STABILITY INDEX OF THE TREATED WATER FROM AL-KARKH AND AL-RASHEED WATER TREATMENT PLANTS IN BAGHDAD CITY

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ABSTRACT

An analysis was performed on the treated water from two water treatment plants in Baghdad city. This analysis was used to evaluate the stability of the treated water from these plants and that will flow in the distribution system to consider its corrosivity. The variation in water stability with time and distance from the north to the south of Baghdad was indicated. The analysis showed that the flowing water in the distribution system in Baghdad is corrosive to very corrosive water by calculating Ryznar stability index (RI). In Al- Karkh WTP in the north, RI maximum ranged between 7.958 to 9.403 where RI minimum ranged between 7.03 to 7.915. Where in the south Al-Rasheed WTP, RI maximum ranged between 7.119 to 8.63 and RI minimum ranged 6.679 to 7.994. The corrositivity of water decreased in the water flowing down stream. The water quality parameters affecting RI was discussed which were calcium, alkalinity, total dissolved solids and pH.

الخلاصة

في هذا البحث تم تحليل الماء من محطتين لتنقية المياه في مدينة بغداد. والهدف من هذا التحليل هو لايجاد استقرارية هذه المياه التي تجري داخل شبكة توزيع الماء و معرفة مدى تآكلها. وقد بين البحث مدى تغير هذه الاستقرارية مع الزمن و المسافه بين شمال و جنوب مدينة بغداد. تبين من التحليل بأن المياه الخارجة من محطات التنقية و التي تجري في شبكة التوزيع لمدينة بغداد ذات صفة تآكلية وذلك من حساب معامل الاستقرارية. في محطة الكرخ لتنقية الماء في شمال مدينة بغداد تراوح معامل الاستقرارية الاعظم بين 7.956- 9.403 و معامل الاستقرارية الادنى 7.915 - 7.03 وفي جنوب بغداد محطة الرشيد لتنقية

المياه كان معامل الاستقرارية الاعظم للماء المعالج 7.119 - 8.63 و تراوح معامل الاستقرارية الادنى بين 7.994-6.679 ومن هذه النتائج نلاحظ بان تآكلية الماء تقل بأتجاه الجريان من الشمال الى جنوب من مدينة بغداد اعتمادا على صفات الماء التي تؤثر على معامل الاستقرارية . ومن هذه الصفات والتي تمت مناقشتها تركيز الكالسيوم, القاعديه, الاملاح الكليه الذائبه و درجة الحامضيه .

KEY WORDS

Water Stability, Stability Index, Ryznar Index, Metal Corrosion, Water Quality.

INTRODUCTION

Control of water quality in the distribution system seeks to preserve the basic characteristics of water during its conveyance from the point of production and treatment to the consumers tap. The finished water should be completely stable in its compositional and physical attributes. Also the conveyance system and accessory structures (pipelines, distributing reservoirs, mains and serves pipes) should be reactively inert to the water being conveyed. Most water quality parameters affect the corrosion process to some degree and that each pipe material is affected differently. Altering one parameter to subdue its effect on the corrosivity of water may well change other water quality characteristics, perhaps rendering the water even more corrosive or less likely in some other way to meet drinking water standards (AWWA, 1971). This complex interrelationship of water quality factors that affect corrosion was dictated by many researchers.

Millete et al. (1980) Joined in a national survey covering water supplies serving approximately one fifth of the US population which showed that almost 70% of the representative utilities to have moderately to highly aggressive waters, where 16-18% had highly aggressive waters. The data were analyzed using the Langelier Index (LI) and Ryznar Index (RI). The mean value of LI for the representative utilities was - 1.17 indicating aggressive waters. The data also showed that 20% of the utilities of water supplies had an average RI above 10 indicating very aggressive water. A comparison between the two indices showed good agreement in the results.

Pisigan and Singly (1985) reported the influence of some water quality parameters in particular the LI on the corrosion of galvanized steel using a dynamic circulating water system. Metal pipes (25mm x 50mm) were used in a 40 day experimental run. The corrosion damage was evaluated in terms of weight loss of the metal. Three types of water were tested. The results showed that the greatest corrosion was in the water A of LI = - 0.46 where corrosion in water C of LI= 0.57 was greater than in water B of LI= 0.04. Change in water quality parameter were monitored, hardness and alkalinity exhibited a continuous decline. The rate of decrease of hardness was much greater in water A and C than in water B. The pH dropped initially and then increased slightly at the end of the 40 days.

Pisigan and Singly (1987) dictated from their experimental work that increasing the buffer capacity at a constant water alkalinity of 100mg/l as $CaCO_3$ in the pH range 6-9 decreased the corrosion rate of mild steel. However an increase in the buffer capacity at various pH by raising the alkalinity did not lower the corrosion rate because of the effects of higher ionic strength and conductivity. Also higher chloride content increased the corrosion rate in some waters of high buffer capacities. A chlorine residual 1-1.5mg/l as Cl_2 also accelerated the corrosion rate in mild steel and copper during batch studies. The same effect would be observed in distribution systems because of the high oxidation potential of hypochlorous and hypochlorite ion.

Al Stone et al. (1987) studied the corrosion rate of common plumbing materials. Copper and zinc were investigated as a function of physical and chemical water quality characteristics. For the systems studied, changes in dissolved O_2, conductivity and temperature had a moderate affect on the corrosion rate of both Cu and Zn, whereas pH and chlorine residual affected Cu corrosion rates but not those of Zn. Increases in conductivity up to about 200 µS/cm increased Cu corrosion rates significantly but generally had less effect at higher values. Zinc corrosion rates increased with conductivity up to 1000 µS/cm. For equal conductivities, corrosion rates were greater in systems with chloride than in systems with HCO_3, where SO_4 had an effect equivalent to chloride on aged Cu and Zn electrodes but equivalent to HCO_3 on fresh Cu.

Steve et al. (1987) in a 18 month monitoring program, evaluated the relationship between copper plumbing corrosion and variations in delivered water quality in several communities in the Pacific Northwest. Significant relationships were found for copper corrosion rate dependence on pH and free chlorine residual. The data indicated that as the pH increased from 5.8 at the start of the program to 7.7 after 12 months of operation, the corrosion rate decreased from a weekly average of 21.6µm/year to 10.2 6µm/year (a 54% decline). The regression equation coefficient indicated that the corrosion rate changes with chlorine residual, approximately 25.6µm/year per mg/l chlorine.

WATER STABILITY

Water can exhibit a tendency to either dissolve or deposit certain minerals in pipes, plumbing, and appliance surfaces. This tendency is known as stability. Water that tends to dissolve minerals is considered corrosive. Conversely, water that tends to deposit minerals is considered scaling. The tendency of corrosive water to dissolve minerals can be detrimental to water quality and to the distribution systems. In addition to dissolving calcium and magnesium, corrosive waters can also dissolve harmful metals such as lead and copper from plumbing utilities. The presence of dissolved lead or copper in tap water, require treatment techniques to reduce the corrosiveness of the water. Scaling waters deposit a film of minerals on the pipe wall which reduces and, in some cases, prevents corrosion of metallic surfaces. If the scale deposition is too rapid, however, it can also be harmful. Excessive buildup of scale can damage appliances, such as water heaters, and increase pipe friction coefficients, in extreme cases, scale may clog pipes. Therefore, to prevent corrosion yet but limit scale deposition, the most desirable water is one that is just slightly scaling (Qasim et al., 2000).

OBJECTIVES OF THE STUDY

All WTPs in Iraq are designed as conventional plants. This treatment process does not significantly affect the concentrations of the dissolved constituents, so the characteristics of the raw and treated water are quite the same. The study analyzed the quality of the effluent (treated water) from the treatment plants in Baghdad. This analyze was performed on the treated water from two chosen plants, Al-Karkh WTP in the north of Baghdad and Al-Rasheed WTP in the south. The data of the water quality were recorded in Amant Baghdad (water sector) for the period between 2000 until 2004 for the maximum and minimum recorded parameters. The analysis is to evaluate the stability of the water flowing from Al-Karkh and Al-Rasheed WTPs to consider its corrosivity. The variation in water stability with time and distance from the north to the south of Baghdad is to be indicated.

COMMON METHODS USED TO MEASURE WATER STABILITY

The most common methods used for calculating the stability of water are Langelier saturation index (LI) and Ryznar stability index (Degremont, 1991; Kawamura, 2000; Millete et al., 1980; MWH, 2005; and Qasim, et al., 2000).

1-Langelier Index (LI)

Describes a saturation index based on determined parameters which have been used in estimating the corrosion potential of water. This index compares the actual pH of the water to the pH of the water if it were saturated with calcium carbonate (Qasim et al., 2000).

The basic equations used for the determination of LI are:
LI = pH actual – pH saturation eq.1
where pH actual = measured pH of water
pH saturation = (pk`2 – pk`s) + pCa^{+2} + pAlk + S eq.2
(pk`2 – pk`s) = dissociation constant based on temperature and total dissolved solids or ionic strength.
pk`2 = acidity constant for the dissociation of bicarbonate.
pk`s = mixed solubility constant for $CaCO_3$
pCa^{+2} = - log (calcium ion in moles / liter)
pAlk = - log (total alkalinity in equivalent of $CaCO_3$/ liter)
S = salinity correction term = $2.5\ \mu^{½} / (1+5.3\ \mu^{½} + 5.5\ \mu)$ eq.3
where μ = ionic strength
For total dissolved solids content less than 500 mg/l ,the ionic strength may be estimated by $2.5 \times 10^{-5} \times$ TDS . An alternate approximation of ionic strength can be made using the total hardness and total alkalinity (Millete et al., 1980). Table 1 shows the scale and corrosive tendencies of water at different Langelier index.

Table 1 Scale and Corrosion Tendencies of Water with Different Langelier Index

LI /Range	Indication
The index is zero	Water is in equilibrium.
A positive index	Oversaturation and the tendency of water are to lay down a protective coating in the pipe.
A negative index	Under saturation and the tendency of water to be aggressive to the pipe. The greater the value, the greater the aggressiveness.

2-Ryznar Index (RI)

The same parameters in the Langelier saturation index are also used in this index. The Ryznar index is a quantitative index of the amount of calcium carbonate scale that would be formed and to predict the corrosiveness of waters that are non scale forming (REF). The equation for the determination of RI is:

RI = 2pH saturation - pH actual eq.4

Table 2 lists the scale formation or corrosive tendencies of waters with various Ryznar index values (Qasim et al., 2000).

Table 2 Scale and Corrosion Tendencies of Water with Various Ryznar Index Values

RI/Range	Indication
Less than 5.5	Heavy scale formation
5.5 to 6.2	Some scale will form
6.2 to 6.8	Non-scaling or corrosive
6.8 to 8.5	Corrosive water
More than 8.5	Very corrosive water

RESULTS AND DISCUSSION

The stability of the treated water from the two plants (Karkh and Rasheed) was calculated according to the water quality of the effluents of these plants. In this study the Ryznar Index (RI) was used to evaluate the stability of the effluent from these plants using eq.4. The US Environmental Protection Agency (USEPA) has recommended the use of Langelier index and Ryznar index by utilities to monitor the corrosion potential of water (Pisigan and Singly, 1985). The measured parameters of the treated water that affect the stability index are calcium concentration, alkalinity, total dissolved solids and pH.

CALCIUM (CA)

After bicarbonate, calcium is the second most prevalent constituent in most surface waters of the world and is generally among the most prevalent three or four ions in groundwater. Weathering and soil ion exchange reactions are the main sources of calcium in natural waters. Common minerals forms of calcium are calcite, also known as aragonite ($CaCO_3$), gypsum ($CaSO_4.H_2O$) anhydrite ($CaSO_4$) and fluorite (CaF_2). Calcium is generally present as the free ion Ca^{+2} in natural waters and adsorbed into soil particles calcium concentrations can reach several handred milligrams per liter in arid regions or under conditions where hydrogen ion activity is higher than under atmospheric equilibrium conditions. Waters with calcium levels between 60 and 100 mg/L are generally considered moderately hard to hard as calcium is a primary constituent of water hardness. Calcium is of importance to industry as a component of scale. The precipitation of $CaCO_3$ scale on cast iron and steel pipes helps inhibit metallic corrosion but the same precipitate in boilers and heat exchangers adversely affects heat transfer. Water high in calcium have a nuisance value in wash waters both domestic and industrial, as the alkaline environment causes precipitation of the calcium (scale) on fixtures and soap (MWH, 2005). Increasing the Ca concentration will decrease the corrosivity of water, as Ca is important in various roles, including calcium carbonate scales, mixed iron/calcium carbonate solids and the formation of a passivating film on the surface of the pipe, to control corrosion (Schock, 1989).
From the recorded data the maximum concentration of Ca ranged between 53 to 143 mg/l in Al-Karkh WTP as shown in Fig.1a.Whereas in Al-Rasheed WTP the maximum concentration was 62 to 146 mg/l. The minimum concentrations shown in Fig.1b ranged 46 to 74 mg/l in Al- Karkh and 62 to 130mg/l in Al- Rasheed .These results indicate that calcium increased from the north to the south in the treated water in Baghdad city. Also a slight increase could be observed with time in Al-Rasheed WTP where the Ca concentrations remain at low and constant values in Al-Karkh WTP in the north of Baghdad.

ALKALINITY (ALK)

Alkalinity is a measure of the ability of water to resist changes in pH. Alkalinity in water is due to the presence of weak acid systems that consume hydrogen ions produced by other reactions or produce hydrogen ions when they are needed by other reactions allowing chemical or biological activities to take place within water without changing the pH. The primary source of alkalinity is the carbonate system, although phosphates, silicates, borates, carboxylates, and other weak acid systems can also contribute. In water treatment plants, alkalinity is required in the coagulation process for the reaction of alum, lime could be added if the natural alkalinity is not enough for this reaction (MWH, 2005).

Fig.2a shows the maximum alkalinity in Al-Karkh WTP ranging from 124 to 161 mg/l as $CaCO_3$ with a slight difference in Al-Rasheed WTP which was 126 to 169 mg/l as $CaCO_3$. The minimum values were 94 to 143 mg/l as $CaCO_3$ in Al-Karkh and 122 to 158 mg/l as $CaCO_3$ in Al-Rasheed as shown in Fig.2b. Also indicating that the alkalinity increased in the effluent from the south WTP. Corrosivity of water decreases as the alkalinity increases where it is necessary to provide a stable pH throughout the distribution system for corrosion control of metal pipes (Schock, 1989). Low iron corrosion rates and iron concentrations in the distribution systems have been associated with higher alkalinities (Pisigan and Singley, 1987). The alkalinity of the treated water from the two plants seems to decrease with time which could be observed from these Figs.

TOTAL DISSOLVED SOLIDS (TDS)

TDS in water are due to inorganic salts. Principally these inorganic constituents are calcium, magnesium, sodium, and potassium salts of bicarbonate, chloride, sulfate, nitrate and phosphate. These compounds originate from weathering and leaching of rocks, soils and sediments. Also some of these compounds are added to the water in the treatment plant (MWH, 2005).

The variation of TDS in the treated water was large from the two plants as shown in Fig.3a and Fig.3b. In Al-Karkh WTP the maximum values ranged between 280 to 680 mg/l and the minimum between 240 to 540 mg/l. The TDS increased in the Al-Rasheed WTP where the maximum concentrations reached 340 to 1020 mg/l and the minimum 330 to 800 mg/l. The conventional treatment process does not affect the dissolved content of the treated water so the high TDS concentrations in Al-Rasheed effluent are due to the raw water quality entering this plant. The increasing amounts of dissolved solids in the Tigris River are due to the discharge of waste water, leaching of fertilizers and the natural weathering of the soil. These concentrations are decreasing with time from the two plants as shown in Figs.3a and 3b.

HYDROGEN ION CONCENTRATION (PH)

pH is a measurement of the acid base properties of a solution. pH is important in water treatment as it directly influences the dosages of chemicals added to reduce hardness and coagulate particles (MWH, 2005).The higher pH of the water in the distribution system will decrease the solubility of the corrosion by products formed in the system (Schock, 1989).

The maximum values of pH ranged between 7.5 to 8 in Al-Karkh WTP and in Al-Rasheed WTP from 7.4 to 7.9. The minimum values varied between 6.9 to 7.6 in Al-Karkh and in Al-Rasheed from 7.1 to 7.9. As shown in Figs.4a, and 4b.This variation in pH of the effluent from the water treatment plants depend on the amount of coagulants added for suspended solids removal and the chlorine dose used for disinfection. The variation of pH with time seems to be stable in the two plants. From these Figs.pH max ranged between 7.6 to 7.9 where the min. ranged 7.2 to 7.8.

RYZNAR INDEX (RI)

The effect of TDS content on water corrosivity is a complex issue. Both the species and the concentration of ions are important factors. Some species such as carbonate and bicarbonate reduce corrosion, whereas chloride, sulfate, bromide and nitrate ions markedly accelerate corrosion. Temperature also affects the corrosion process. Higher water temperatures accelerate the rate of corrosion by increasing the rate of the cathodic reaction. The chemical reaction rate generally is doubled for every 8°C increase in temperature (Kawamura, 2000). Fig.5a and 5b show the variation in the stability index RI of the effluents from the two plants.

In Al-Karkh WTP RI max ranged between 7.958 to 9.403 where RI min ranged between 7.03 to 7.915. In Al-Rasheed WTP RI max ranged between 7.119 to 8.63and RI min ranged 6.679 to 7.994. According to Table 2 the effluents from these plants are classified corrosive to very corrosive water (RI is more than 6.8). The high RI value in the treated water from Al-Karkh WTP was because of the low Ca and alkalinity content. The RI max. for the two plants remain varying between 8.0-8.5 in Al-karkh and 7.5-8.0 in Al-Rasheed, where RI min. ranged 7.5-7.7 and 7.1-7.3 respectively. This may indicate a constant corrosivity with time. The corrosivity index show that the water is corrosively high in the north part in Baghdad city (Al-karkh WTP) and decreases at the south (Al-Rasheed WTP).

CONCLUSIONS

1-Water quality affects the corrositivity of the treated water flowing from the WTPs to the distribution system in Baghdad city. The parameters most influence the corrosion and leaching the materials of the distribution system are:
a- Calcium (Ca) concentration increased in the treated water from Al-Rasheed WTP that might decrease its corrosivity.
b- Alkalinity (Alk) increased in the effluent of water treatment plant in the south that affects the corrosivity inversely.
c- The increasing amounts of the total dissolved solids (TDS) in the Tigris River are due to the discharge of waste water, leaching of fertilizers and the natural weathering of the soil. These concentrations are high in the flowing water in the south of Baghdad. As mentioned before the treated water also contains high amounts of these contents that will increase the corrosivity of the water.
2- The calculated stability index RI indicated that the treated water from the two plants was corrosive to very corrosive water. The corrosivity index show that the water is highly corrosive in the north part of Baghdad city (Al-karkh WTP) and decreases at the south (Al-Rasheed WTP).

RECOMMENDATIONS

Control of water quality in the distribution system seeks to preserve the basic characteristics of water during its conveyance from the point of production and treatment to the consumers tap. The finished water from the two treatment plants should be completely stable in its compositional and physical attributes. Several methods could be applied in the treatment plants to produce stable water like pH adjustment or adding corrosion inhibitors. The treatment process in Al-karkh plant should be highly adjusted, as the corrosivity index indicates very corrosive water.

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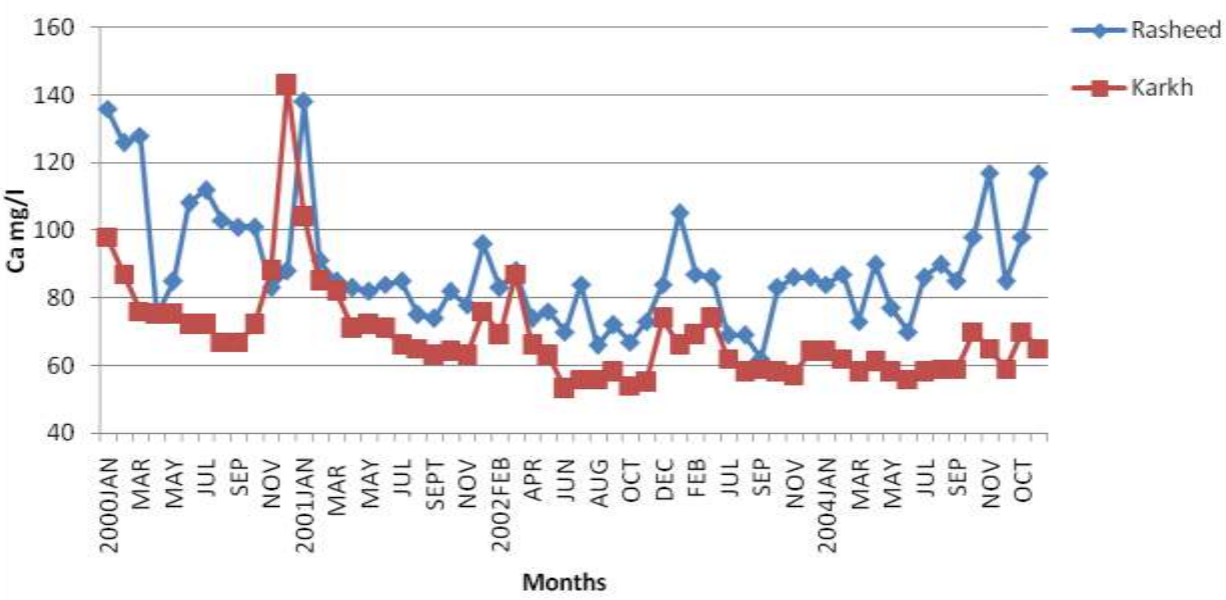

Fig. 1a Max. Ca Concentration

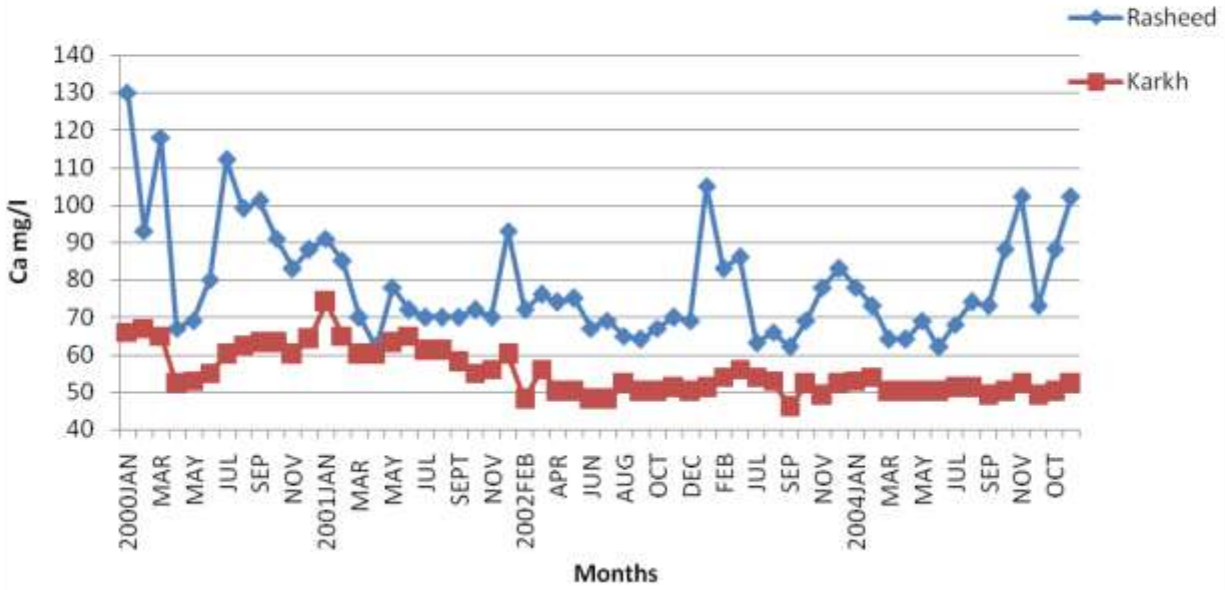

Fig. 1b Min.Ca Concentration

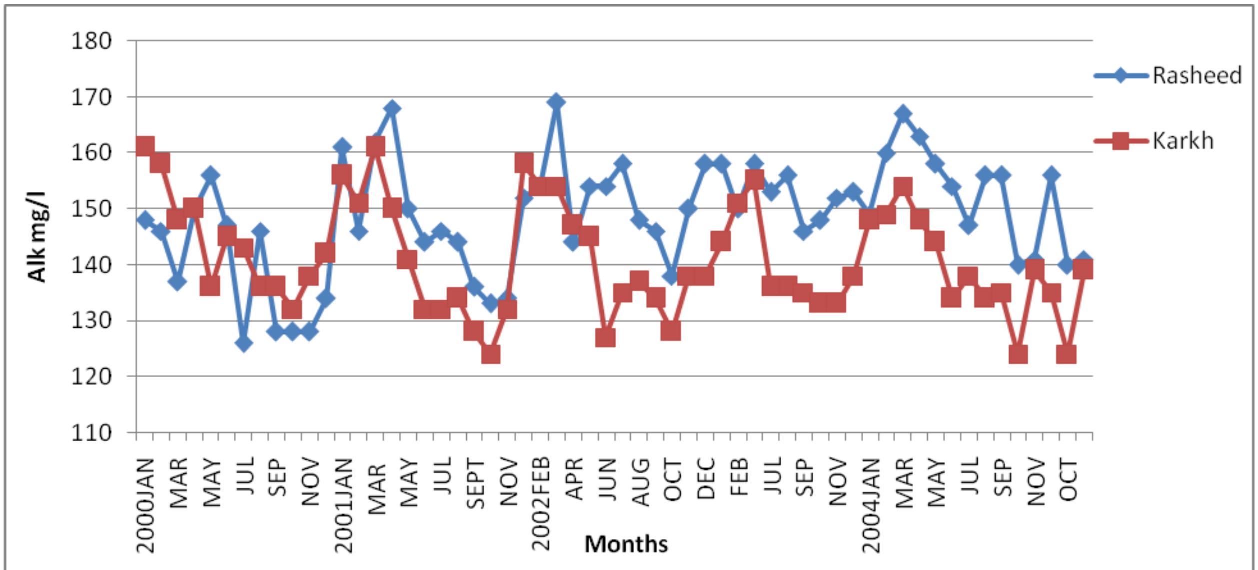

Fig. 2a Max. Alkalinity

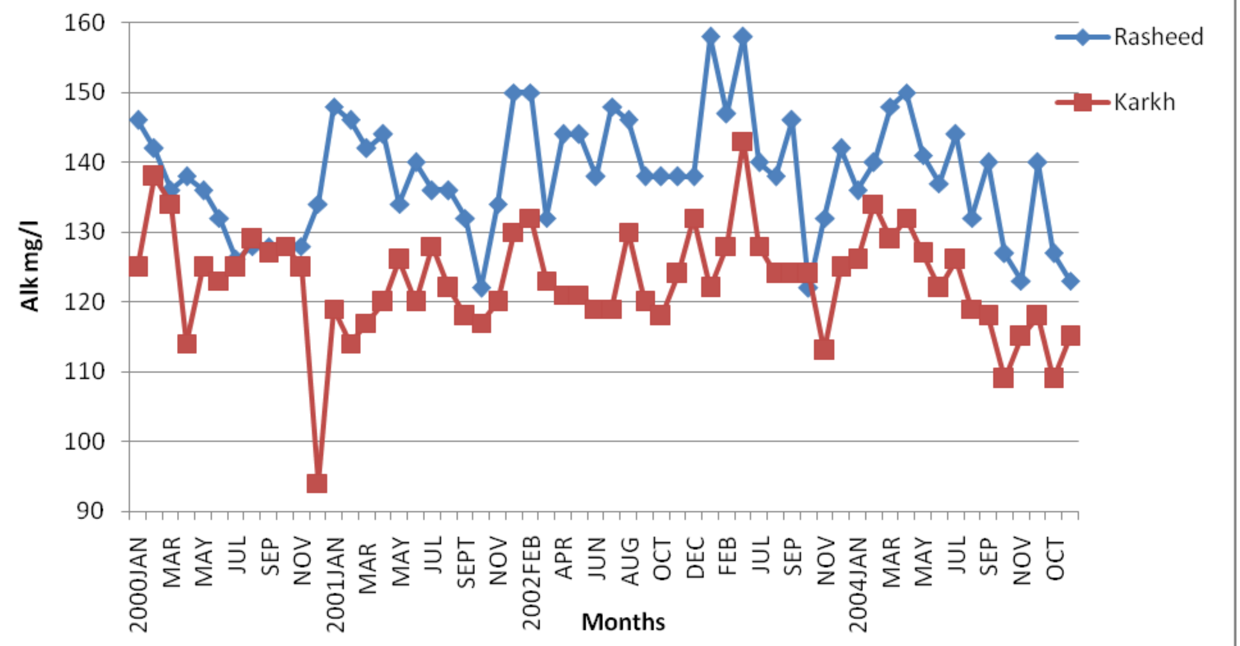

Fig. 2b Min.Alkalinity

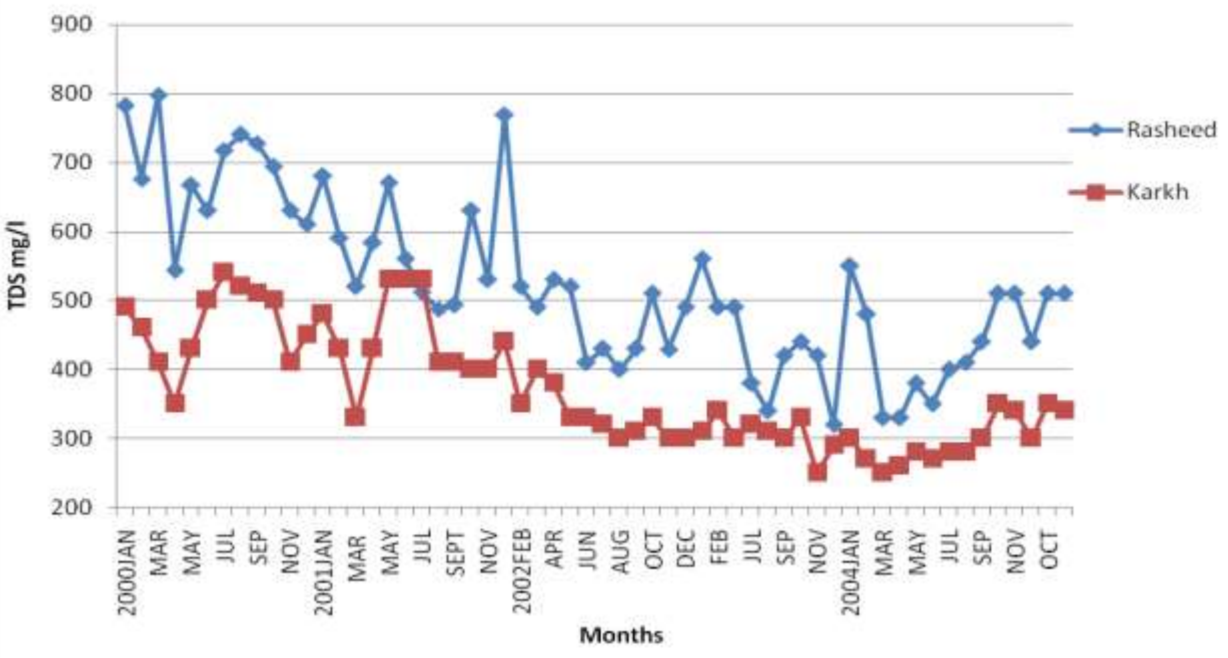

Fig.3b Min.TDS Concentration

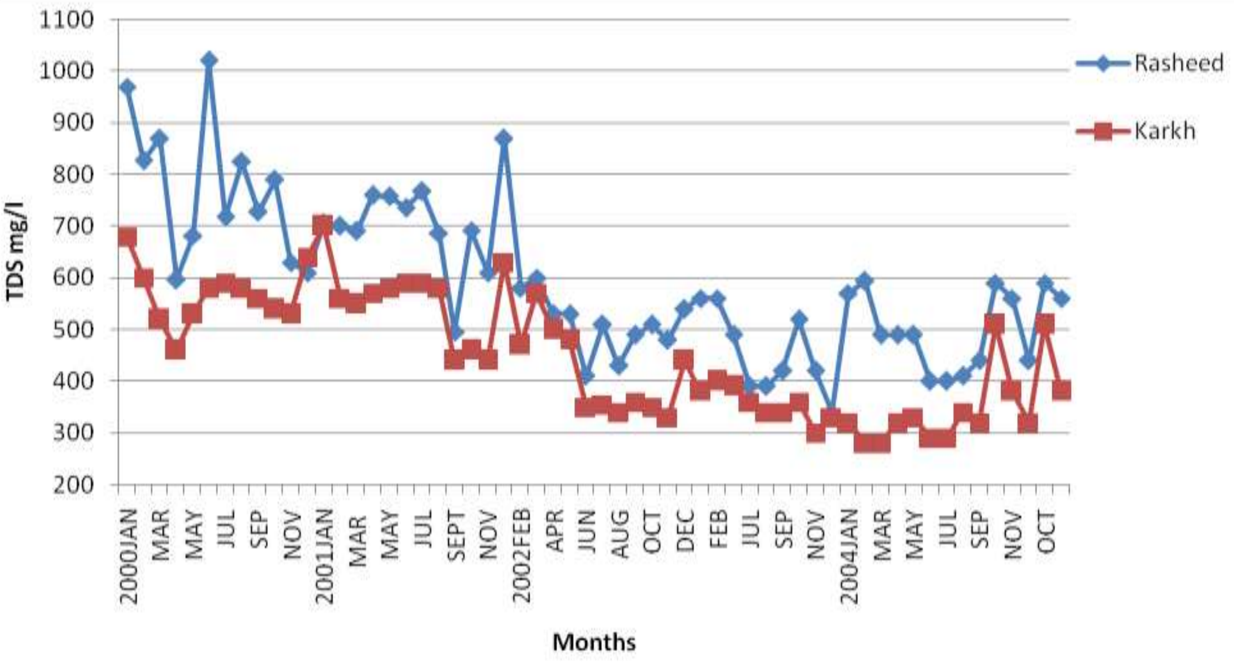

Fig. 3a Max.TDS Concentration

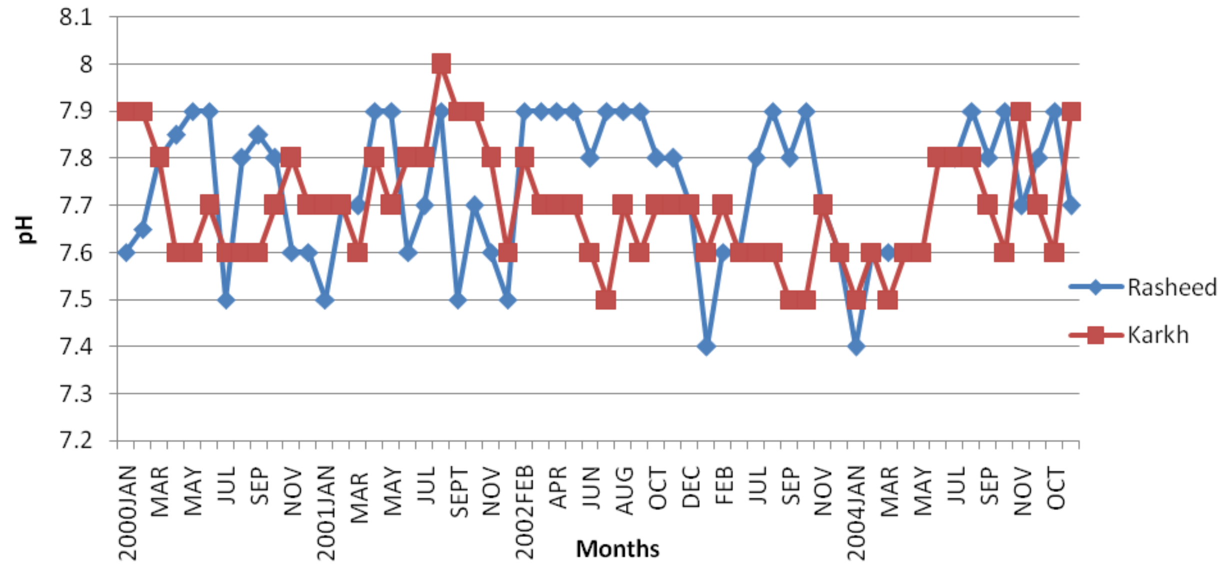

Fig.4a Max. pH

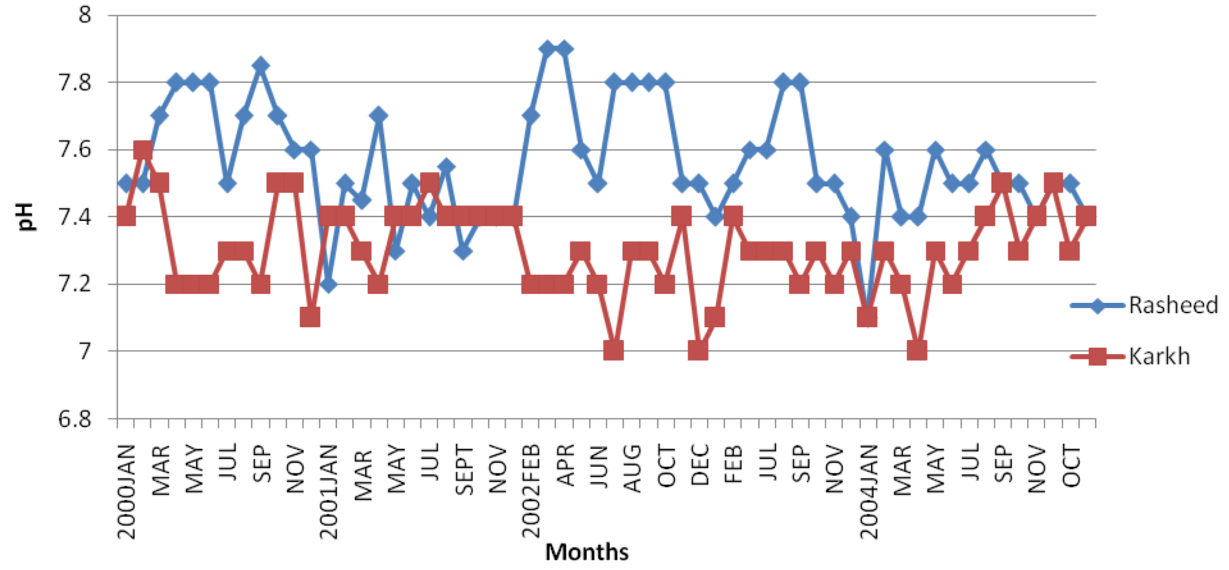

Fig.4b Min. pH

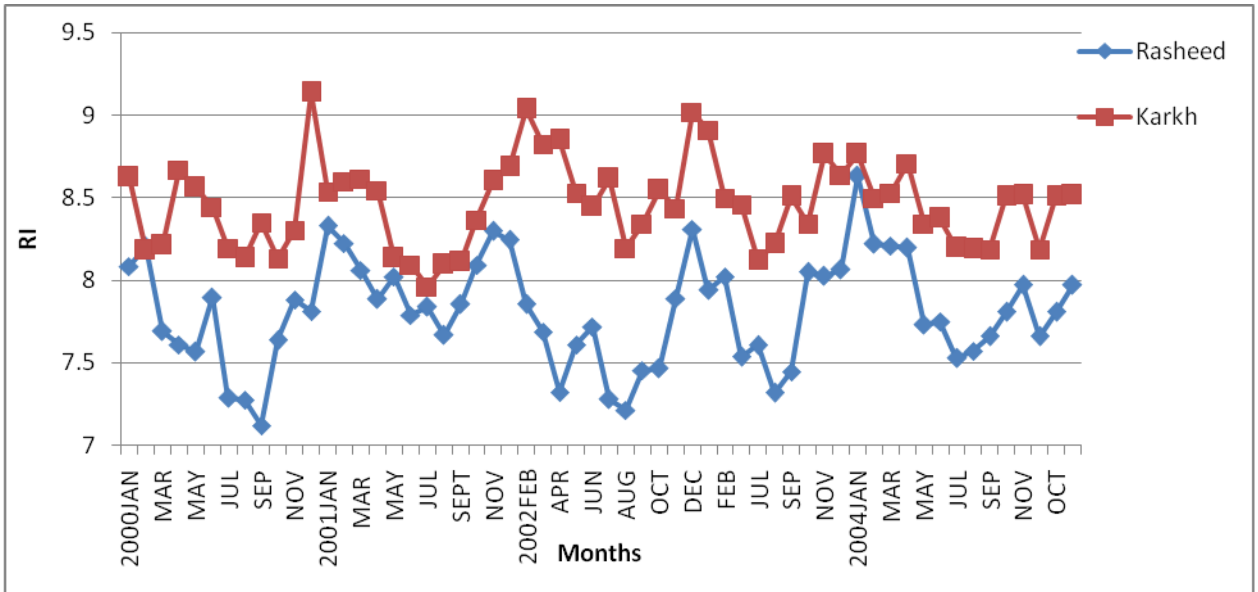

Fig.5a Max.Ryznar Index

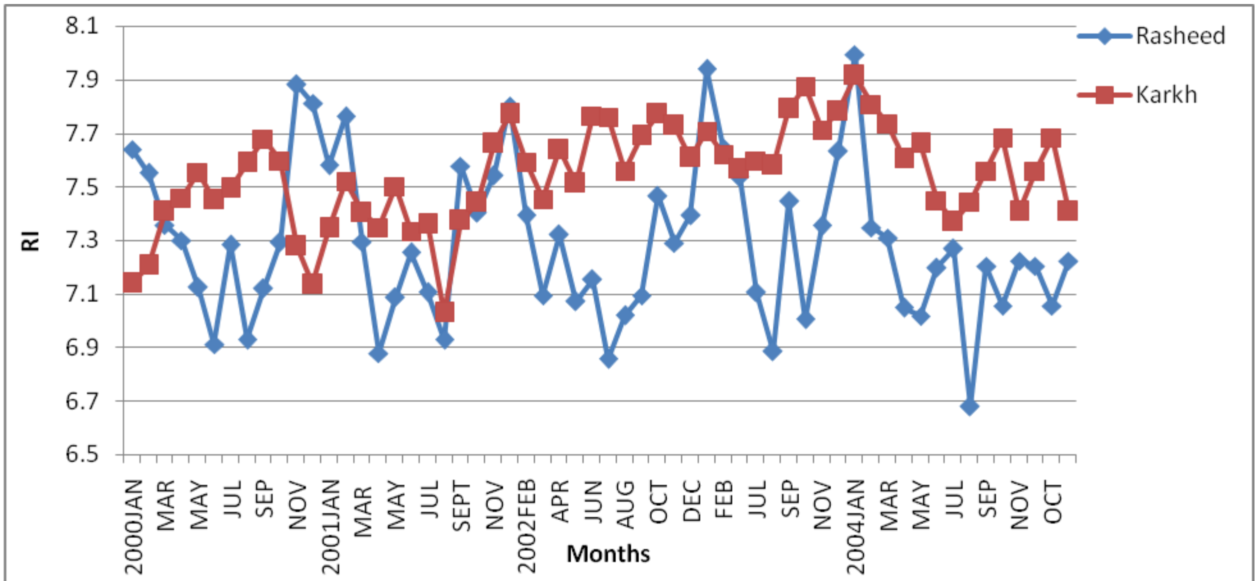

Fig.5b Min.Ryznar Index