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Research paper

A study on the corrosion index of Tap Water(TW) and Reclaimed Water(RW) using KWI(Korea Water Index) and KRWI(Korea Reclaimed Index Water) method

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Abstract

This study aim to find the corrosion index of Tap water and Reclaimed water using KWI (Korea Water Index) and KRWI (Korea Reclaimed Water Index) method. The impact of corrosion inhibiting factors (pH ,hardness, alkalinity) and corrosion accelerating facor (TDS, chlorine ion, sulphate ion) has studied. The corrosion assessment method based on the corrosion index is used in predicting corrosion and offering information on the control of corrosive water quality.

Keywords: *Pipelines corrosion, main factor of pipeline corrosion, KWI index method, KRWI index method*

1. Introduction

Corrosion is a process in which metallic materials respond chemically or electrochemically to surrounding environments. In a narrower sense, corrosion means that a metallic material loses its property as it degenerates in the environment where it is used. The metal is produced by applying energy to an oxidized ore in nature; metal corrosion is a natural phenomenon as metal returns to its original oxidized state.

Generally, the corrosion of water pipes can be divided into inner surface corrosion and outer surface corrosion. The main factor in the inner surface corrosion is water quality, while that in the outer surface corrosion differs by external environments. Underground pipes can be affected by factors included in soil. Pipes installed inside concrete or bits, such as the water supply pipes in a building, can be affected by concrete or atmosphere factors. Among these factors, the quality of water that contacts the inner surface of the pipes may affect the inner surface corrosion the most.

Lee (1) studied the corrosion in pipelines because of TW and RW. He conducted the experiment on four different types of pipes Cast iron pipe (CIP), Galvanized steel pipe (GSP), Stainless steel pipe (STSP) and Polyvinyl chloride (PVCP). It has found that that the ionic contents are more in RW as compared to TW and those ionic contents were the main reason of faster corrosion in pipelines. The corrosion accelerator factors have larger effects on pipe corrosion as compared to corrosion inhibiters . In terms of pipe materials, the corrosion rate was fastest in CIP, followed by GSP, and STSP; PVCP exhibited no electrochemical corrosion.

This study aim to find the corrosion index of Tap water and Reclaimed water using Korea Water Index (KWI) and KRWI (Korea Reclaimed Water Index) method. The corrosion assessment method based on the corrosion index is used in predicting corrosion and offering information on the control of corrosive water quality. The most representative corrosion indices are the ones based on the saturation of calcium carbonates, that is, the indices based on the corrosion related to various aqueous chemical factors such as: Ph, Temperature, alkalinity, calcium hardness, magnesium, Dissolved oxygen, Conductivity, chlorine residual, acidility, chloride, sulphate and Total organic carbon etc.

2. Methods and materials

2.1 Simple pipeline analysis

In Korea, the Stainless steel pipes (STSP), Galvanized Steel pipes (GSP), Cast iron pipes (CIP) and Polyvinyl chloride pipes (PVC) are mainly used in reclaimed water supply system. These 4 types of pipes are used as test devices for the experiment. In order to circulate the water continuously, the test devices are placed in a loop with the tank and underwater pump is used to supply reclaimed water and tap water as shown in the Fig 1.

The total of eight loops having overall length of 2.5 m each were used in this experiment and the diameter of the pipes were 15mm .The water was supplied with the velocity of 1.5 m/sec and was replaced after every 24 hours.

The test devices are basically the coupons that were positioned in the acrylic chamber. The coupons were 15 mm (H) x 20 mm (W) x 3mm (D). Before being used, the coupons were sterilized at 120 ºC for about 15 minutes and then dried at 105 ºC for about 24 hours. The coupons were positioned underwater . The corrosion rate of the coupons were analyzed after collecting them as the time passed.

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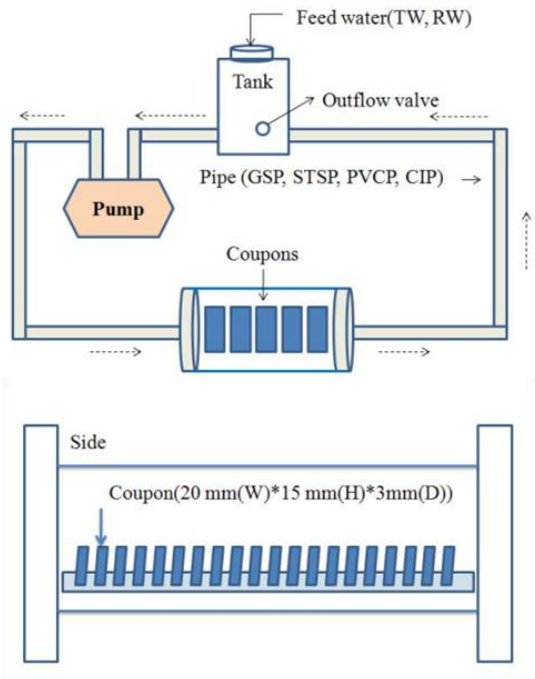

Fig. 1: Schematic of simulated distribution loop system and coupon tester used in experiment

2.2 Korea Water Index (KWI) and Korea Reclaimed Water Index (KRWI)

KWI non-dimensionalized the difference between relative water quality characteristics by assuming the optimal water quality and comparing it to the current water quality for controlling corrosiveness. The assumptions made for this model are as follows:
1. Physical and chemical characteristics of the water quality are excluded.
2. The effect of each water quality factor on corrosion is identical.

$$KWI = \frac{\sum_{I=1}^{n}\frac{Wqin}{Wqoi} + \sum_{1=1}^{2}\frac{Wqoi}{Wqaci}}{n1+n2} \quad (1)$$

W qo : Optimal water quality for corrosion inhibition.
W qin : measured corrosion inhibition water quality.
W qac : measured corrosion acceleration water quality.
n1: The number of items for corrosion inhibition water quality.
n2: The number of items for corrosion acceleration water quality.

If KWI is smaller than 1, then the water is corrosive. If it is larger than 1, then it is noncorrosive. If KWI is 1, then water is in an equilibrium state. The assessment of corrosiveness with KWI showed that RW was influenced more by corrosive accelerators than by corrosion inhibitors. It seems necessary to develop a new index for RW and the optimal water quality standard of KWI that is suitable to water quality. For these reasons, the optimal quality of the reclaimed water and KRWI modified KWI have developed.

$$KRWI = \left[\left(2 * \frac{\sum_{I=1}^{n}\frac{Wqin}{Wqoi} + \sum_{1=1}^{2}\frac{Wqoi}{Wqaci}}{n1+n2}\right) + \left(\frac{\sum_{I=1}^{n}\frac{Wqin}{Wqoi} + \sum_{1=1}^{2}\frac{Wqoi}{Wqaci}}{n3+n4}\right)\right]/3 \quad (2)$$

n3: The number of added items for corrosion inhibition water quality
n4: The number of added items for corrosion acceleration water quality

3. Result and Discussions

3.1. Korea Water Index (KWI)

KWI do not only offer the information on corrosion, it also present the quantitative basis for controlling corrosive water. The Fig. 2 indicates the results of the corrosiveness assessment of RW and TW using WKI. Fig. 2 (a) is the diagram applied the all KWI model while (b) and (c) are the corrosion inhibitors and corrosion accelerators among the KWI model components. Table 1 shows the optimal TW quality for preventing corrosion, developed by Lee et al. (2001) and that was applied to calculate the KWI value of TW.
Considering all the accelerating and inhibiting factors of water quality presented that the corrosiveness of TW was shown to be higher than RW.
That of RW was 2, exceeding the corrosiveness standard of 1, which shows that the effect of corrosion accelerators is larger than that of corrosion inhibitors. The value used as the optimal water quality of KWI is based on TW. Another optimal water quality value suitable for RW was necessary; therefore, KRWI was developed.

Table 1: Effective factors of controlling corrosion at TW

Inhibition factor	Value	Acceleration factor	Value
Cl^- (mg/L)	10	TDS (mg/L)	85
pH	7.5	Hardness (mg/L as $CaCO_3$)	80
SO_4^{2-}	10		
Alkalinity (mg/L as $CaCO_3$)	60		

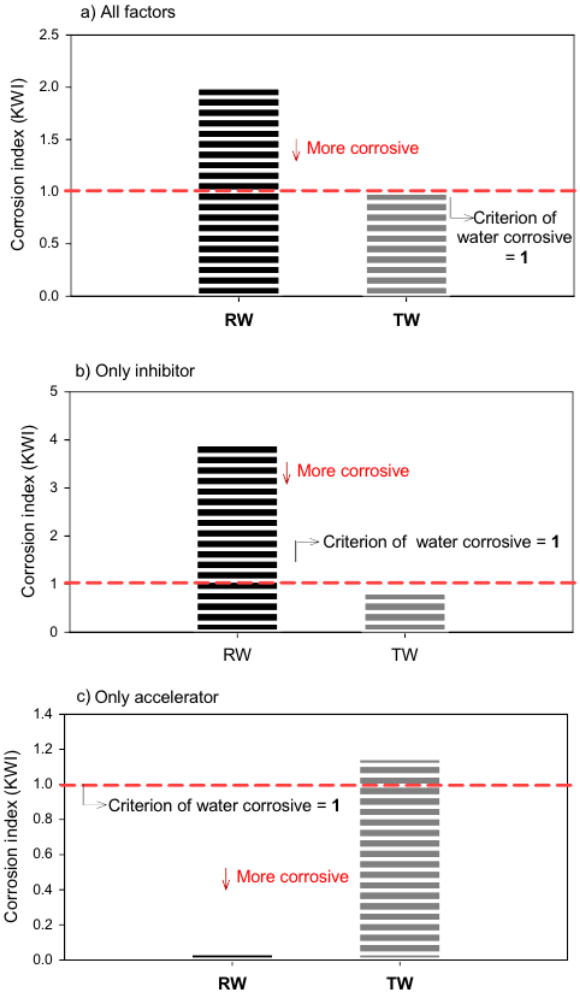

Fig. 1: Corrosiveness assessment of RW and TW using WKI

3.2. Development Korea Reclaimed Water Index (KRWI)

This study identified the corrosion inhibiting factors and corrosion accelerating factors that have impact on the corrosion of reclaimed water based on the water quality measurement results and statistically analyzed data. The most optimum water qualities obtained by statistical analysis of measurement results of effluents from nationwide sewage reutilization facilities are in Table 2.

Table 2: Effective factors of Controlling corrosion at RW

Inhibition factor	Value	Acceleration factor	Value
Cl^- , SO_4^{2-}	200~500	Alkalinity	350 [3]
Chlorine	0.2 [3]	NH_4^+	1.0
PO_4^{3-}	0.5	Hardness	650 [4]
TDS	500	pH	7.5 (5.8~8.5) [3]

※ all values in mg/L except pH

The corrosion inhibiting factors (pH, hardness, alkalinity degree) and the corrosion accelerating factors (TDS, chlorine ion, sulfate iron) suggested in Table 2 have direct impact on the reclaimed water. They are same with the factors applied on KWI. Other than these, it is possible to add ammonium ion, phosphate ion concentration of suspended heterotrophic bacteria and nitrification degree on the KRWI as the factors that are closely related to the reclaimed water corrosion through statistical analysis. Considering the characteristic of reclaimed water used in this study, if the impact of chlorine ion (500 mg/L basis) or sulfate ion (200 mg/L basis) would be big because of the incoming sea water, it is possible to calculate by adding them as the additional points in the KRWI calculation.

In this tests, the KRWI had been calculated by having;
1) pH, hardness and alkalinity degree as the corrosion inhibiting factors,
2) TDS, chlorine ion and sulfate ion as the corrosion accelerating factors
3) residual chlorine concentration, ammonium iron and phosphate iron as the additional factors. The result values are suggested in Table 3 and Fig. 3.

The most appropriate water quality values for reclaimed water and the water quality of reclaimed water used in the tests had been substituted in the equation.
The result was that all three models had corrosive water qualities. When all factors having impact on corrosion had been reflected, it was 0.77 in Fig. 3(a). When only corrosion accelerating factors had been considered, it was 0.61 in Fig. 3(c). When only corrosion inhibiting factors had been reflected, it was 0.89 in Fig. 3(b). Consequently, all three models were corrosive with values less than 1.
If the existing indices that had been made based on tab water, or, the most appropriate values for corrosion inhibition would be used on the reclaimed water, it is possible that the corrosiveness would be incorrectly expressed because they do not reflect the characteristics of reclaimed water and the offset effect between corrosion accelerating factors and corrosion inhibiting factors. Therefore, it can be said that expressing the index by substituting the values suggested in Table. 2 better expresses the water quality characteristics of reclaimed water.

Table 3: KRWI (RW) and KWI (TW) values

Classification	All Factor	Only Inhibitor	Only Accelerator
RW	0.77	0.61	0.89
TW	0.99	0.83	1.15

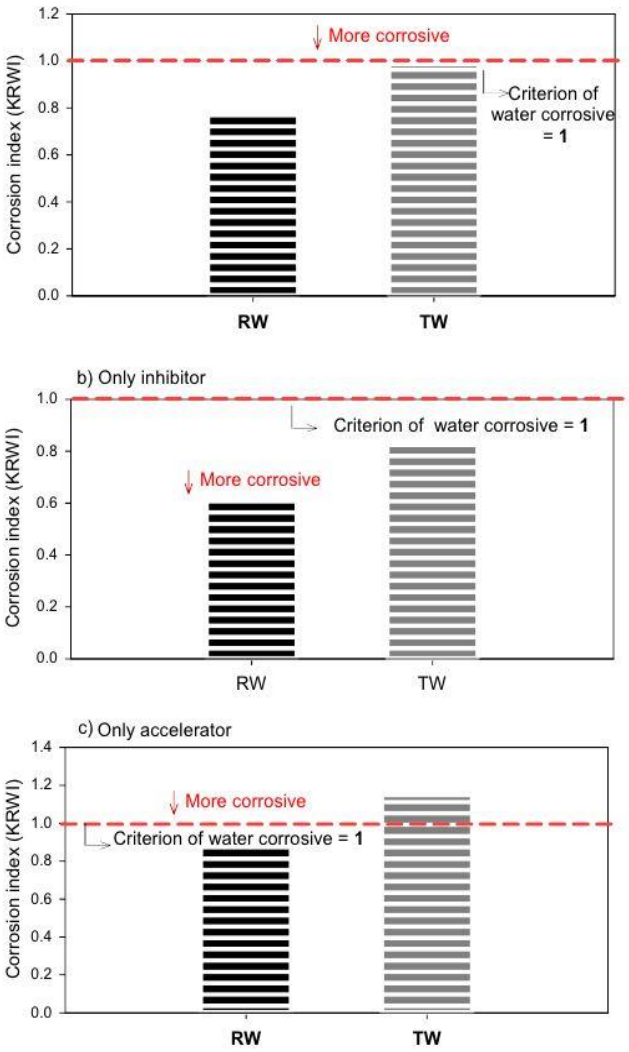

Fig. 2: KRWI values of RW and TW

4. Conclusion

Reclaimed water gets more impact from the corrosion accelerating factors than the corrosion inhibiting factors. Thus, Korea Reclaimed Water Index (KRWI), which is appropriate to the water quality characteristics of reclaimed water, had been developed and suggested. KRWI had been calculated by adding the residual chlorine, ammonium ion and phosphate ion to consider the characteristics of reclaimed water, in addition to the existing KWI factors. When the KRWI had been applied on the reclaimed water used in this test, all three models showed corrosiveness. When it would be assumed that all factors related to corrosion had been considered, it showed 0.77, which was lower by 0.22 than the tab water applied of KWI. It had been found that it better reflects the offset effect between corrosion accelerating factors and corrosion inhibiting factors than the case when KWI would be applied on reclaimed water.

Acknowledgement

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References

[1] H.D. Lee, U. Rasheed and M.S. Kong (2018), A study on the comparison of corrosion in water supply pipes due to tap water (TW) and reclaimed water (RW)", *Water*, Vol.10, No. 4, pp.496.
[2] Lee H., Bae C., Park J., Chung W. and Kwak, P. (2001), Evaluation of water quality characteristics effects on the internal corrosion of galvanized steel service pipe in the building", *Journal of Korean Society on Water Quality*, Vol.17, No.5, pp.627-635
[3] *A Guidebook for Reuse of Treated Wastewater*, The Ministry of Environment (2007)
[4] *Guideliness for water reuse*, U.S. Environmental protection policy (2014)