform counts are high (over 200 colonies/100 ml of a water sample) in a body of water, there is a greater chance that disease causing organisms are also present. If you are swimming in waters with high levels of fecal coliform, you have a greater chance of developing a fever, nausea or stomach cramps from swallowing disease-causing organisms, or from pathogens entering the body through cuts in the skin, the nose, mouth, or ears. Some examples of diseases and illnesses that can be contracted in water with high fecal coliform counts include typhoid fever, hepatitis, gastroenteritis, and dysentery and ear infections.

Fecal coliform bacteria are living organisms, unlike the other conventional water quality parameters. The fecal coliform bacteria multiply rapidly when conditions are good for growth and die in large quantities when they are not.

Untreated sewage, poorly maintained septic systems, un-scooped pet waste, and farm animals with access to streams can cause high levels of fecal coliform bacteria to appear in a water body.

Comparison FC within the two years of sampling showed significant difference in parameter between the two years. Comparison of FC at different seasons showed a significant difference between seasons in this parametet at level of 5%. Consequently, winter had the highest FC count in 2009-2010. There was no significant difference between spring and summer in this parameter in 2009-2010. In addition, autumn had the least FC count. Moreover, there was no observable interaction between the year and season (Table 3-15, Figure 3-17 and Figure 3-18). There was a significant difference between the sampling stations during the two years at level of 1%. Consequently, station 6 showed the most FC counts during the two years.

The mean average count of Fecal Coliform during winter was more than other seasons because of increase in activities of the roadside restaurants and concentration of humans for different purposes around the river. Maximum amount of Fecal coliform was measured at summer in station 6 and the minimum amount at station 1. We observe in this diagram that the amount of Fecal coliform increased noticeably in the three final stations at all seasons because of increase in village waste in the region. Moreover, increase for Fecal coliform is likely during winter, because of the concentration of farm animals beside the villages.

TABLE 3-13 : VARIANCE FOR FECAL COLIFORM VALUES IN DIFFERENT YEARS AND SEASONS.

Variance Source	Degree of freedom(DF)	Sum of square (SS)	Mean sum of square(MS)	F- Statistics (F)	P-value
year	1	1043.139	1043.139	1.276	0.261
Season	3	4411.565	1470.552	1.799	0.017*
Station	5	88176.468	17635.294	188.524	0.000**
year*Season	3	54.077	18.026	0.022	0.996
Error	130	106291.917	817.630		
Total	138	203483.000			

Split-plot design.
**Significant level of %5*
***Significant level of %1*

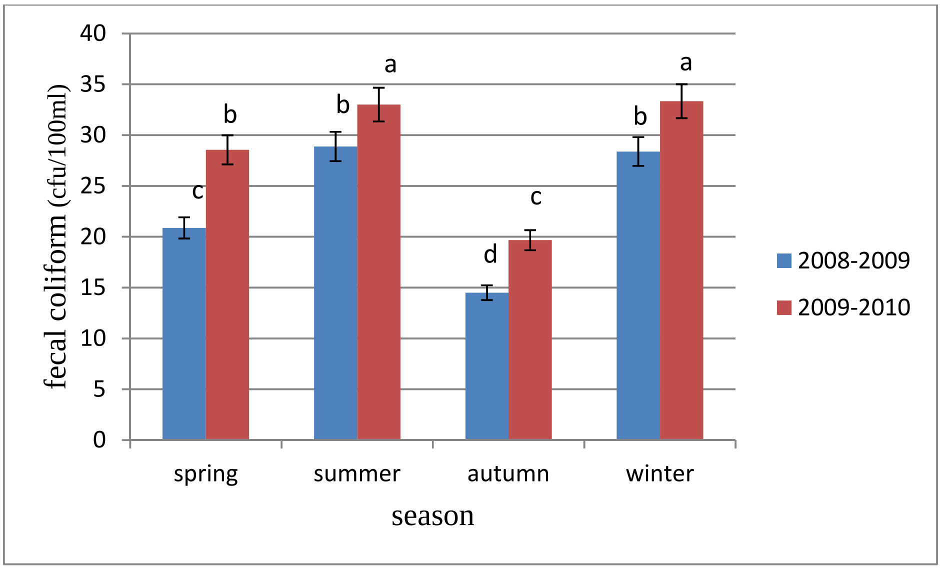

FIGURE 3-17 : SEASONAL CHANGES OF FECAL COLIFORM VALUES

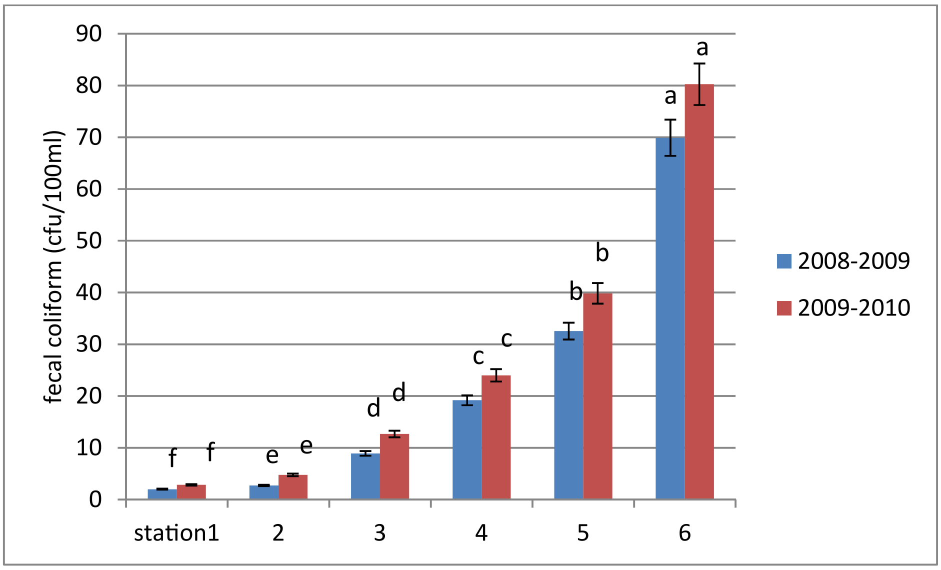

FIGURE 3-18: STATIONS CHANGES OF FECAL COLIFORM VALUES

TABLE 3-14 : VALUES (MEAN±SD) OF T, PH, DO, BOD_5, COD, EC

IN DIFFERENT YEARS AND SEASONS.

Year	Season	T	pH	DO	BOD	COD	EC
1	1	5.1±4.5^{c}	8.6±0.41^{a}	6.1±1.04^{a}	20.33±7.53^{ab}	39.8±12.8^{ab}	765.05±81.7^{a}
1	2	21.0±2.5^{a}	7.8±0.21^{c}	5.9±0.67^{a}	16.91±7.39^{b}	25.3±8.9^{c}	703.6±50.2^{ab}
1	3	5.6±4.0^{c}	7.9±0.12^{b}	5.2±0.36^{b}	20.06±12.11^{ab}	35.5±17.2^{b}	656.44±124.9^{b}
1	4	10.2±2.7^{b}	8.1±0.18^{b}	5.1±0.75^{b}	22.38±7.30^{a}	43.5±22.0^{a}	389.0±56.6^{c}
2	1	5.5±4.6^{c}	8.5±0.45^{a}	6.1±1.02^{a}	20.31±7.50^{ab}	39.8±12.8^{ab}	775.0±81.7^{a}
2	2	18.8±4.3^{a}	7.8±0.19^{c}	5.7±0.92^{a}	16.13±6.34^{b}	26.1±7.6^{c}	647.5±93.6^{b}
2	3	5.9±3.8^{c}	7.9±0.16^{b}	5.2±0.37^{b}	20.05±12.10^{ab}	35.5±17.2^{b}	655.44±124.4^{b}
2	4	11.3±2.6^{b}	8.09±0.23^{b}	5.15±0.78 ^{b}	22.35±7.33 ^{a}	43.5±22.2^{a}	385.0±56.6 ^{c}

season1: spring, season 2: summer, season 3: autumn, season4: winter.
Year1:2008-2009, year2:2009-2010.

TABLE 3-15 : VALUES (MEAN±SD) OF N [NO3], NO2, NH4, PO4

IN DIFFERENT YEARS AND SEASONS

Year	Season	$N[NO_3^-]$	NO_2^-	N	NH_4^+	PO_4^{3-}
1	1	2.5±0.58 [b]	0.13±0.20[b]	1.29±1.31[ab]	0.029±0.015[c]	0.07±0.05[b]
1	2	1.9±1.6[c]	0.11±0.15[b]	0.91±0.89[b]	0.093±0.097[b]	0.16±0.12[a]
1	3	4.09±2.2[a]	0.05±0.03[d]	0.74±0.90[c]	0.008 ±0.007[c]	0.09±0.05[b]
1	4	3.1±1.43[b]	0.12±0.20[b]	1.37±1.06[a]	0.288±0.261[a]	0.08±0.04[b]
2	1	2.56±0.57[b]	0.15±0.20[a]	1.27±1.32[ab]	0.082±0.765[b]	0.10±0.06[b]
2	2	3.08±2.12[b]	0.09±0.13[c]	0.74±0.72[c]	0.139±0.132[b]	0.12±0.11[b]
2	3	4.08±2.23[a]	0.08±0.04[c]	0.74±0.90[c]	0.058±0.037[b]	0.10±0.05[b]
2	4	3.12±1.42 [b]	0.14±0.17[a]	1.34±1.07[a]	0.274±0.279[a]	0.10±0.09[b]

season1: spring, season 2: summer, season 3: autumn, season4: winter.
Year1:2008-2009, year2:2009-2010.

TABLE 3-16 :VALUES (MEAN±SD) OF Q, FECAL.COLIFORM

IN DIFFERENT YEARS AND SEASONS

Year	Season	Q	Fecal coliform
1	1	2.03±0.57 [c]	20.88±23.51 [c]
1	2	1.85±0.52[c]	28.58±32.74[b]
1	3	5.92±4.24[b]	14.50±16.04[d]
1	4	10.62±3.59[a]	28.38±29.26[b]
2	1	2.01±0.56[c]	28.55±32.87[b]
2	2	2.49±1.21[c]	33.00±35.84[a]
2	3	5.91±4.23[b]	19.66±20.08[c]
2	4	10.58±3.54 [a]	33.33±33.50 [a]

season1: spring, season 2: summer, season 3: autumn, season4: winter.
Year1:2008-2009, year2:2009-2010.

3.3 Statistical Analysis

3.3.1 Cluster analysis (CA)

Cluster analysis was used to find the similar groups among sampling stations.

All the data in chapter 4 were entered into the software in a single form resulting in the Dendrogram output (Figure 3-19) which shows the grouping of six sampling station in 3 significant branches. The three stations of 1, 2 and 3 construct the first branch. Overall, the branch can be associated with the region with less pollution throughout the year. The second branch contains station 4, which is considered as a station with average pollution. This station receives the most pollution from plants and pisciculture.

The two stations downstream of the river (5 and 6) forms the third branch, which has; altogether, the most pollution and is associated with the regions with high pollution. The discharge of urban and rural wastewater in the form of non-concentrated raw wastewaters from agricultural activities was the main factors of pollution in the region and sampling stations.

The results show that CA technique is useful in presenting a vital classification of surface water at the catchment basin, because the costs, in view of the number of the sampling stations, can be reduced in the future projects for monitoring the river. In other words, decrease in the number of sampling stations and the proper selection of their site in future projects, will reduce the costs. Simeonov et al., 2003[70]; Singh et al., 2004, 2005[64,65]; Shrestha and Kazama, 2007[67]; Kim e al., 2005[85], achieved similar results by this method.

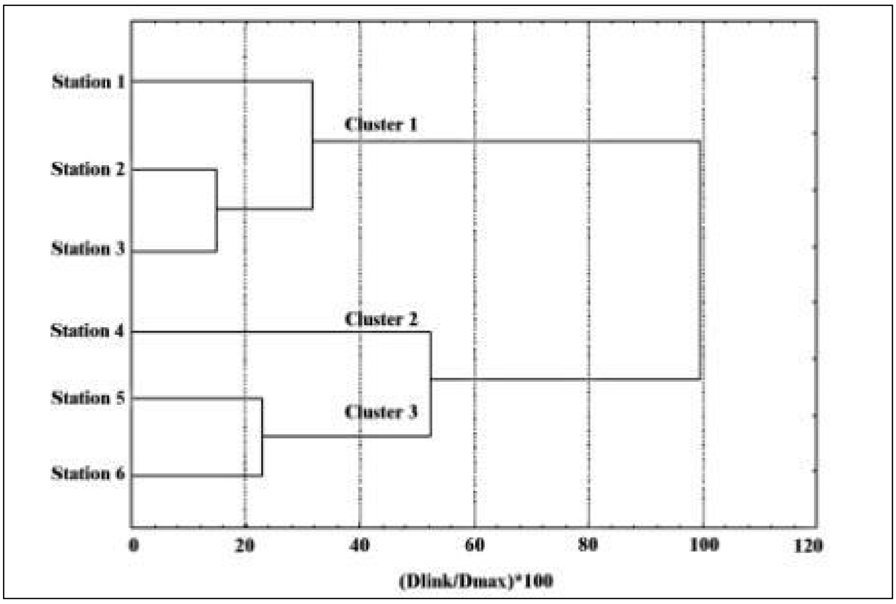

FIGURE 3-19: CLUSTER ANALYSIS DENDROGRAM FOR SAMPLING STATIONS ON THE WATER QUALITY PARAMETERS TALEGHAN RIVER

3.3.2 Principal Component Analysis (PCA) and Factor Analysis (FA)

PCA and FA were performed for ten variables and 6 stations in order to recognize the effective parameters in the seasonal changes of water quality.

An eigenvalue presents a significant measurement of the productive factors; therefore, the factors with high eigenvalue are the most important. Eigenvalues of 1 and higher are considered as significant. Classification of the factor loading consists of the following: above 0.75 powerful, between 0.5 and 0.75 average and between 0.3 to 0.5 poor (weak) (Liu et al., 2003[86]; Azid et al., 2015[87]). **Error! Not a valid bookmark self-reference.** shows that the factor loading of each variable and loading above 0.75 are clear.

Two factors include more than 79% from total variance in each chapter in relation to the data of water quality.

Each parameter of water quality, which connects powerful correlation co-efficiency to the factors, can be recognized as the important and significant parameter in the seasonal changes of water quality.

Parameters of temperature, nitrate, total solids and water flow of the rivers are significant in terms of this consideration and they are the most important influential parameters in the seasonal changes of water quality in the Taleghan River.

Nitrate and total phosphate with the amount of positive powerful loading of 4 and 3 seasons of year respectively were among the most important and influential parameters in the changes in the water quality which is justified by application of agriculture fertilizers and their components in the streams of farmlands entering the river.

Also parameters of fecal coliform and BOD_5 are among the significant parameters in changes in the water quality during 3 seasons of the year.

Total solids in each season are among of the most influential parameters in the changes in the water quality of Taleghan river catchment.

This is due to sand and gravel mining activities and agricultural runoffs, which increase the concentration of total suspended solids (TSS) and total dissolved solids (TDS) respectively.

Temperature and flow rate also are among the most important effective parameters in the four seasons, which show the considerable seasonal changes in the catchment of Taleghan River.

TABLE 3-17 : DESCRIBES THE VALUES OF THE FACTOR LOADING AND VARIANCE WATER QUALITY PARAMETERS IN FOUR SEASONS

Spring

Parameters	Factor 1	Factor 2
DO	-0.469378	-0.148037
FC	0.614498	0.643152
pH	-0.783326	0.092188
BOD	0.584410	0.788055
T	0.979687	0.155363
T-PO_4	0.835711	0.455109
NO_3	0.809634	0.400579
Turbidity	0.647648	0.588594
TS	0.858754	0.427671
Q	-0.029961	-0.971562
Total variance	66.76	12.78

Summer

Parameters	Factor 1	Factor 2
DO	-0.597647	0.304315
FC	0.293020	-0.916665
pH	-0.209820	0.709617
BOD	0.274419	-0.945053
T	0.877256	-0.388125
T-PO_4	0.809927	-0.316944
NO_3	0.891154	-0.382278
Turbidity	0.945618	0.207756
TS	0.963221	0.004151
Q	0.220494	0.937110
Total variance	56.27	26.72

Autumn

Parameters	Factor 1	Factor 2
DO	-0.411572	-0.689406
FC	0.203639	0.970522
pH	0.952242	-0.080639
BOD	0.383669	0.847985
T	0.571153	0.757020
T-PO_4	0.645750	0.502638
NO_3	0.779876	0.518308
Turbidity	0.924559	0.201680
TS	0.929444	0.172037
Q	0.344720	-0.901087
Total variance	62.20	23.52

Winter

Parameters	Factor 1	Factor 2
DO	-0.923622	0.144697
FC	0.599720	-0.750414
pH	-0.551234	-0.535932
BOD	0.699093	-0.554966
T	0.790312	-0.476537
T-PO_4	0.273547	0.828664
NO_3	0.908698	-0.184864
Turbidity	0.875526	0.178500
TS	0.866869	0.167717
Q	-0.144104	0.955230
Total variance	53.72	27.96

TABLE 3-18 : PARAMETERS OF THE MOST MEANINGFUL CONTRIBUTIONS TO THE QUALITY OF WATER IN ANY SEASON TALEGHAN

Season	Strong positive factor loading parameters	Strong negative factor loading parameters
Spring	T, BOD, T-PO_4, NO_3, TS	pH, Q
Summer	T, T-PO_4, NO_3, Turbidity, TS, Q	FC, BOD_5
Autumn	FC, pH, BOD, T, NO_3, Turbidity, TS	Q
Winter	T, T-PO_4, NO_3, Turbidity, TS, Q	DO, FC

3.4 Quality Properties of Water by NSFWQI

The vertical pivot of the graph has been graded from zero to one hundred as quality index of each parameter and horizontal pivot expresses the amount or density of the measured parameter for each parameter based on the determined unit. Strike of each parameter amount to the related graph and drawing the imaginary line from the strike point to the vertical pivot will determine the quality index of the target parameter in the range of zero to one hundred. Then, water quality index will be determined by the following formula:

$$NSFWQI = \sum_{i=1}^{n} Wi\, qi \qquad \text{EQUATION 28}$$

In which

W_i = weight factor of each parameter
q_i = sub-index of each parameter
n= Number of the existing parameters in index calculation

This means that if the pesticides concentration becomes more than 0.1 mg/l, the index value, however, will be zero. Also, if the concentration of toxins becomes more than the allowable amount for drinking, the index amount is supposed as zero. The devoted weights and sub-index graphs of each parameter are shown respectively in **Error! Not a valid bookmark self-reference.**. Moreover the water quality classification is presented in table 3-5.

TABLE 3-19 : THE WEIGHT FACTOR OF INDEX PARAMETERS OF NSFWQI

parameters	Weight Factors
DO	0.17
FC	0.16
PH	0.17
BOD	0.11
T	0.10
T-PO4	0.10

NO_3	0.10
Turbidity	0.08
TS	0.07

TABLE 3-20 : WATER QUALITY CLASSIFICATION:

Change domain	**Quality**
100-90	Excellent
90-70	Good
50-70	Average
25-50	Bad
25-0	Very bad

DO parameter in this index is based on the amount of oxygen saturation (saturate %); therefore, it is necessary to convert the measured concentration, which is based on mil/lit, into saturation percentage before using the related graph for determining the sub-index of DO parameter. since the water temperature as well as the height from free water level have an effective role in oxygen saturation; therefore, the amount of oxygen saturation is estimated the following two formulas. The following formulas are used to calculate the oxygen saturation based on mil/lit in water temperature. (APHA, 1992)[88]:

$$\ln o_s(T,0) = -139.34411 + \frac{1.575701\times 10^5}{T_a} - \frac{6.642308\times 10^7}{T_a^2}$$

$$+\frac{1.243800\times 10^{10}}{T_a^3} - \frac{8.621949\times 10^{11}}{T_a^4}$$

O_s (T, O): the density amount of saturation solution oxygen in pressure of 1 atmosphere (mgo_2/l).

To: water temperature based on Kelvin's degree (k).

Height effect from free water level on the amount of saturation oxygen is determined through the following formula (Chapra, 1997[83]):

$$O_s(T,elev) = e^{\ln o_s(T,0)}(1 - 0.0001148elev)$$ **EQUATION 29**

O_s: the values of saturation DO have been denoted in the different stations based on percentage in **Error! Not a valid bookmark self-reference.**.

To determine the sub-index of temperature changes, the difference between temperature of downstream and upstream stations was denoted and the quality amount of this sub-index was recorded.

TABLE 3-21: DO SATURATION DETERMINATION BASED ON THE PERCENTAGE OF STATIONS IN TWO YEARS

Station	DO (mg/L)	Water T (C)	Water surface Elevation (m)	DO saturatin value (%)
Spring				
1	7.3	13	1935	89.07
2	4.3	15	1144	49.09
3	5.3	16	704	58.42
4	5.4	17	425	58.42
5	5.1	18	175	54.98
6	4.9	17	92	51.24
Summer				
1	6.7	16	1935	87.26
2	4.5	19	1144	55.84
3	4.2	25	704	55.84
4	3.6	25	425	45.8
5	4.3	25	175	53.10
6	4.2	26	92	52.32
Autumn				
1	7.1	11	1935	82.77
2	7.1	11	1144	74.12
3	5.7	13	704	58.85
4	6.1	14	425	62.23
5	6.0	17	175	63.35
6	5.6	18	92	59.78
Winter				
1	9.1	6	1935	93.98
2	8.8	6	1144	81.38
3	8.2	7	704	73.49
4	7.1	9	425	64.57
5	7.1	11	175	65.71
6	7.0	12	92	65.65

The results of NSF index for the four seasons in Taleghan River include the values of sub-index of each parameter and eventually the total index for each station is shown in **Error! Not a valid bookmark self-reference.**. Moreover, the necessary classification for the total index values is presented for different stations in Table 3-23.

TABLE 3-22 : WATER QUALITY MONITORING ALONG WITH TALEGHAN RIVER

Season	Station	Water Quality index								Total result
		T	DO	NO_3	Turbidity	FC	pH	BOD	PO_4	
Summer	1	93	93	97	82	80	92	34	100	**53**
	2	81	52	96	35	74	86	30	97	**56**
	3	67	51	94	5	61	85	25	98	**55**
	4	93	38	91	5	67	82	30	96	**56**
	5	93	48	86	5	63	88	10	97	**48**
	6	89	47	70	5	39	84	5	96	**49**
Fall	1	93	89	97	70	91	77	95	100	**46**
	2	93	80	96	72	91	73	80	100	**51**
	3	85	56	95	67	76	70	80	100	**50**
	4	89	60	95	5	74	66	61	96	**50**
	5	81	63	80	5	70	66	38	98	**46**
	6	89	57	86	5	50	66	5	96	**47**
Winter	1	93	98	97	82	86	86	95	98	**69**
	2	93	88	86	70	91	86	80	97	**82**
	3	89	79	96	80	80	84	80	97	**64**
	4	85	65	96	5	78	86	80	96	**52**
	5	85	67	95	5	73	84	51	97	**34**
	6	89	67	95	5	54	84	11	98	**38**
Spring	1	93	94	97	82	73	83	38	99	**79**
	2	85	42	97	63	82	79	42	98	**68**
	3	89	55	96	31	64	82	23	98	**69**
	4	89	56	96	5	67	79	25	97	**70**
	5	89	50	67	5	47	80	13	96	**67**
	6	89	45	75	5	43	76	5	96	**68**

TABLE 3-23 : WATER QUALITY INDEX (NSFWQI)

Station	Spring	Summer	Fall	Winter
1	Very good	Good	Very good	Very good
2	Good	Good	Good	Very good
3	Good	Fair	Good	Good
4	Good	Fair	Good	Good
5	Fair	Fair	Fair	Good
6	Fair	Bad	Fair	Fair

According to the table a decreasing pattern of water quality is observed from upstream to downstream of the river from very good to fair (Stations 5 and 6).

3.5 Different consumptions of river (Drinking and Agriculture Usage)

Chemical parameters play an important role in classification and determination of water quality for different consumptions. The discussion aims to classify the water quality of Taleghan River in its region for irrigation and drinking as well as determination of water type or in other words recognition of Ion domination Anion and Cation in the Taleghan River.

To achieve this goal, chemical and physical parameters were considered: 7 main Ions and 2 parameters of temperature and electrical conductivity (EC) of the water. It is observed that in general the concentration of Anions and Cations, , increased more during the low water season than the high water season because the flow increased in the river resulting in greater dilution of water and a decreased concentration of Anions and Cations.

Chemical specification of the river water at different stations is shown in piper diagram (Figure 3-17 and Figure 3-18). By using this diagram, we can specify the type of the river water. The triangle shape diagrams express the concentration of Cations and Anions (triangle in the left shows the concentration of Cations and the right the concentration of Anions). The oval shape diagram contains both Anions and Cations. Based on the piper diagram, we understand that the dominant water type in the Taleghan River is Calcium bicarbonate at both seasons. In other words the dominant Cation is Calcium and the dominant Anion is Bicarbonate.

Since the concentration of Bicarbonate and Calcium in Taleghan River is noticeably higher than other Anions and Cations, we conclude that the origin of ions is the erosion of rocks and soil. As we see, the amount of Bicarbonate (in Figure 3-19) with the mean of about 50% was the dominant Anion of the river and Calcium with the mean of about 80% was the dominant Cation. In the oval diagram, which contains both Cation and Anion, it is clear that Color and Sulfate concentration together make up the mean of about 60% of the main Anions of water. The concentration of two Cations of Sodium and Potassium together make up on average about 10% of the main Cations of the river.

Schoeller is a semi-logarithm diagram on which the main Ions have been drawn based on (mg/l). Thus, the diagram is used to determine the degree of water quality for drinking. Schoeller diagram for the four beginning months of each season in a year was drawn in figures 35 and 36. The chemical classification of drinking water according to the Schoeller diagram is shown in Figure 3-19.

Figure 3-6: classification of drinking water according to Schoeller diagram classification based on concentration of the main Ions.

The water quality classification at each station can be specified by considering the first column of figure 37, which shows the common classification for the concentration of various Ions (mg/l). In spite of the high concentration of Calcium Bicarbonate in the water sample in comparison to the other Ions, the condition of the river water was determined as acceptable for drinking in each case. The concentration of other Ions did not exceed 3 (mg/l); therefore, they fall in the class of good quality.

The results of major anions and cations analysis of the samples collected in two seasons (winter 2008 and summer2009).

TABLE 3-24: RESULTS OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES(WINTER 2008)

Stations	Sodium N^+	Magnesium Mg^{2+}	Calcium Ca^{2+}	Potassium K^+	Bicarbonate HCO_3^-	Sulfate SO_4^{2-}
	mg / l	mg / l	mg / l	mg / l	mg / l	mg / l
S1	21.62	14.59	138.3	1.4	222	194.1
S2	21.16	37.69	88	2	183	207.5
S3	20.7	41.34	27	2	2007.4	230.6
S4	13.34	26.75	106.2	1.4	201.4	186.4
S5	41.17	47.42	122.2	2	170.08	235.5
S6	42.55	31.61	82.16	2	201.3	204.2

TABLE 3-25 : RESULTS OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF SURFACE WATER SAMPLES(SUMMER2008)

Stations	Sodium Na^+	Magnesium Mg^{2+}	Calcium Ca^{2+}	Potassium K^+	Bicarbonate HCO_3^-	Sulfate SO_4^{2-}
	mg / l	mg / l	mg / l	mg / l	mg / l	mg / l
S1	17.25	24.32	122.2	1.6	201.3	144.1
S2	14.49	24.32	140.3	1.2	189.1	240.5
S3	20.24	20.67	124.2	1.2	152.5	153.7
S4	19.78	30.4	104.2	1.2	219.6	144.1
S5	38.67	33.83	114.2	1.6	237.9	144.1
S6	40.25	44.99	92.18	1.2	231.8	96.06

The chemical characteristics of water compositions based on major ion concentrations were evaluated on a Piper diagram (Figure 3-20, Figure 3-21).

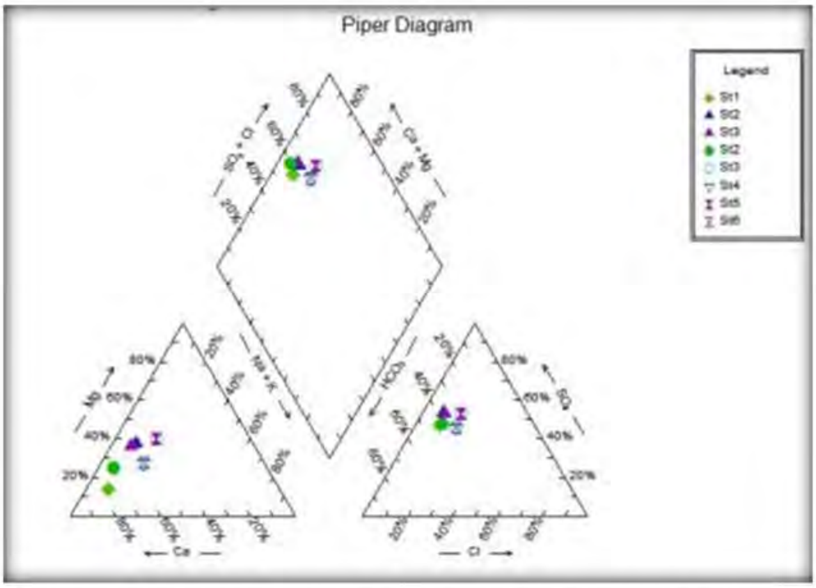

FIGURE 3-20 : PIPER DIAGRAM SHOWING THE CHEMICAL COMPOSITIONS OF SURFACE WATER (WINTER 2008)

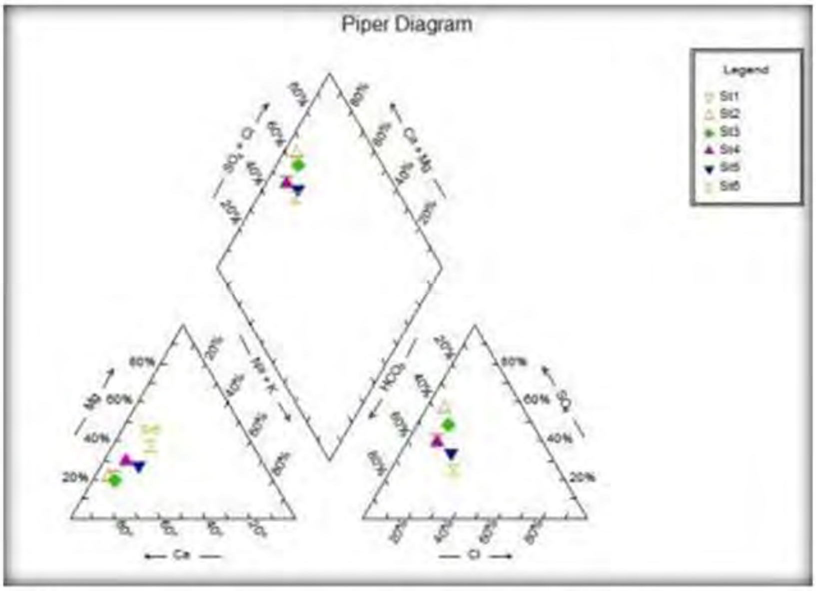

FIGURE 3-21 : PIPER DIAGRAM SHOWING THE CHEMICAL COMPOSITIONS OF SURFACE WATER (SUMMER 2009)

- Drinking Usage

The analysis of the outmen diagram shows the dominant water type in the Taleghan River as being Calcium bicarbonate in both seasons. In other words the dominant Cation is Calcium and the dominant Anion is Bicarbonate.

Since the concentration of Bicarbonate and Calcium in Taleghan River is noticeably more than other Anions and Cations, we conclude that the ions originate from rocks and soil erosion. As we see, the Bicarbonate concentration (in Figure 3-20) with the mean of about 50% was the dominant Anion of the river and Calcium with the mean of about 80% was the dominant Cation. In the oval diagram, which contains both Cation and Anion, it is clear that Color and Sulfate concentration together make up the mean of about 60% of the main Anions of water. The concentration of two Cations of Sodium and Potassium together make up on average about 10% of the main Cations of the river.

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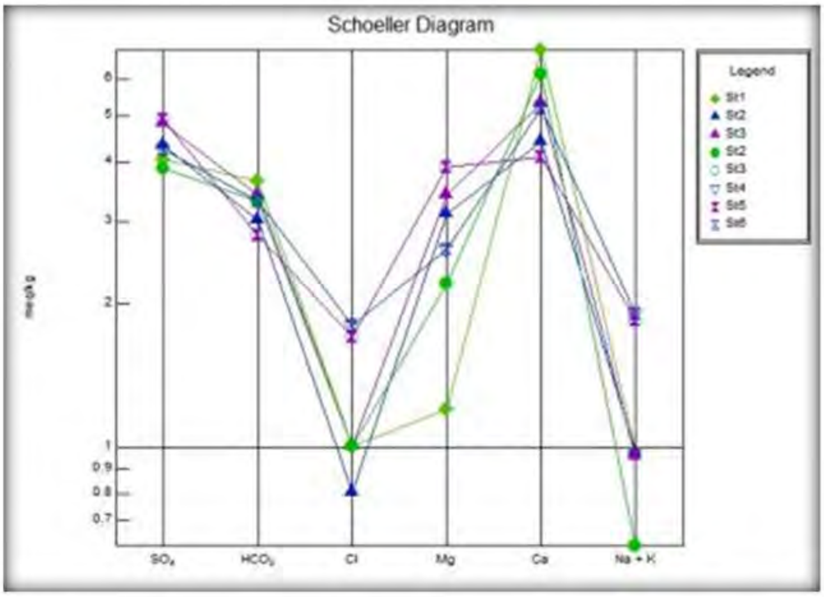


FIGURE 3-22 : CHEMICAL ANALYSIS OF SURFACE WATER ON SCHOELLER DIAGRAM (WINTER 2008)

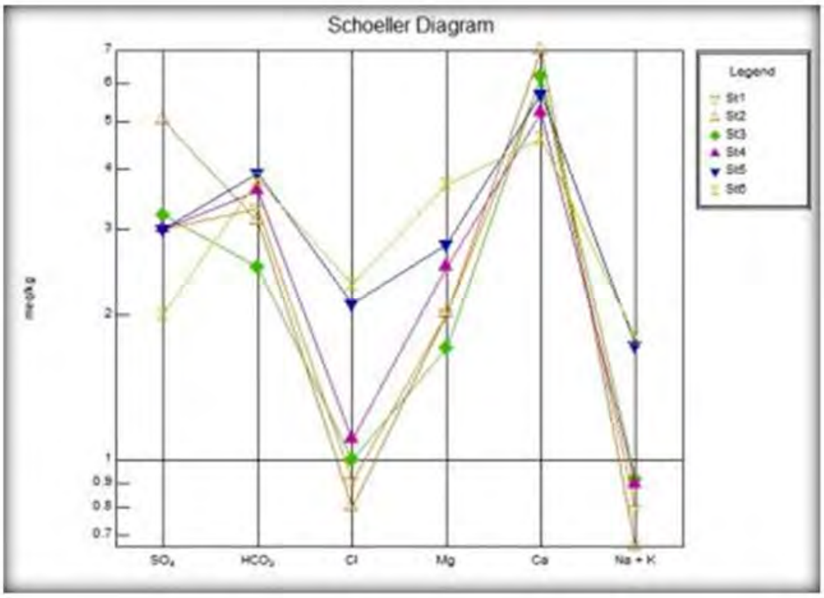


FIGURE 3-23 : CHEMICAL ANALYSIS OF SURFACE WATER ON THE SCHOELLER DIAGRAM (SUMMER 2009)

- Agriculture Usage

The class of water quality at each station can be determined by the first column of Figure 3-24, which shows the common classification of concentration of various Ions in (mg/l). In spite of the high Calcium Bicarbonate concentration in the water sample in comparison to the other Ions, the condition of the river water is determined as acceptable for drinking in each case. The concentration of other Ions does not exceed 3 (mg/l); therefore, they fall in the class of good quality.

In the formula, Sodium, Calcium and Manganese are also based on mg/l. The SAR parameter presents a more trustable assessment of danger of Sodium in water quality; therefore, it allows a more accurate assessment of Sodium in soil than Na percentage (Tiwari and Manzoor, 1988[76]). Sodium replacement is absorbed instead of Calcium and Magnesium and it is taken as a danger resulting in damage to soil as well as condensation and infiltration to soil (Sundaray et al. 2006[75]).

When the parameters of SAR and EC are observed in a certain water sample, its classification for agricultural irrigation can be determined by drawing a diagram. The United State Salinity Laboratory (USSL) Diagram can be used for rapid identification of water class for irrigation. In this diagram, danger of Sodium or in other words the SAR parameter is shown on Y axis and the danger of salinity, which is measured by EC, makes up the X axis (Figure 3-24, Figure 3-25).

Water types, are divided into the four classes: S1, S2, S3 and S4 based on danger of Sodium (SAR) and C1, C2, C3 and C4 based on danger of salinity (EC).

Water with low Sodium (S1) can be used for irrigation on almost any soil. Water with average Sodium (S2) causes a tangible danger over soft soils with high capacity of conversion of Cation and under treatment of low soil (water washing)… This water can be used for the soil with severe structures or organic soil which has a high penetration. Water with high Sodium (S3) can be harmful in most of soils and it needs a special management in this case. Water with very high Sodium (S4), in general, is inadequate for agricultural irrigation unless a special measure is taken for the soil.

Water with low salinity (C1) can be used for irrigation in most soils and agricultural products. A little treatment of soil is necessary, which can be achieved by normal irrigation. However, the soil with very high penetration is an exception. Water with low salinity (C2) can be used if we do a little treatment of the soil. Water with high salinity (C3) cannot be used for the soils with limited drainage. Water with very high salinity (C4) is inadequate in normal conditions.

The value of RSC and Na% indexes were respectively 1.25 mg/l and 60% for all samples in the low and high water seasons. Therefore, the quality of water in relation to the two indexes is adequate for irrigation.

All sampling stations, except for the sixth station in the high water season and the first second, third and fifth stations in the low water season fall within the S1C2 class. Therefore, water quality is almost adequate for irrigation with low Sodium and average salinity. In high water season the sixth station and the fourth and fifth stations in the low water season fall within the S1C3 class. In this part, water with low Sodium and high salinity cannot be used without an adequate and sufficient drainage. Essentially, it can be used for the special plants with an average resistance to salinity.

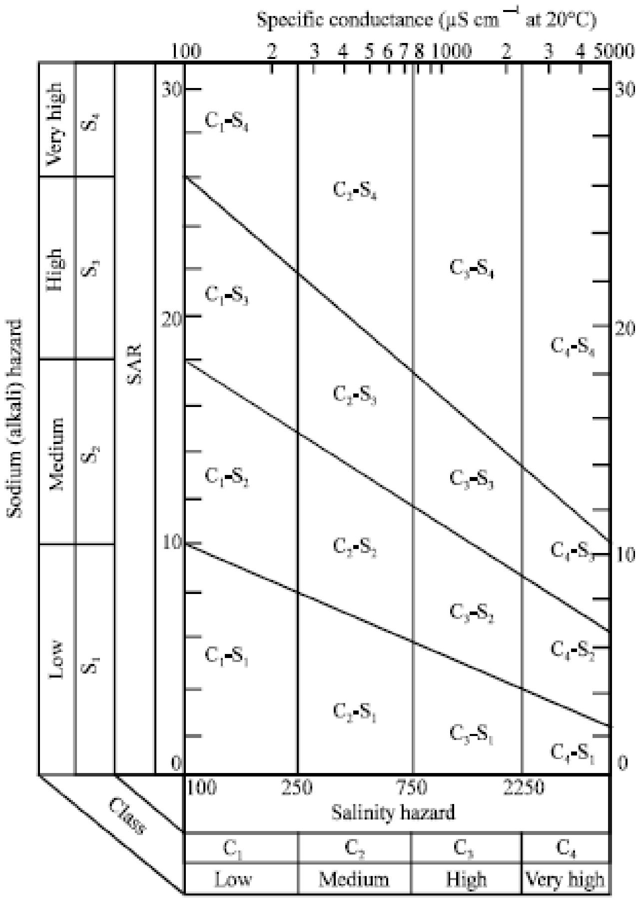


FIGURE 3-24: USSL DIAGRAM FOR CLASSIFICATION OF IRRIGATION WATERS (BROWN, AND BARNWELL1987[89])

3.6 Mathematical Model of River Water Quality (QUAL2K)

3.6.1 Entry of data:

The geometric dimensions and the velocity of the river water in the sampling stations were used to determine the hydraulic specifications at each station. The two empirical formulas of 2-4 and 3-4 are used to estimate the average velocity and the depth of water.

$$U = aQ^b \qquad \text{Equation 30}$$

$$U = \alpha Q^\beta \qquad \text{Equation 31}$$

By applying the volumetric flow, Brown and Barnwell (1989[89]) determined the range of band b values as 0.4-0.6 and 0.3-0.5 for velocity and depth respectively. Moreover, the total sum of b and b should be less or equal to 1 and if it is one, the channel of the river will be in a rectangular form. The index coefficients of a, as parameter of b, and b have been measured and calculated using the values of velocity, depth and flow of water in two seasons: spring, summer as well as water. The Hydraulic specifications of 65 chosen sections of the river are shown in Table 3-26.

TABLE 3-26 : RANGE OF HYDRAULIC CHARACTERISTICS OF THE RIVER

Number of range	Deep		Speed	
	Coefficient	*Exponent*	*Coefficient*	*Exponent*
1	0.778069	0.48	0.228061	0.35
2	0.782516	0.48	0.229969	0.35
3	0.787181	0.48	0.231941	0.35
4	0.792079	0.48	0.233979	0.35
5	0.797227	0.48	0.236089	0.35
6	0.758905	0.48	0.229969	0.35
7	0.710827	0.52	0.226276	0.37
8	0.698545	0.52	0.228028	0.37
9	0.686485	0.52	0.229773	0.37
10	0.674641	0.52	0.23151	0.37
11	0.663003	0.52	0.23324	0.37
12	0.651566	0.52	0.234963	0.37
13	0.640323	0.52	0.236679	0.37
14	0.629268	0.52	0.238387	0.37
15	0.618394	0.52	0.240089	0.37
16	0.607697	0.52	0.241784	0.37
17	0.597169	0.52	0.243472	0.37
18	0.586807	0.52	0.245153	0.37
19	0.576606	0.52	0.246828	0.37
20	0.566559	0.52	0.248497	0.37
21	0.556664	0.52	0.250159	0.37
22	0.554713	0.51	0.251815	0.37
23	0.545035	0.51	0.253464	0.37
24	0.535494	0.51	0.255108	0.37
25	0.526087	0.51	0.256746	0.37
26	0.522024	0.51	0.258377	0.37
27	0.517875	0.5	0.259444	0.37
28	0.487678	0.5	0.259587	0.36
29	0.460872	0.5	0.256503	0.36
30	0.436829	0.5	0.253958	0.36
31	0.422656	0.49	0.251856	0.36
32	0.40273	0.49	0.250124	0.36
33	0.38315	0.49	0.248932	0.36
34	0.3521	0.49	0.249087	0.36
35	0.320997	0.49	0.249243	0.36
36	0.289842	0.49	0.249398	0.36
37	0.258634	0.49	0.249555	0.36
38	0.227372	0.49	0.249711	0.36
39	0.196058	0.49	0.249868	0.36
40	0.164689	0.49	0.250026	0.36
41	0.133267	0.49	0.250183	0.36
42	0.101792	0.49	0.250341	0.36
43	0.354821	0.49	0.2505	0.36
44	0.355686	0.48	0.243184	0.37
45	0.34965	0.48	0.240624	0.37
46	0.34359	0.48	0.238057	0.37
47	0.337505	0.48	0.235483	0.37
48	0.331396	0.48	0.232901	0.37
49	0.325262	0.48	0.230312	0.37
50	0.319103	0.48	0.227715	0.37
51	0.322464	0.48	0.274071	0.37
52	0.162501	0.42	0.241457	0.45
53	0.171375	0.42	0.261233	0.45
54	0.183505	0.42	0.287405	0.45
55	0.198978	0.42	0.326239	0.45
56	0.198659	0.42	0.34379	0.45
57	0.198602	0.42	0.36307	0.45
58	0.198873	0.42	0.384433	0.45
59	0.199559	0.42	0.408347	0.45
60	0.200783	0.42	0.435448	0.45
61	0.202716	0.42	0.466625	0.45
62	0.205615	0.42	0.450059	0.32
63	0.210413	0.42	0.485346	0.32
64	0.160187	0.42	0.605313	0.32
65	0.114915	0.51	1.115255	0.48

3.6.2 System parameters

The reaction for the different stations was computed by use of the following formulas and entered into the software as information. If we ignore the effect of on the reaction, the total empirical presented formula based on the velocity and depth y water is so:

$$k_a(20°C) = A\frac{V^B}{D^C}$$

Equation 32

In this formula, k_a is the reaction in temperature of 20° c (day-1), v is velocity of water (m/s), d is depth of water (m), A, B and c are the experimental parameters. A, B and C are determined by Table 3-27.

TABLE 3-27 : EXPERIMENTAL PARAMETERS FOR THE EQUATION COEFFICIENTS BAZDMSH

Position water flow river	C	B	A	Formula
Laminar flow, Deep	1.5	0.5	3.93	O'Connor and Dobbins,(1958)[90]
Average depth, Fast Flow	1.673	0.969	5.026	Churchill et al., (1962)[91]
Shallow	1.85	0.67	5.34	Churchill et al., (1962)[92]

Formula 3-4 is to compel reaction in temperature 20 c; the formula presents the reaction in temperature t of the river.

$$K_a = k_a(20°C) \times 1.024^{(T-20)}$$

Equation 33

the three formulas mentioned in table 4-4 were applied to determine the regime of Taleghan River, . Churchill's formula has been applied for reaction stations in the stations 2, 3, 4 and 5, which have a turbulent regime and the river depth is not too much, and Owen's formula has been applied in the shallow stations of 1, 6 and 7 and 0. The Connor and Dobbins formula has been applied for the final station where the velocity is very low and the river depth is quite high.

The range of the model parameters was determined based on the existing information in the the software user guide file.

TABLE 3-28 : EXPERIMENTAL PARAMETERS FOR THE EQUATION COEFFICIENTS REARIATION

Parameters	Unit	Amount	Amount maximum	Amount minimum	Auto calibration
Carbon	gC	40	50	30	No
Nitrogen	gN	7.2	9	3	No
Phosphorus	gP	1	2	0.4	No
Dry weight	gD	100	100	100	No
Chlorophyll	gA	1	2	0.4	No
ISS settling velocity	m/d	0.06128	2	0	Yes
O2 for carbon oxidation	gO_2/gC	2.69	-	-	-
O2 for NH4 nitrification	gO_2/gN	4.57	-	-	-
Fast CBOD oxidation rate	-	1.894	5	0	Yes
Oxygen inhibit model CBOD oxidation	-	Exponential	-	-	-
Oxygen inhibit parameter CBOD oxidation	L/mgO2	0.60	0.60	0.60	No
Oxygen inhibit model nitrification	-	Exponential		-	-
Oxygen inhib parameter nitrification	L/mgO2	0.60	0.60	0.60	No
Oxygen enhance model denitrification	-	Exponential		-	-
Oxygen enhance parameter denitrification	L/mgO2	0.60	0.60	0.60	No
Oxygen inhib model phyto resp	-	Exponential	-	-	-
Oxygen inhib parameter phyto resp	L/mgO2	0.60	0.60	0.60	No
Oxygen enhance model bot alg resp	-	Exponential	-	-	-

It is necessary to note that water quality models are based on the ultimate CBOD5 and not on CBODS.

We should compute the CBODS values based on the CBOD before running the software because the CBOD measured in Taleghan station within four seasons during 2 years was recorded based on the five days CBOD in the laboratory and Qual2k is not able to model BOD_5. Formula 4-4 converts $CBOD_5$ into ultimate CBOD (Chapra, 2006[83])

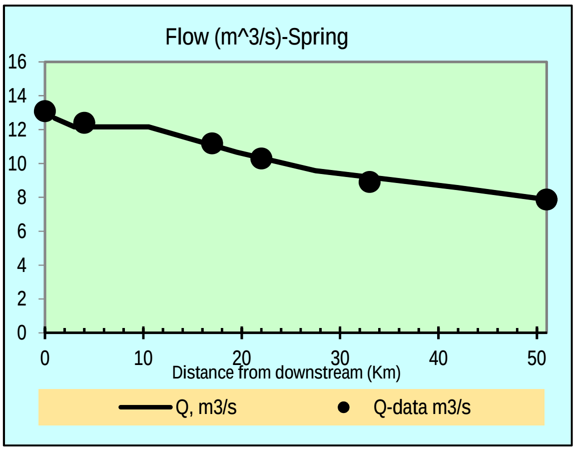
K= rate of analysis of CBOD day-1 in the bottle based on range of k between 0.3 and 0.05 per day (Chapra, 1997[83]). If we assume the decrease rate of BOD five per day, the usual amount of K is 0.23 day (Brown and Barnwell, 1985[89])

The ultimate values of CBOD were calculated by considering K as 0.23, and the measured CBODF was entered into the software. Furthermore the parameters of temperature, flow, pH, DO, CBOD, nitrate, velocity and depth were selected as measured parameters for input of the model.

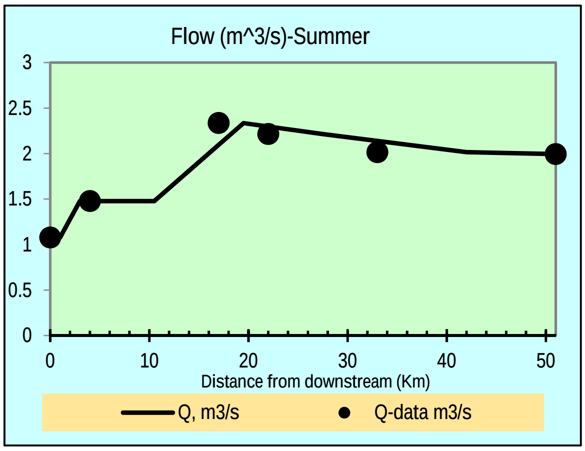
Five secondary rivers located in Taleghan catchment basin and entering the main channel of Taleghan River were considered as the point resources, and the measured quality parameters of the rivers, water were entered into the model.

- **Flow**

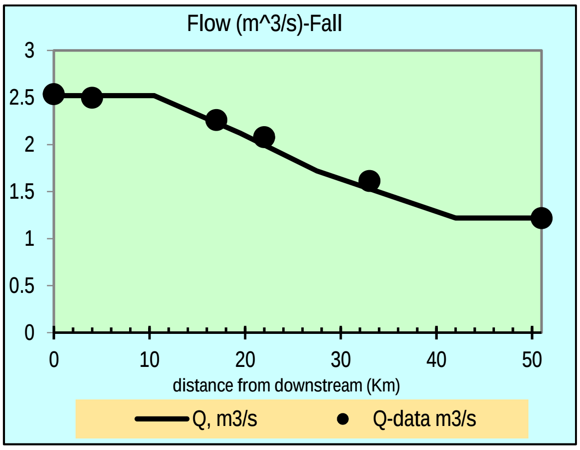
The positive slopes from river upstream to downstream in all seasons except summer show the increases in river flow amount (figure 3-33). In addition, higher flows occurred in winter and spring because of increased rainfall and snow melting in these seasons accordingly. As it's shown in figure 3-33 for the summer season, the chart has a negative slope from upstream to downstream. In this period flow amount of river was decreased. This is because of many reasons especially increasing agricultural uses of river and Sub River's water and increasing evaporation in this season.



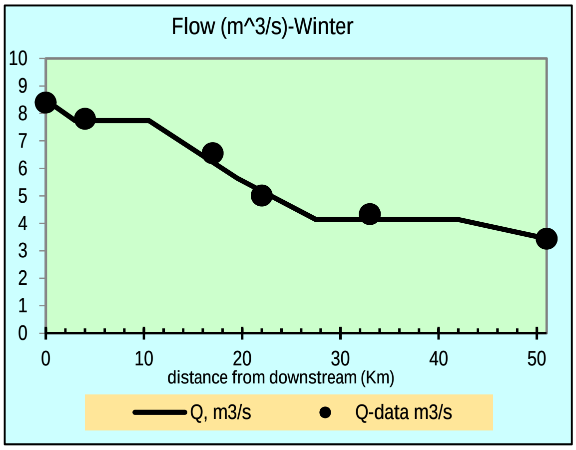
(a)



(b)



(c)



(d)

FIGURE 3-25 : SEASONAL VARIATION OF FLOW OVER DIFFERENT STATIONS OF THE RIVER IN 2009

- **pH**

pH is another important parameter to analyze river water quality. The Qual2k results for pH are shown in figure 3-34. The changes in pH values were relation to seasons which was related to photosynthesis intensity, if the effect of wastewater drainages were neglected. Overall, pH values show that Taleghan River has the tendency toward alkalinity.

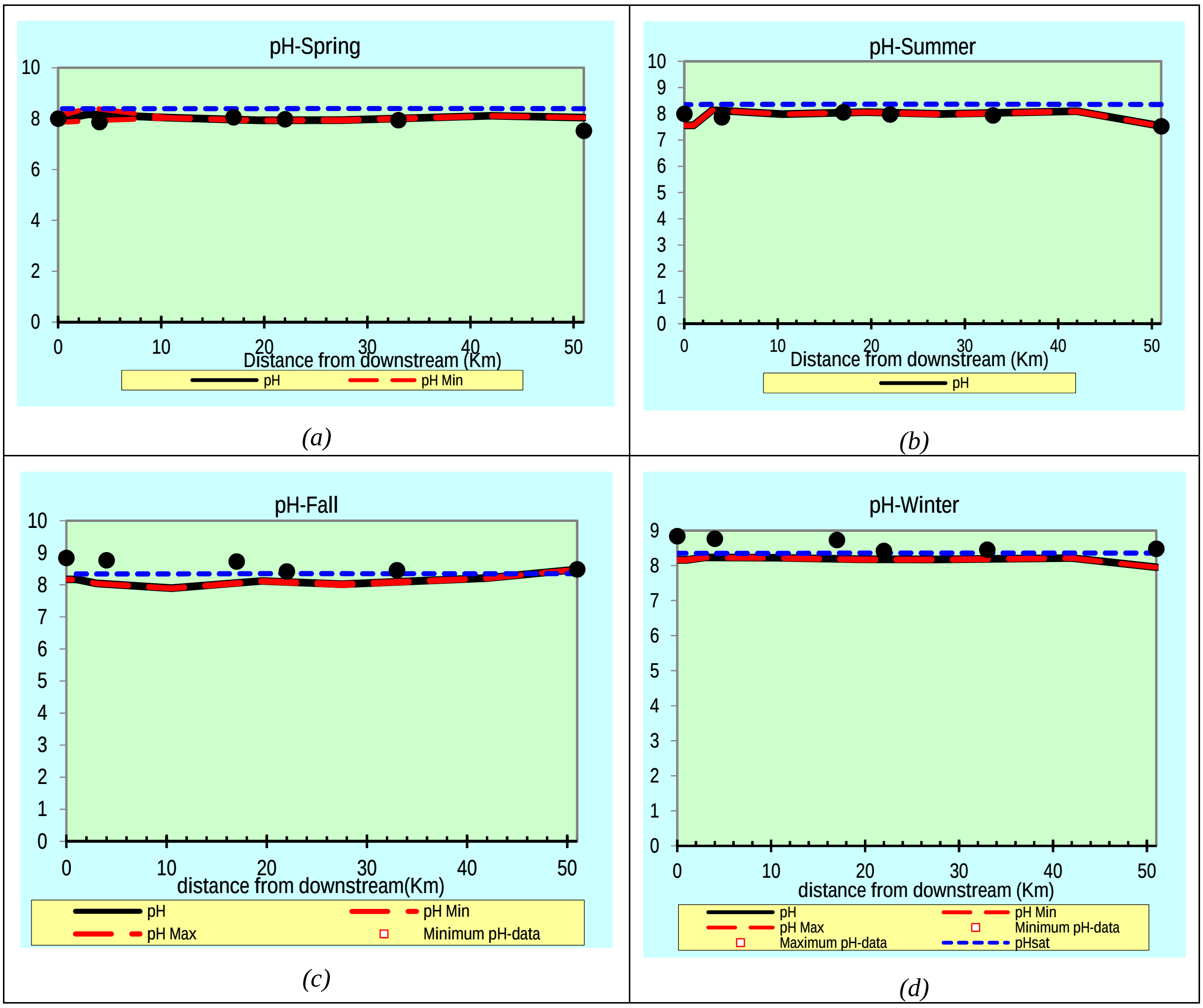


FIGURE 3-26 : SEASONAL VARIATION OF PH OVER DIFFERENT STATIONS OF THE RIVER IN 2009

- **Conductivity**

Since, Taleghan River is not exposed to different type of soils from stations 1 to 6; it was predictable that conductivity should be constant between stations.

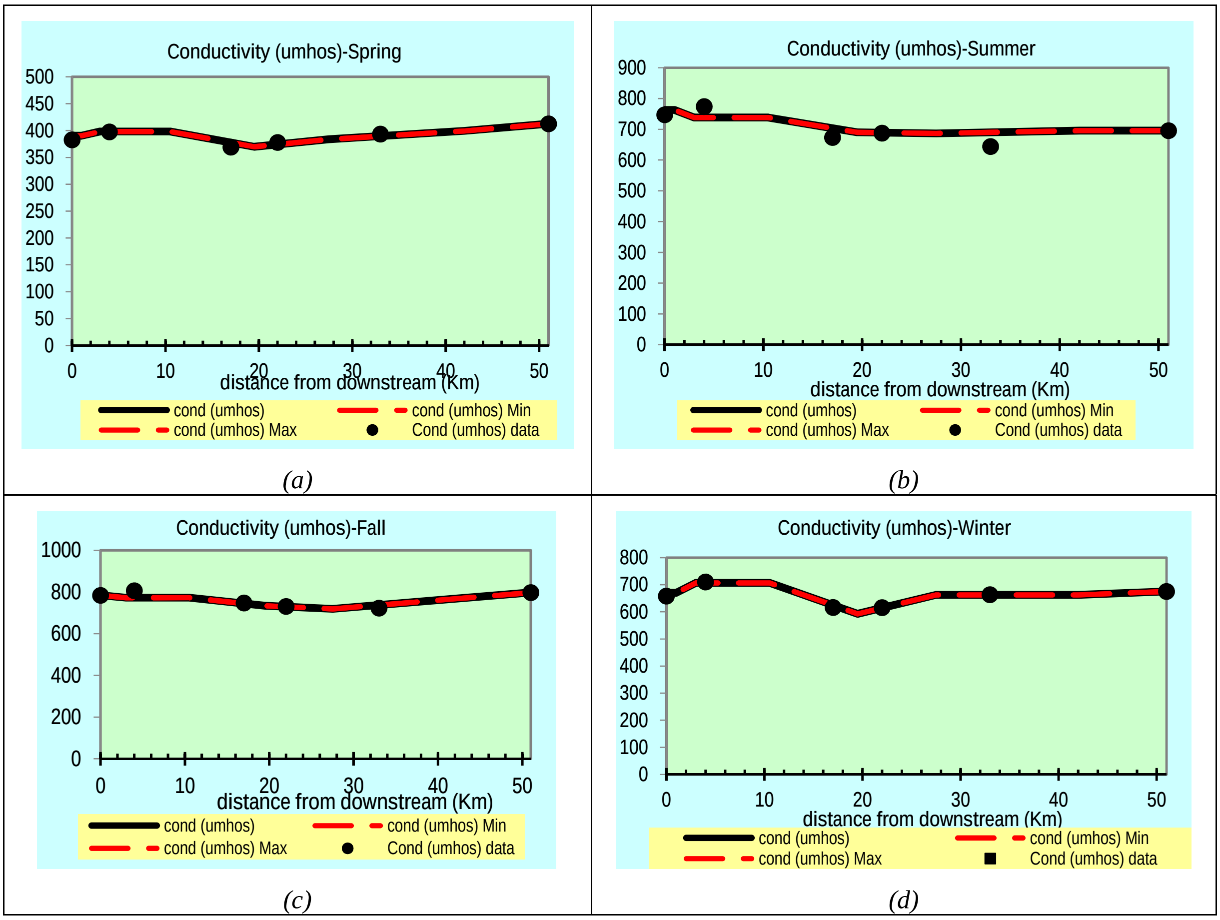


FIGURE 3-27 : SEASONAL VARIATION OF CONDUCTIVITY OVER DIFFERENT STATIONS OF THE RIVER IN 2009

- **CBOD**

Another considered quality parameter in this study was the ultimate CBOD of river water. Biochemical Oxygen Demand or BOD_5 has a direct relationship with the amount of dissolved oxygen in rivers. The more rapidly oxygen is depleted in the stream cause the greater CBOD.

As organic materials enter a stream, the BOD_5 will be raised. Organic materials may include leaves and woody debris; dead plants and animals; effluents from pulp and paper mills, wastewater treatment plants discharges and urban storm water runoff. CBOD or Carbonaceous Biochemical Oxygen Demand is measured instead of BOD_5 when nitrification is not completed. In modeling by Qual2k models, to consider uncertainty due to possible incomplete nitrification, the model measure CBOD instead of BOD_5.

The CBOD changes along river channel from upstream (Station1) to downstream (station6)(figure 3-36). In an overview in all seasons except fall, CBOD increases especially in the downstream (station6) where in comparison with other station, the human activity and organic pollution penetration is in their maximum level. In a more detailed view, for example in winter season, the CBOD change in each season is out of a specified pattern. It might be due to the river CBOD value's high dependence to the amount and the type of incoming pollution to river.

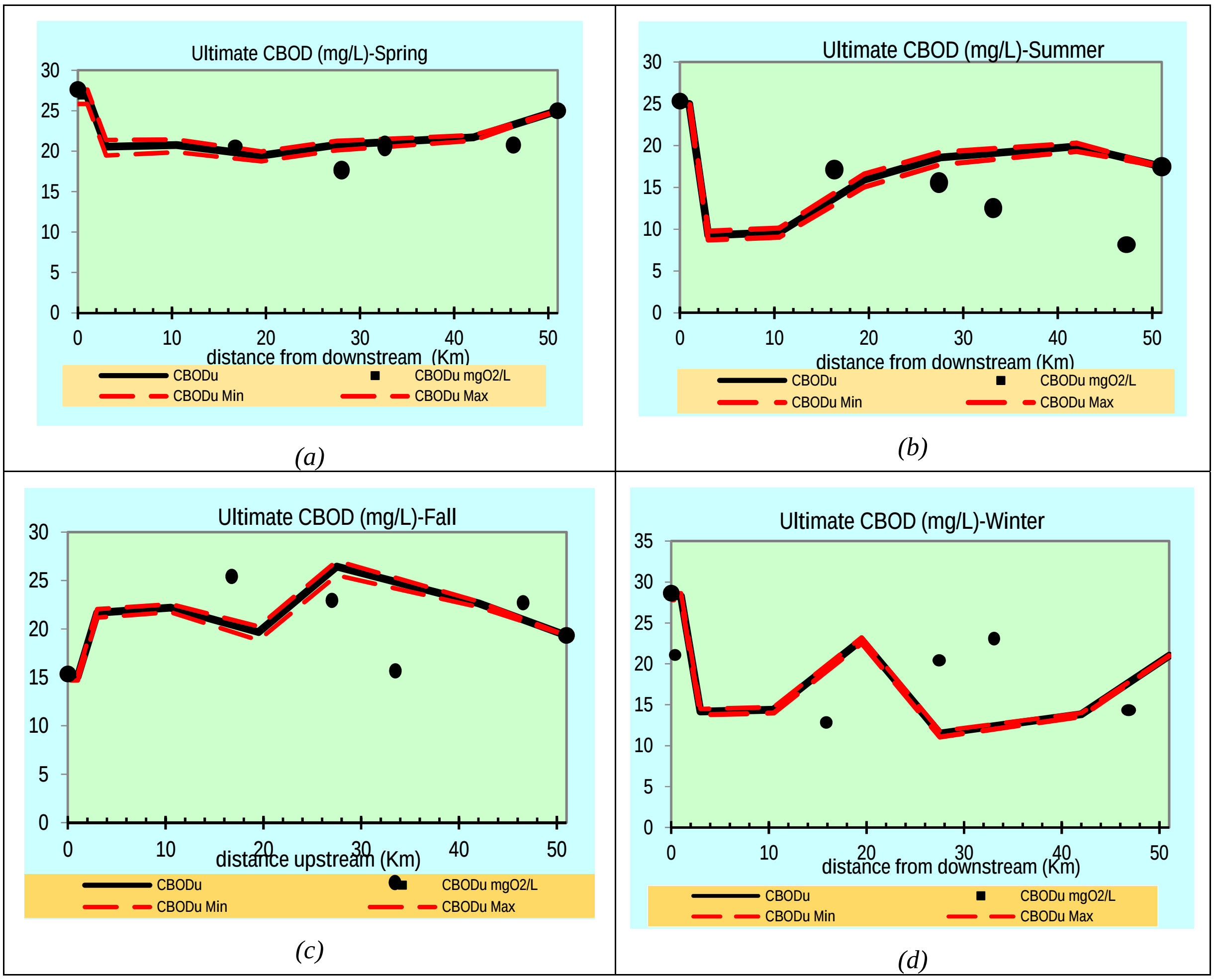
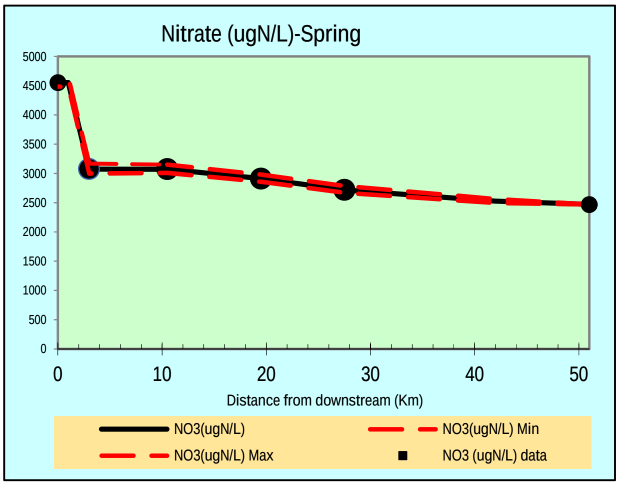


FIGURE 3-28 : SEASONAL VARIATION OF CBOD OVER DIFFERENT STATIONS OF THE RIVER IN 2009

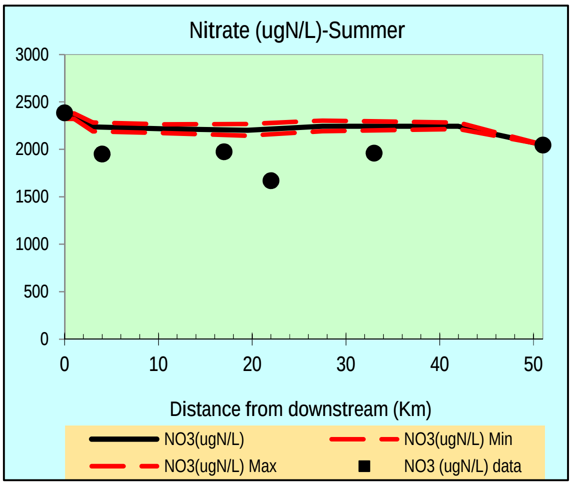
- **NO_3**

Another considered quality parameter in this study was the ultimate NO_3 of river water. This parameter has a direct relationship with the amount of wastewater pollution in rivers.

The slopes from river upstream to downstream and in all seasons show that NO_3 increase from upstream to downstream in river (figure 3-37). This is because of more human contaminating activities in this station and also presence of organic waste. Organic waste comes from raw or poorly treated sewage; runoff from farms and animal feedlots and natural sources like decaying aquatic plants, animals and fallen leaves in water.



(a)



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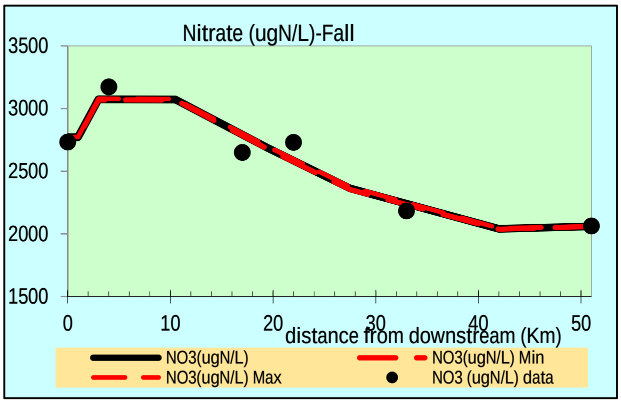

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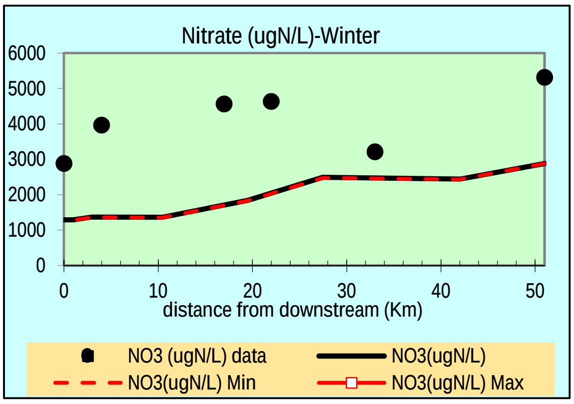
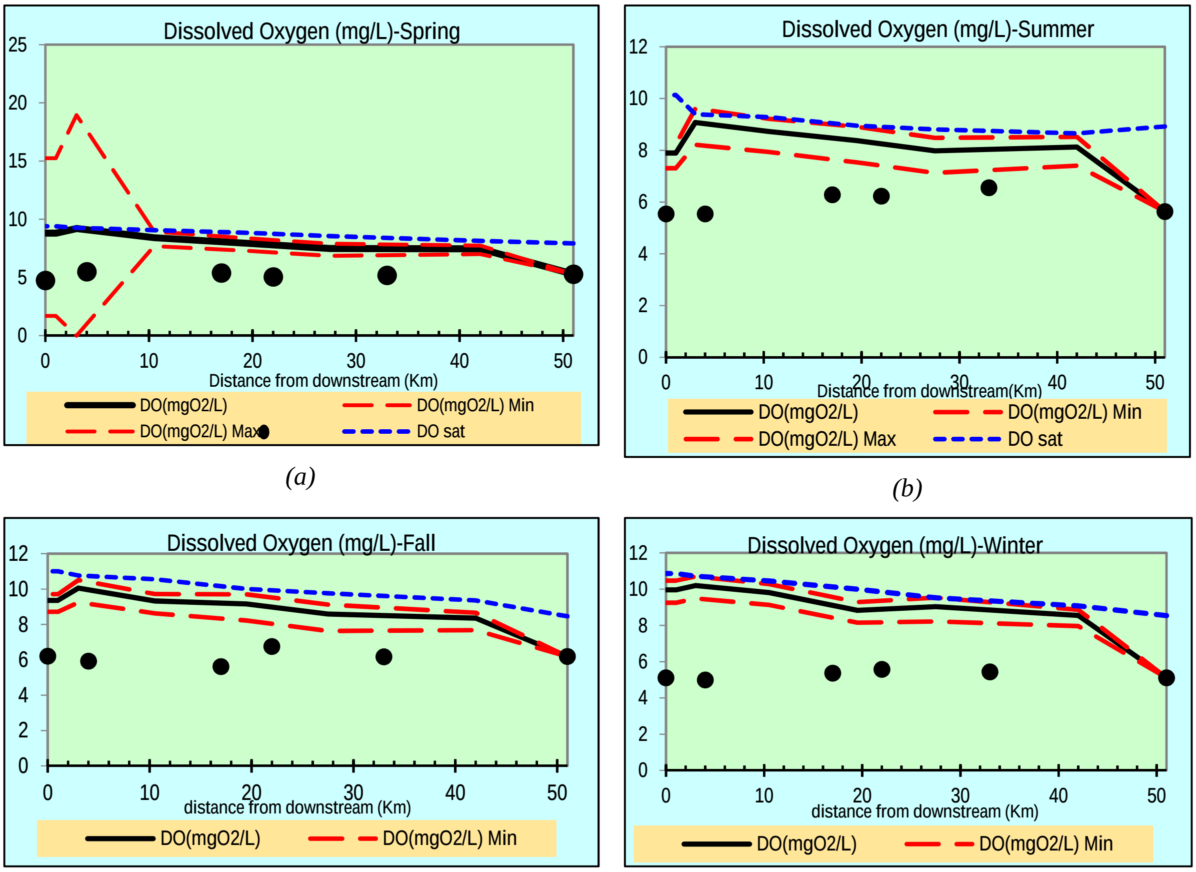


(d)

FIGURE 3-29 : SEASONAL VARIATION OF TOTAL N OVER DIFFERENT STATIONS OF THE RIVER IN 2009

- **Dissolved Oxygen**

Since the content of dissolved oxygen in water is affected by many factors such as the hydrodynamic and biochemical processes, its distribution is very complicated. The trendiness' positive slopes from river upstream to downstream, in all seasons shows that amounts of DO increase from upstream to downstream. There is a significant decrease in DO in downstream (station 6). This is because of more human contaminating activities in this station and the presence of organic waste. Organic waste comes from raw or poorly treated sewage; runoff from farms and animal feedlots and natural sources like decaying aquatic plants, animals and fallen leaves in water.

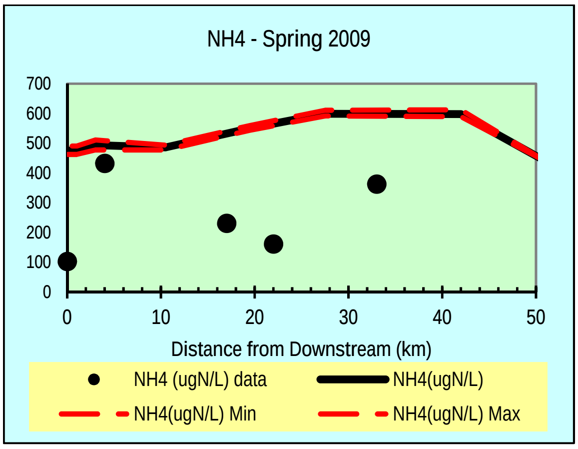


(a) *(b)* *(c)* *(d)*

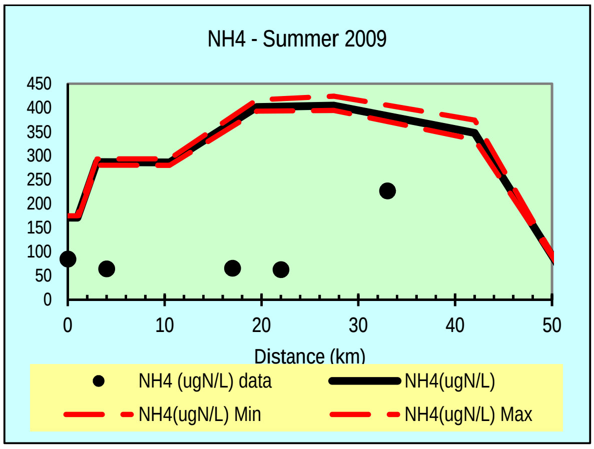
FIGURE 3-30 : SEASONAL VARIATION OF DO OVER DIFFERENT STATIONS OF THE RIVER IN 2009

- **NH_4**

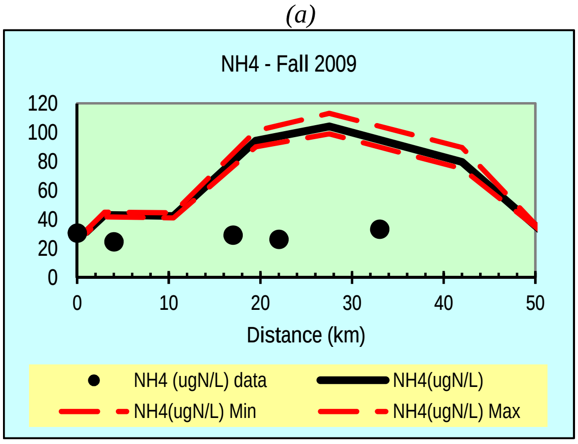
The slopes from river upstream to downstream and in all seasons show that NO_3 increase from upstream to downstream in river (figure 3-39). This is because of more human contaminating activities in this station and also presence of organic waste. Organic waste comes from raw or poorly treated sewage; runoff from farms and animal feedlots and natural sources like decaying aquatic plants, animals and fallen leaves in water.



(a)



(b)



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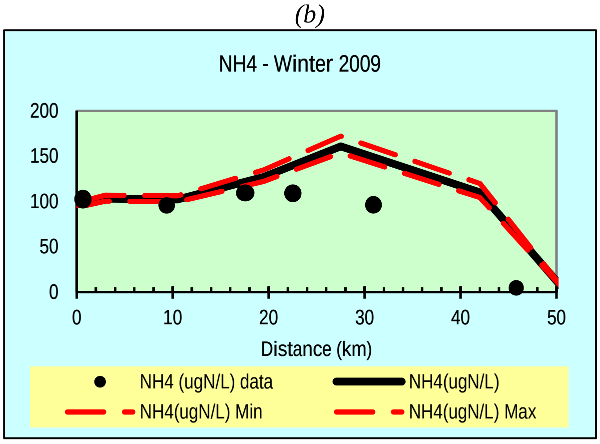


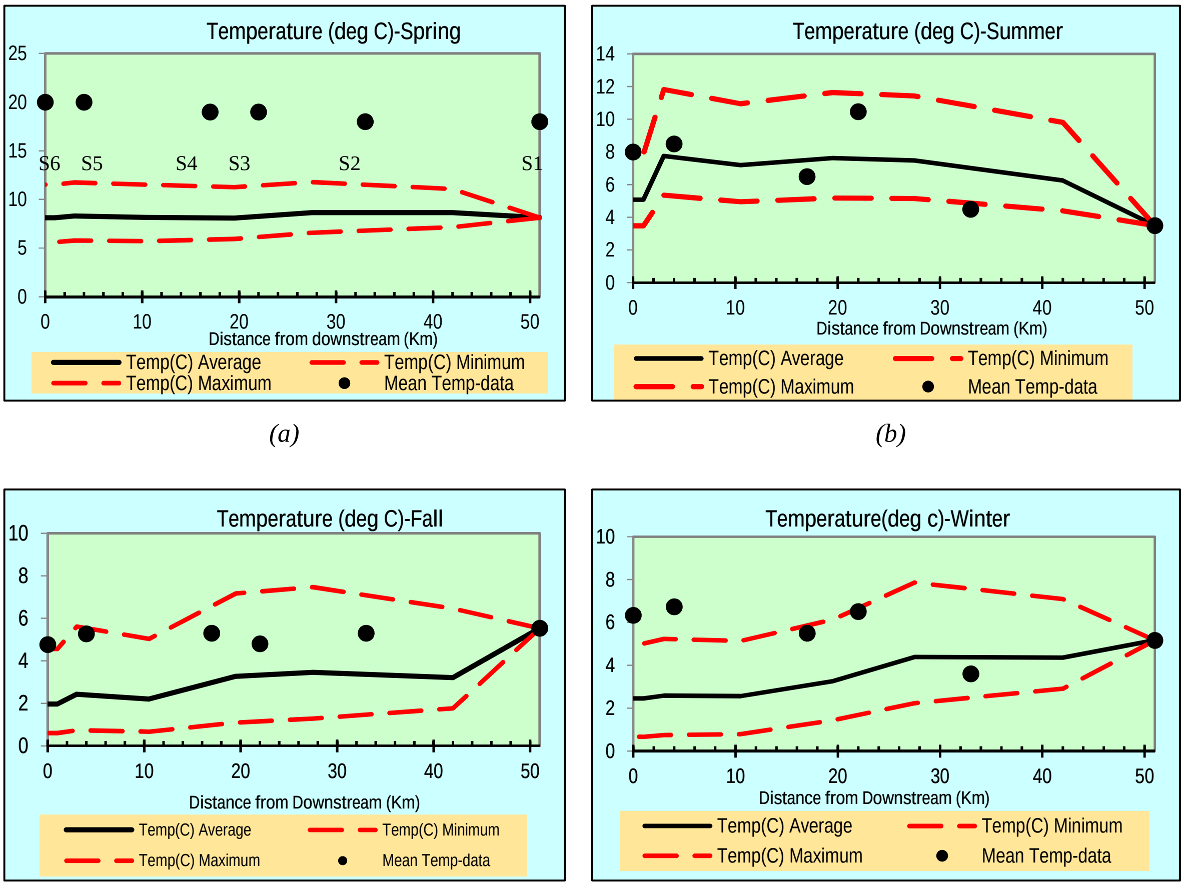
(d)

FIGURE 3-31: SEASONAL VARIATION OF NH4 OVER DIFFERENT STATIONS OF THE RIVER IN 2009

- **Temperature**

One of the most important parameters in water quality modeling is the temperature of water. Temperature has a significant effect on dissolved oxygen levels in water since cold water holds more dissolved oxygen than warm water. Water temperature tells many things about the health of a river. It also affects photosynthesis, as temperature goes up, the rate of photosynthesis and plant growth goes up and more plants grow and more fishes and aquatic animals die. For example, stonefly nymphs and trout need cool temperatures. Dragonfly nymphs and carp can live in warmer water. If water temperatures change, too much, many organisms no longer can survive.

Temperature of water determines its sensitivity to toxic wastes and disease. Wastes often cause the increase water in temperature and decrease in oxygen levels. The river water temperature change is shown in figure 6. From upstream to downstream the water temperature decreases.



(a) *(b)*

(c) *(d)*

FIGURE 3-40: TALEGHAN RIVER TEMPERATURE CHANGES DURING DIFFERENT SEASONS OF 2009

Generally, an increasing pattern is observed in the value of parameters flow, BOD, NO_3 and DO from the upstream towards downstream of the river in all seasons. Parameters pH and EC show a constant behavior over all sampling stations in different seasons. Total nitrogen and organic N had decreasing pattern from origins of the river towards the lake.

3.7 New collection data and comparison with former data

In order to have a general view over the temporal variations of major parameters within the study area, another sampling was performed in autumn 2016 and the results were compared with those of autumn 2009. All procedures including sampling, sample preservation and transport to lab, sample digestions, quality control and quality assurance schemes were the same as the process in 2008-2009 and 2009-2010 periods. The results of such comparison are shown in following figures:

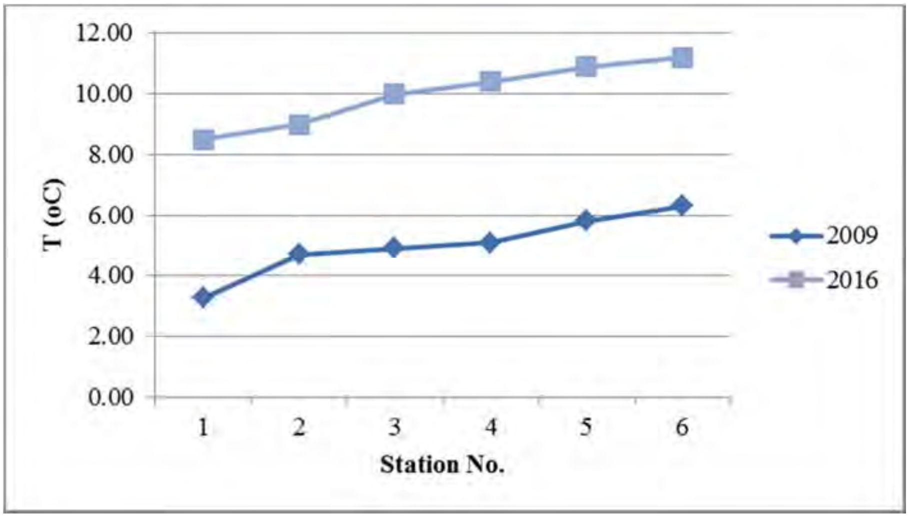


FIGURE 3-32 : COMPARISON OF T VALUES BETWEEN AUTUMN 2016 AND 2009

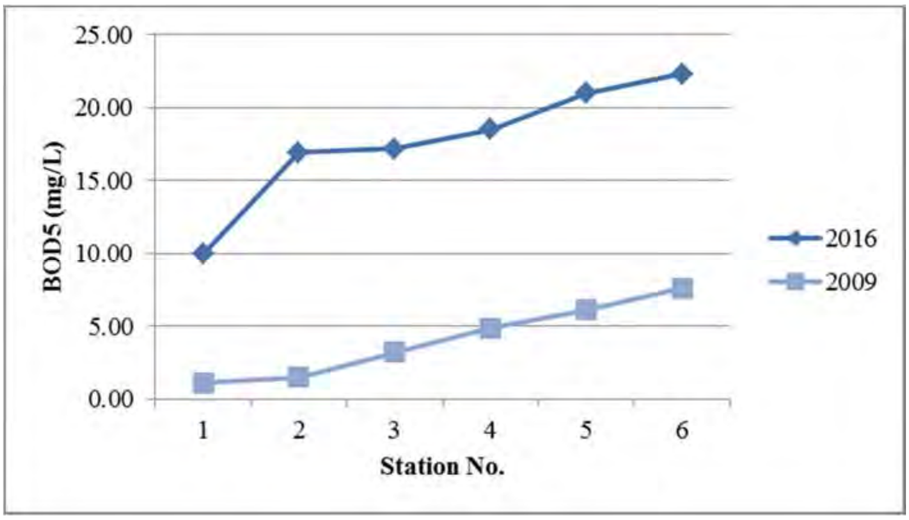


FIGURE 3-33 : COMPARISON OF BOD_5 BETWEEN AUTUMN 2016 AND 2009

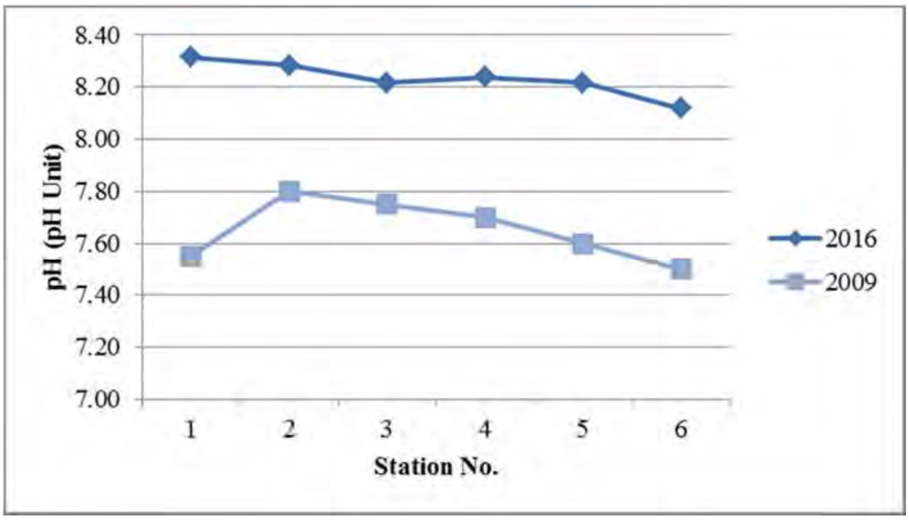


FIGURE 3-34 : COMPARISON OF PH VALUES BETWEEN AUTUMN 2016 AND 2009

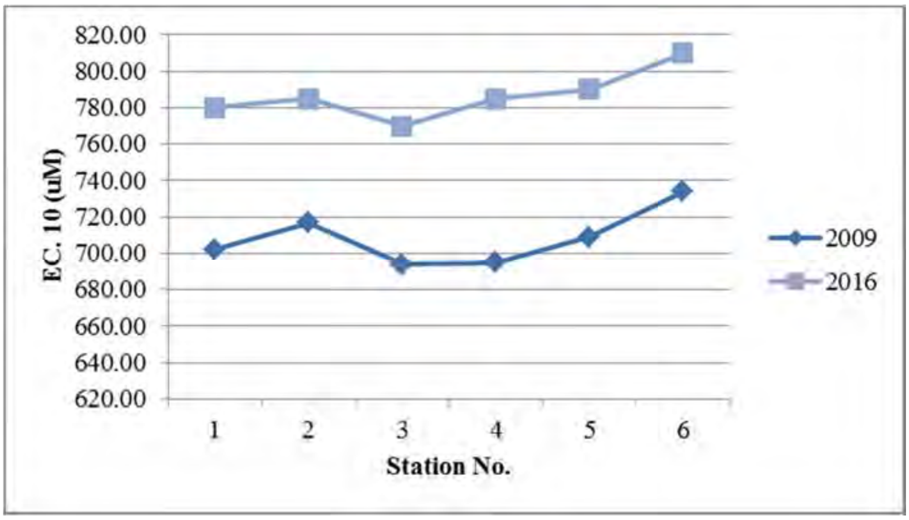


FIGURE 3-35 : COMPARISON OF EC VALUES BETWEEN AUTUMN 2016 AND 2009

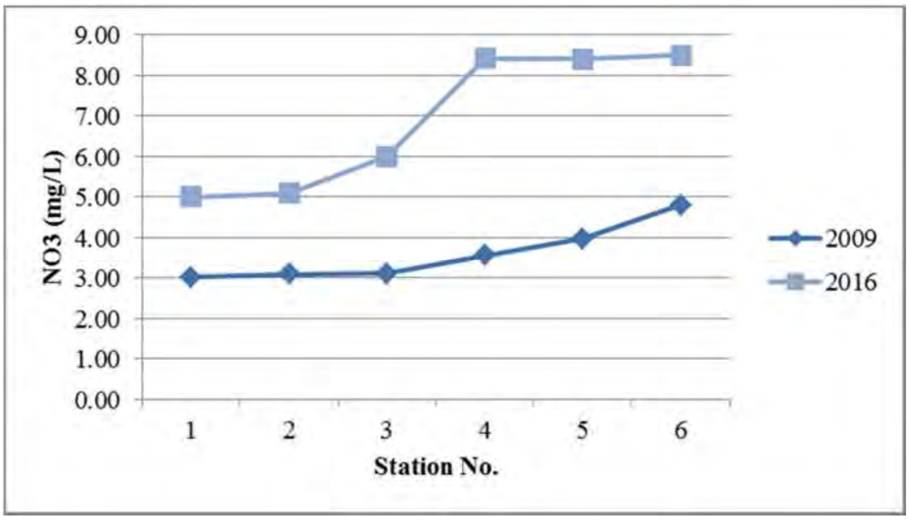


FIGURE 3-36 : COMPARISON OF NO_3 VALUES BETWEEN AUTUMN 2016 AND 2009

The above figures present an overview of Taleghan Rivers' quality parameters changes during 7 years from 2009 to 2016. As it's shown in figures, there is a significant change in parameters values in these years. For example the rate of temperature changes of river water has an approximately 7◦c. increase from 2009 to 2016 and this increase subsequently caused the increase in BOD_5.

From the above figures it's understood that the pH has so much changes during these years. But in a detailed view, it can be seen that the pH value in 2009 year has less variation in comparison with 2016 and accordingly it has been more healthy water for animals and fishes in 2009.

Different factors can affect parameters changes and river water quality during these years. The most important factors are as follows**:**

- Population: The population has increased during these years. Also increasing population have caused increase in water use and more tourist a year along the river channel. The more tourists can cause more incoming pollution to river water and accordingly more NO_3 and BOD.
- Global warming: global warming is a serious problem these days all over the world. The earth temperature increase could cause more

4 Conclusion

For the first time, studies were conducted on the quality of most Iranian rivers; an analysis was made of the main parameters of water quality to identify specific consumption and an initial assessment of the Talegan River, the waters of which are mainly used for drinking and agriculture. Using the Qual2K model to study fluctuations in water quality showed that there were changes in the parameters of Flow, CBOD, Temperature and DO in different seasons of 2009. Control over industries and the number of tourists will lead to improved water quality in the lower reaches (after the dam) of the Taleghan River

Taleghan River is used for different purposes such as drinking water in Tehran metropolitan and Karaj city, local economy and irrigation. Of course, inlet waters were limited at this period and wastes were introduced to the river, however, the examined parameters did not show critical point and no serious problems seems to exist as far as water quality is concerned. However, optimization of sampling stations and controlling the water of the River needs to continue. Controlling tourists and other visitors who camp near the River banks can help improve the quality of the water behind the Taleghan dam.

Maximum value of Fecal Coliform was measured in summer at station 6 and the minimum value was at station 1. The value of Fecal Coliform got a noticeable increase in the three final stations in all seasons due to an increase in rural wastewater in the region. Also, an increase for Fecal Coliform is likely in winter, due to the concentration of farm animals near the villages. Another factor that effect on Fecal Coliform was increasing in activities of the restaurants that dispose sewage into river.

For evaluation of Taleghan River water for drinking purposes, Piper and Schoeller Diagrams were used in this study. According to the piper diagram, the type of surface water in October, January, April and July samples was calcium-bicarbonate, which is the typical water type in the study area. It should, therefore, be stated that the concentrations of the major anions and cations, are still not so high near other bodies. Like many rivers of the world, Taleghan River is alkaline. The dominant anion and cations of the river are bicarbonate and calcium respectively. High bicarbonate and calcium amounts were natural and geological origin such carbonic stones during soil erosions.

Based on the qualitative evaluation along the river, the urban wastewater of Taleghan city enters into Taleghan River at station 6. However the quality of river water is appropriate for drinking and agricultural consumptions in all stations. According to the aforementioned issues, to improve the river water quality, it is necessary for the relevant authorities to build a wastewater treatment plant for Taleghan City.

Also, because of the intense reduction in the dissolved oxygen in downstream of the agriculture complex, the construction of re-aeration structures such as concrete spill ways in the river can contribute to promote its power of self-purification.

According to the Schoeller diagram, the river is chemically suitable for drinking. According to the results of Na percentage and RSC indexes as well as the USSL diagram, that the river water quality can be classified into two types (namely low Sodium-low salinity and average Sodium-average salinity).

Consideration of NSF index for determining quality of the river water in sampling stations of Taleghan River shows that water quality get decrease from upstream region toward downstream region. Of course, the index of variation does not show a critical condition; instead it underlines the need for a control measure by construction of a wastewater treatment plant for the city of Taleghan and its villages. Overall, the analysis of the measured results during the two years shows that quality of water can be used for drinking and agricultural consumptions. In view of the touristic nature of the region, in particular in summer, the presence of people from the other regions such as Tehran in this season the decrease in the river flow as well as the agricultural activities, there is an increasing need for proper trainings for controlling the environmental pollutions.

Water quality variations alongside the river were modeled using Qual2K model. Results showed that parameters Q, BOD_5, NO_3 and DO obeyed an increasing scheme in all seasons of 2009. EC and pH amounts in water showed a relatively constant pattern while nitrogen concentration indicated a decreasing trend from upstream towards the lake.

Finally, for awareness of last quality conditions of Taleghan River, sampling and measurement of some parameters including T, pH, BOD_5, EC and NO_3 were done in 2016.

Results of such comparison show that the value of parameters T and NO_3 increased during this 7-year period. On the contrary, the parameters of BOD_5 and pH indicate a reduction in their values. Furthermore, the parameter EC shows a constant behavior over the period.

According to the aforementioned issues, to improve the river water quality it is necessary that the relevant authorities should execute wastewater collection and treatment systems for Taleghan City and nearby villages.

Also, for prevention of an intensive reduction in the dissolved oxygen in downstream of Taleghan River, manufacturing re-aeration structures such as concrete spill ways can increase river power of self-purification and water dissolved oxygen.

5 Recommendations

According to the results of this research the following suggestions are presented:

- Results of cluster analysis should be considered in optimization of the number and location of monitoring stations. It is proposed that one station in the non polluted zone, one in low polluted zone and two in the polluted zone should be considered.
- Given the important uses of this water resource (drinking water source for Tehran City) as well as the seasonal variations of different parameters, it is proposed that a kind of online monitoring system be considered for the selected stations for the parameters of BOD, NO_3 and EC.
- Implementation of pretreatment units on local sand and gravel mines, villages and restaurants.
- Water withdrawal from river and its tributaries for irrigation purposes should be strictly controlled by authorities.
- Increasing the level of awareness and knowledge of local farmers, citizens and also tourists about water quality concerns within the study area. This may be implemented through instructions in mosques, schools, restaurants and even road signs.
- The implementation and activities of large and medium industries (with polluting potential) should be strictly controlled by environmental authorities in the area.
- The quality river buffer zone in the vicinity of Taleghan City should be strictly respected to prevent further pollution of river water.

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