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RAW WATER QUALITY ANALYSIS TO DISCOVER THE CAUSE OF PIPELINE SCALLING PROBLEM IN PT. X (ICE PRODUCTION COMPANY)

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ABSTRACT

PT. X is one of the ice companies in which its largest company is located in Bali, more precisely in the Pidada area, North Denpasar. Based on field observations the area is an area that has a calcareous soil structure. The water source of PT. X was extracted from the groundwater. From the field observation, it was found that the pipeline network, that connected the inlet water to water treatment system and ice production units, was severely covered by faint white scale. In order to discover the origin of this scale, water quality testing need to be carried out. From the results, it was found that the total hardness in the inlet water, taken from the groundwater tap, was 162.85 mg/l with calcium concentration of 2.15 mg/l and iron 3.83 mg/l. Water quality testing was also carried out in the water treatment unit consisting of resin softener where the total hardness surprisingly increased into 279.81 mg/l, calcium concentration was 2.96 mg/l, iron concentration was 0.55 mg/l. Even after being treated in softener resin, the total hardness increased sharply to 483 mg/l, which categorized as extreme hardness. The increase in total hardness indicates that there was a failure in the operation of the water treatment system, even it also contributed to the higher hardness and calcium concentration. This over-year's treatment failure has been causing accumulation of hardness and calcium concentration in the compartment of both water treatment system and ice production unit that inflicts a higher hardness level in the effluent.

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1. INTRODUCTION

Groundwater plays a crucial role in the terrestrial hydrological cycle and in sustaining ecosystems, as it accounts for more than 30% of global freshwater resources (Frappart *et al.,* 2019). The natural hydrochemistry of groundwater is the result of processes such as the evapo-concentration of atmospheric salts supplied as marine aerosol, dust and salts dissolved in rainwater, the interaction of water with soil minerals and the incorporation of residual saline waters (Rivera-Rivera *et al.,* 2020). Declining water quality has become a global concern as anthropogenic activities expand, and climate change threatens to cause serious alterations to the water cycle (Abbott *et al.,* 2019). Water quality is generally related to several chemical and physical parameters (Da Cunha *et al.,* 2020). Water quality is indicated by various physical parameters such as pH, total solids, total suspended solids, alkalinity, free CO_2, dissolved oxygen, hardness, chlorine content and sodium content (Daghara, Al-Khatib, and Al-Jabari 2019). Hardness and pH are some of the parameters which are considered as the most important parameters in the context of chemical parameters (Devkota and Johnson, 2019). Hardness is generally related to the concentration of carbonate, sulfate, chloride and nitrate with various cations such as calcium and magnesium, which are generally present in the form of $CaCO_3$ (ppm) (Da Cunha *et al.,* 2020).

Calcium (Ca^{2+}) is generally the most abundant cation in uncontaminated groundwater systems, particularly those in contact with limestone, dolomite, gypsum or sandstrones (Rivera-Rivera *et al.,* 2020). An existence of the calcium, magnesium and carbonate ions on the earth layer influences the hydrochemistry of groundwater (Tirkey *et al.,* 2017). PT. X is located on Jalan Pidada, based on field observations, the area has a calcareous soil structure. Consequently, the concentration of these minerals will affect the condition of the groundwater quality around the area because the minerals in the soil will dissolve in the aquifer layer or groundwater layer. In general, groundwater quality can be affected by number of factors especially the general geology of the area and chemical weathering caused by the interaction between water and various rock thereabouts (Dhok, Patil, and Ghole, 2013). The source of water used to produce ice by PT. X is coming from groundwater in that area. Thus, the groundwater quality in this company might contain high minerals form the soil, which do not meet the water quality requirement for the ice production. Due to the presence of water hardness, PT. X need to remove the hardness by installing a water treatment in the form of an

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ion exchanger resin. Furthermore, PT. X also installed filters such as activated carbon and zeolite to reduce levels of other divalent minerals. Zeolite are considered to be one of the widely used natural inorganic soil conditioners to improve physical and chemical properties of soil especially cation exchange capacity (Nakhli *et al.,* 2017). According to Hailu in (Hailu *et al.,* 2019), zeolite is highly efficient for hardness removal and can be employed in the drinking water treatment plant.

The presence of calcium carbonate and calcium sulfate as a cause of scaling can also increase the corrosion rate for pipes made of aluminum and carbon steel (Osorio-Celestino *et al.,* 2020). Sediment or scale generally appears when the mineral concentration in a particular water source exceeds the mineral saturation level. This occurs due to changes in the physical components of water including pressure, temperature and pH. In addition, precipitation also occurs when the concentration of total dissolved solid (TDS) is low so that the solubility of carbonate decreases (Kiaei and Haghtalab 2014). Sher *et al.,* (2021) conducted a research about removal of micropollutants from municipal wastewater using various kind of activated carbon under the presence of water hardness condition. According to the research, there was no significant effect of water hardness was found in the formation of floc or settling performance as the concentration of Ca^{2+}/Mg^{2+} ions affects the sedimentation process only at the high level of hardness (Sher *et al.,* 2021).

Scaling phenomenon on the water distribution pipe at PT. X is a problem that has been occurred for 4 years since 2017, and so far, no research nor testing has been carried out regarding the quality conditions of the raw water sources used by PT. X, both by PT. X and the researchers. Indeed, PT. X had planted a water treatment system consisted of softener resin to remove total hardness and silica sand to remove Iron and Manganese ion. Nevertheless, the scaling problems keep happening even getting worsened over year. Therefore, this research was made to test the water quality to determine the level of hardness and calcium content in water at PT. X, both from influent water that was coming from groundwater and the effluent water from the water treatment system and the ice production system.

2. RESEARCH METHODOLOGY

2.1 Literature Studies

In this study, a literature study was conducted to obtain an overview of the area of PT. X and

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the workflow of the groundwater usage from water quality treatment facilities to ice production. In addition, studies were also conducted to obtain secondary data and references that can be used in the analysis process. This study emphasize on the effects of hardness parameters and metals that cause scaling on either pipe or channel, because the primary data showed a high hardness number from each sample points.

2.2 Sample Collection and Water Quality Testing

Sampling method referred to US EPA (EPA 2016) standards on Drinking Water Sampling Procedures. In this study the samples were taken at three sampling points. The water treatment and ice production workflow can be seen on Figure 1. Firstly, water was taken from the influent faucet when the water was first drawn before entering the water treatment unit which consists of softener resin and zeolite. Then the second sample is taken from the effluent channel of the water treatment unit before entering the ice production unit. This action was intended to determine the level of efficiency of the water treatment unit by looking at the difference between the concentration of pollutants entering and the concentration of pollutants leaving the water treatment unit. Then, the final sample was taken from the effluent of ice production unit where the residual water was disposed into the closest drainage system. This last sample was taken in addition to measure the amount of total hardness that was potentially disposed by PT. X to the nearest water body.

Testing the samples' water quality was carried out at the Analytical Laboratory, Udayana University. Several water quality parameters tested included pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Zinc (Zn), Iron (Fe), Manganese (Mn), Calcium (Ca), Hardness, and Total Dissolved Solids (TDS). The test was carried out based on the standard testing of Standard Methods for the Examination of Water and Wastewater (Jenkins, 1982).

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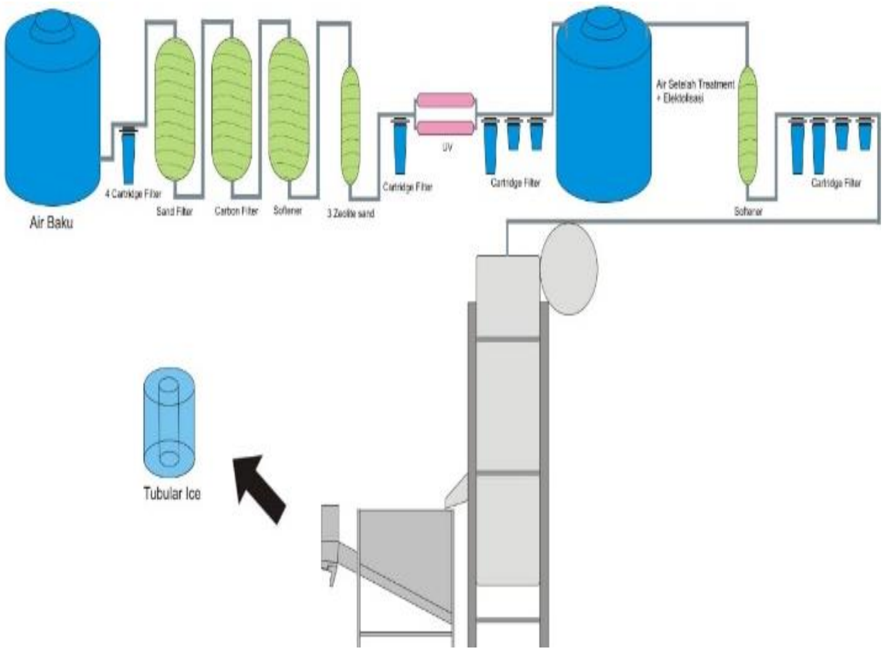

Figure 1 Water treatment and ice production workflow

2.3 Water Quality Data Analysis

Data processing was carried out by comparing the concentration of pollutants in the tested water with the drinking water quality standards stipulated in Government Regulation (PP) No. 82 of 2001 concerning Water Quality Management and Water Pollution Control with Class I standards and Law of the Minister of Health of the Republic of Indonesia No. 492 of 2010 concerning Requirements for Drinking Water Quality. Apart from using these rules, the hardness level will also be compared with the hardness classification shown in Table 1.

Table 1 Hardness classification

Water Hardness (mg/l)	Hardeness Levels
0 - 50	Soft
50 - 100	Moderately soft
100 - 150	Slightly hard
150 - 250	Moderately hard
250 - 350	Hard
>350	Extremely Hard

Source : Aksever, Karagüzel, and Mutlutürk 2015

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3. RESULT AND DISCUSSION

3.1 Inflow Water Quality Analysis

The influent channel mentioned in this research referred to a channel that drains water sources from groundwater before being used for ice production process. The results of influent water quality testing and comparison with the quality standards of water sources at PT. X can be seen in Table 2. From the table, it can be seen that there are several parameters that exceed the quality standard, such as zinc (Zn) and iron (Fe). The presence of these metals has been known since the initial field observation as the visuals of the water samples taken from the source were reddish in color and over time Fe deposits were formed in the form of solid reddish orange of $Fe(OH)_3$. Presence of iron in the water leads to unpleasant odor of the water and can cause health problems if consumed in a long time. Taste and any kind of odor in water is the result of ions and inorganic minerals salts like Mg, Na, Ca, K (Agrawal, Sharma, and Sharma 2020) and metals such as iron. In aqueous system, metals exist as hydrated ions resulting from the interaction of water molecules that bind to the metal ions via electrostatic ion-dipole bonds (Abdullah *et al.,* 2019). In Table 2, it can also be seen that the concentration of calcium (Ca) was detected up to 2.152 mg/l, this was also followed by the hardness concentration which reached 162.28 mg/l and the total dissolved solid (TDS) reached 250 mg/l. On the contrary, high concentrations of calcium (160 mg/L) could be the cause of death (Yadav, Raphi, and Jagadevan 2020). Water that contained total hardness greater than 300 mg/L could result in heart and kidney related disease (Udhayakumar *et al.,* 2016). In addition, calcium deposits in the form of lime can cause scaling of pipes which results in hydraulic, thermal and mechanical problems in pipelines (Hafid *et al.,* 2015).

Table 2 PT. X's influent water quality data

Parameters	Testing Results	PP 82/2001 Standard Quality	Units
pH	7.54	6-9	mg/l
Zinc (Zn)	0.074	0.05	mg/l
Iron (Fe)	3.834	0.3	mg/l
Mangan (Mn)	0.192	1	mg/l
Calcium (Ca)	2.152	-	mg/l
Hardness	162.85	-	mg/l
TDS	250	-	mg/l

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Furthermore, calcium deposits can also damage the processing compartment, both water quality treatment and ice production compartments. If the hardness level of the water sample was categorized using the water hardness classification as stated in Table 1, the hardness level of the influent water can be classified as moderately hard. This classification results substantiated that the water source that has been used by PT. X to generate ices contains a number of unwanted minerals such as Ca and Mg. Even though the number was not tremendously high, however in the long run, those minerals which precipitate quickly in pH and temperature changes, would accumulate in compartment over decades and consequently would induce further damages. The increase in the temperature or the solution pH leads to the acceleration of calcium carbonate nucleation and crystal growth (Korchef and Touaibi, 2020).

Generally, the raw water cannot be used directly because it probably does not meet the standard criteria of each water usage that has been stated in PP No. 82 of 2001 concerning Water Quality Management and Water Pollution Control. In PP No.82/2001, water quality standards are divided into several classes, namely class 1 for raw drinking water, class 2 for secondary needs including water recreation infrastructure/facilities, freshwater fish farming, livestock, water for planting. The next class, the class 3 is intended for the cultivation of freshwater fish, animal husbandry, agriculture and cropping. Class 4 water is only intended for watering plants.

Therefore, PT. X who has been engaged in the production of ice for consumption, the quality standard used to test water sources is Class 1 quality standards.

3.2 Water Treatment Plant Effluent Quality

The results of water treatment plant effluent quality testing and the comparison with the quality standards of the water source of PT. X can be seen in Table 3. Along with the spike of total hardness, the other parameter such as total dissolved solid (TDS) also experienced a significant increase in concentration. The increase in TDS indicate there is an accumulation of pollutants in the treatment unit system, which occur due to infrequent maintenance, backwash and the absence of periodic replacement for treatment unit compartments. The effluent water from the treatment unit was utilized as the water source for ice production, thereupon the water quality needs to meet the minimum requirements for consumption purposes. The

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standard that has to be used must be the drinking water standard written in the Minister of Health Regulation No. 492 of 2010 concerning Requirements for Drinking Water Quality.

The comparison between the water quality testing result with the effluent standard stated by Minister of Health Regulation No. 492 of 2010 is figured by Table 3. Compared to the Table 2, it can be seen that there was a decrease in the concentration of iron (Fe) even though it was still above the drinking water quality standard. The sloping concentration happened due to the presence of activated carbon and zeolite filters installed in the processing unit whose performance was able to remove iron by 85.7%. The concentration of calcium (Ca) in water increased by 37% from 2.152 mg/l at the influent to 2.966 mg/l at the effluent point. This indicates the failure of the water treatment system to perform a proper pollutant removal especially for the softener resin. This spiking total hardness concentration has been presumably induced by the accumulation of Ca concentration and other divalent ions in the water treatment unit which precipitated in the unit system so that when water was discharged, the debris of solid Ca and the other metal ions would be carried along with the water flow.

Table 3 PT. X's Water Treatment Unit Effluent Quality

Parameters	Testing Results	Ministry of Health 492/2010 Quality Standard	Units
pH	7.6	6.5 - 8.5	mg/l
Zinc (Zn)	0.042	3	mg/l
Iron (Fe)	0.55	0.3	mg/l
Mangan (Mn)	-	0.4	mg/l
Calcium (Ca)	2.966	-	mg/l
Hardness	279.81	500	mg/l
TDS	370	500	mg/l

The increasing concentration of total hardness and calcium concentration from influent to water treatment system effluent substantiated that the failure of water softener resin has been happening for years and no maintenance action has been taken yet from the company. Fundamentally, hardness-causing-ions such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions can be removed by replacing those hardness ions with a non-hardness ion such as sodium (Na^{+}) in form of sodium chloride salt called brine, which attached to exchange medium. As hard water passes the softener resin, the calcium and magnesium will easily generate bonds to the exchange

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medium and the sodium ions are released into the water (Scherer, 2017). The hardness level will increase when more calcium and magnesium dissolves in the water (Scherer, 2017). In the case of PT. X, since the total hardness and calcium concentration increase significantly after leaving the softener unit, there is an indication that PT. X has never been performed a backwash to cleanse the exchange medium from fouling and routinely refilled the brine in order to keep the resin work properly. Consequently, when the hard water passes the softener resin, there is no ion exchange performed as the brine were no longer available. Yet, the calcium and magnesium ions that were previously attached in the exchange medium would be redissolved into the water flow. This phenomenon is called resuspension.

3.3 Final Effluent Channel Quality

The final effluent channel water sample test results are shown in Table 4. In Table 4, it can be seen that the hardness concentration of the ice production unit effluent of PT. X reached 483 mg/l with calcium (Ca) levels of 4.3 mg/l. With a hardness concentration above 350 mg/l, the effluent water condition from the production unit is categorized as extremely hard. This is what causes massive scaling on the final disposal channel of PT. X. The form of this compound does have a tendency to precipitate more easily than dissolved in water, especially calcium carbonate which has a greater tendency to settle every time the temperature is increasing (Ahn *et al.,* 2018). In addition to temperature, pH also greatly affects the deposition of the substances that cause hardness. According to the equation of - log $[H^+]$ = pH, consequently the escalating pH will reduce H^+ concentration in water and trigger more CO_3^{2-} to emerge and then establish bonds with metal ions such as Ca^{2+} and Mg^{2+}. Therefore, it can be concluded that the higher the pH, the tendency for Ca to precipitate will increase. According to the results of the final effluent water test in Table 4, it can be seen that the water has a pH of 8, which in this condition, the tendency for Ca and Mg to be deposited is very high so it is not surprising if there is scaling in the drain pipes and drainage channels of PT. X. The concentration of Ca, hardness and TDS in the final effluent of production unit were higher than its influent as seen in Figure 2, Figure 3 and Figure 4.

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Table 4 PT. X's final effluent quality data

Parameter	Results	Ministry of Health 492/2010 Quality Standard	Units
pH	8.04	6.5 - 8.5	mg/L
Zinc		3	mg/L
Iron	0.104	0.3	mg/L
Mangan		0.4	mg/L
Calcium	4.334	-	mg/L
Hardness	483.67	500	mg/L
TDS	1320	500	mg/L

This phenomenon indicated that there was an accumulation of pollutants in the compartments of ice production machine of PT. X which was settled due to the large number of incoming pollutants that the water treatment system was failed to comply with, consequently the water used in the production unit still carries these pollutants. Furthermore, PT. X discharges its residual water to nearest drainage channel which will leads the water into the downstream water body. With the total hardness level of 483 mg/l, it could potentially harm the aquatic ecosystem of the water body. The average total hardness in freshwater that was considered safe was 97.27 ± 9.58 mg/l maximum (Bhutiani *et al.,* 2016).

3.4 Overall Trends of Hardness-Related Parameters

From the Figure 2, it can be seen that there is a significant spike in calcium concentration, from 2.15 mg/L by influent channel rose into 4.3 mg/L by the final effluent channel. From the influent channel into softener resin effluent, there was an increasing calcium concentration for up to 38%. The same chart pattern was also showed by hardness concentration which rose from 162 mg/L categorized into modest hardness into 483,67 mg/L which was categorized as extreme hardness. Overall, there was a total increase of 101.4%, increase in Calcium (Ca) concentration; 197% in hardness and 428% in total dissolved solids (TDS). It can be concluded that there is a failure in the water treatment unit, especially in softener resins due to the high levels of Ca concentration, total hardness, and TDS at the end of both water treatment and production processes. It signified that there is a potential resuspension occurred in the softener resin due to lack of maintenance performed by the company, as discussed in the previous chapter (chapter 3.2).

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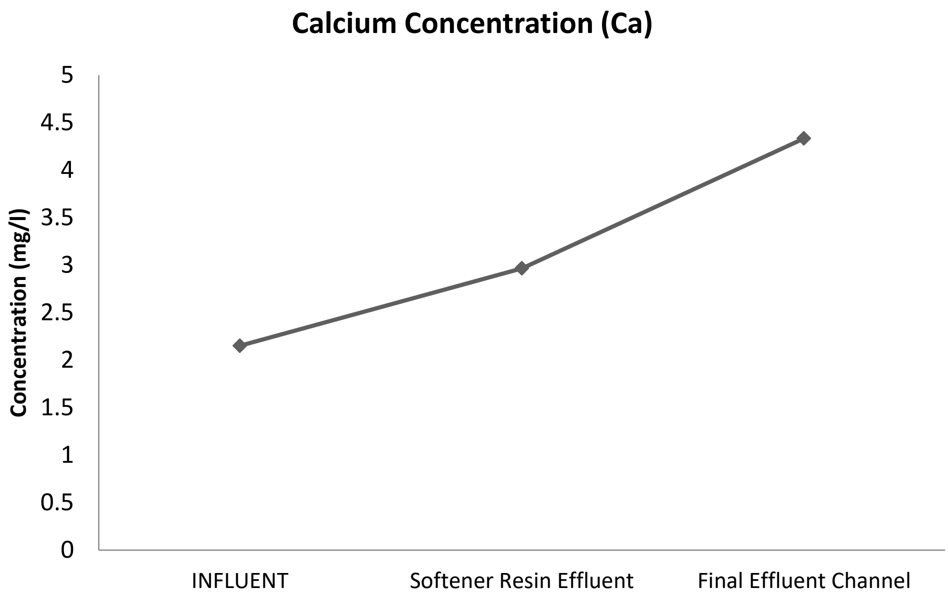

Figure 2 Calcium concentration changes in every sampling point

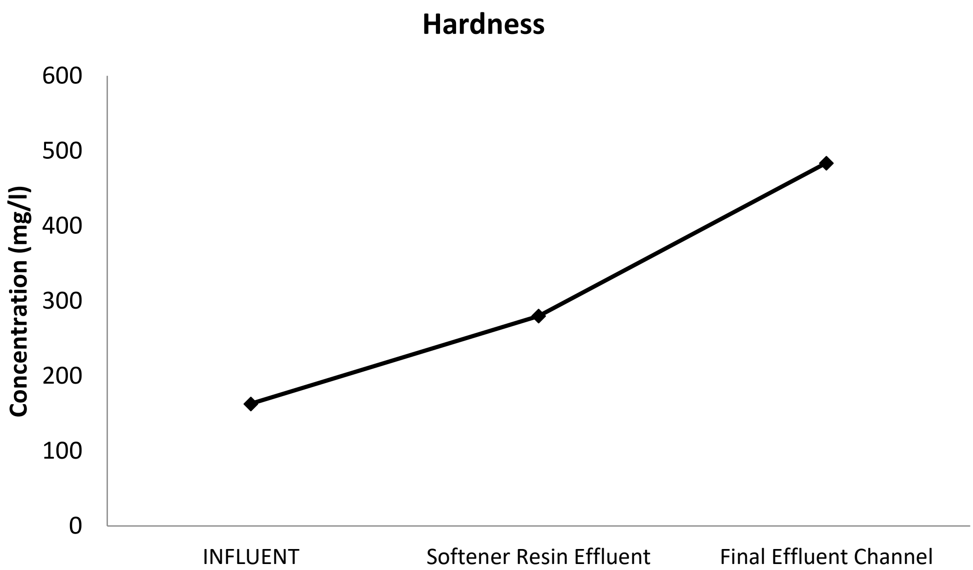

Figure 3 Hardness concentration changes in every sampling point

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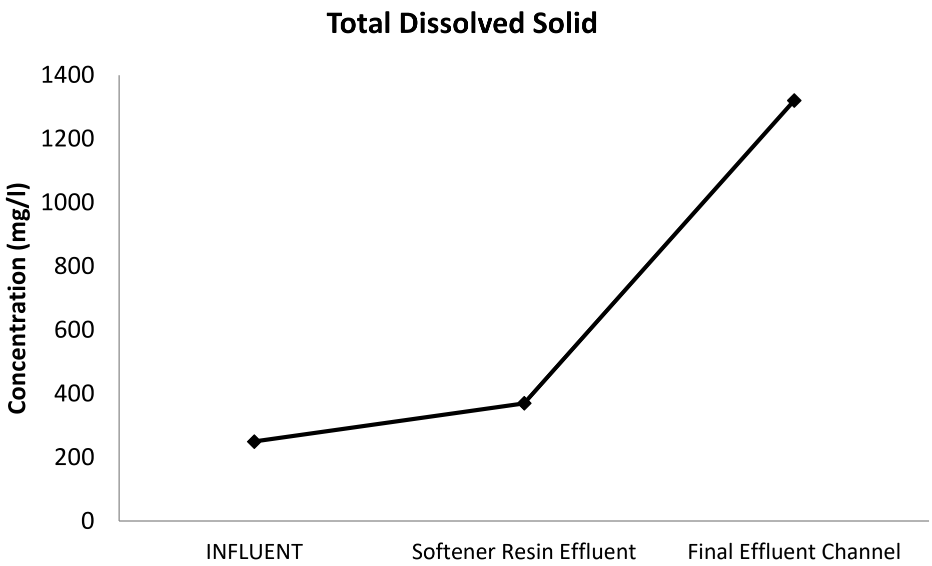

Figure 4 TDS concentration changes in every sampling point

Calcium and other divalent ions that causes hardness, form a precipitate crust to the walls of the production unit, accumulate on pipes, or settle in some corners of the production compartment. If this continues, the pollutants can cause further damage to the production unit compartment and a decrease in the quality of production and water quality of PT. X.

4. CONCLUSION

From the explanation of the analysis, based on primary data from water quality analysis, the hardness concentration in the water source/influent was 162.85 m/l with a calcium concentration of 2.15 mg/l, Manganese 0.19 mg/l, zinc 0.074 mg/l and iron of 3.83 mg/l categorized as modest hardness. From the softener resin effluent hardness concentration was 279.81 mg/l, calcium concentration was 2.96 mg/l, Iron concentration was 0.55 mg/l categorized as Quite Hard. The hardness concentration has increased drastically in the final effluent disposal into 483 mg/l, calcium concentration becomes 4.3 mg/l and iron concentration becomes 0.1 mg/l classified as extreme hardness. This research substantiated that the problem of scaling in the water disposal pipe produced by PT. X was caused by a high level of hardness and categorized as the extremely hard classification. There is an indication that the lack of maintenance in water treatment unit especially in water softener resin leads to resuspension of

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calcium and magnesium ions into the hard water. Hence, it inflicts to the increase of the total hardness, calcium concentration and total dissolved solid concentration in the effluent water.

REFERENCES

Abbott, Benjamin W *et al.,* 2019. Human Domination of the Global Water Cycle Absent from Depictions and Perceptions. Nature Geoscience.

Abdullah, N *et al.,* 2019. Recent Trends of Heavy Metal Removal from Water/Wastewater by Membrane Technologies. *Journal of Industrial and Engineering Chemistry*. 76: 17-38.

Agrawal, Anshul, Neha Sharma, and Prashant Sharma. 2020. Designing an Economical Slow Sand Filter for Households to Improve Water Quality Parameters. Materials Today: Proceedings.

Ahn, Min Kyung, Ramakrishna Chilakala, Choon Han, and Thriveni Thenepalli. 2018. Removal of Hardness Fromwater Samples by a Carbonation Process with a Closed Pressure Reactor. Water (Switzerland).

Aksever, Fatma, Remzi Karagüzel, and Mahmut Mutlutürk. 2015. Evaluation of Groundwater Quality and Contamination in Drinking Water Basins: A Case Study of the Senirkent-Uluborlu Basin (Isparta-Turkey). *Environmental Earth Sciences.*

Bhutiani, R., D., R., Khanna, Dipali Bhaskar Kulkarni, and Mukesh Ruhela. 2016. Assessment of Ganga River Ecosystem at Haridwar, Uttarakhand, India with Reference to Water Quality Indices. *Applied Water Science.*

Da Cunha, João P., A., R. *et al.,* 2020. Water Hardness and PH in the Effectiveness of Glyphosate Formulations. Engenharia Agricola.

Daghara, Azza, Issam A. Al-Khatib, and Maher Al-Jabari. 2019. Quality of Drinking Water from Springs in Palestine: West Bank as a Case Study. *Journal of Environmental and Public Health.*

Devkota, Pratap, and William G. Johnson. 2019. Influence of Carrier Water PH, Foliar Fertilizer, and Ammonium Sulfate on 2,4-D and 2,4-D plus Glyphosate Efficacy. Weed Technology.

Dhok, R., P., A., S., Patil, and V., S., Ghole. 2013. Hardness of Groundwater Resources and Its Suitability for Drinking Purpose. *International Journal of Pharmaceutical and Chemical Sciences*. 2(1): 169-72.

EPA, US. 2016. Quick Guide to Drinking Water Sample Collection. 2nd Ed. United States Environmental Protection Agency.

Frappart, F *et al.,* 2019. The Spatio-Temporal Variability of Groundwater Storage in the Amazon River Basin. Advances in Water Resources.

Hafid, Naima *et al.,* 2015. Characterization of Scale Formed in Drinking Water and Hot Water Pipes in the Taliouine Downtown-Morocco. *American Journal of Analytical Chemistry.*

p-ISSN 2579-9150; e-ISSN 2579-9207, Volume 5, Number 1, page 72 - 85, October 2021
Accredited SINTA 2 by Ministry of Research, Technology, and Higher Education of The Republic of Indonesia No. 23/E/KPT/2019 on August 8th, 2019 from October 1st, 2018 to September 30th, 2023

Hailu, Yonatan *et al.,* 2019. Ion Exchanges Process for Calcium, Magnesium and Total Hardness from Ground Water with Natural Zeolite. *Groundwater for Sustainable Development.*

Jenkins, S., H. 1982. Standard Methods for the Examination of Water and Wastewater. *Water Research.*

Kiaei, Zahra, and Ali Haghtalab. 2014. Experimental Study of Using Ca-DTPMP Nanoparticles in Inhibition of $CaCO^3$ Scaling in a Bulk Water Process. Desalination.

Korchef, Atef, and Meriam Touaibi. 2020. Effect of PH and Temperature on Calcium Carbonate Precipitation by CO2 Removal from Iron-Rich Water. *Water and Environment Journal.*

Nakhli, Seyyed Ali Akbar, Madjid Delkash, Babak Ebrazi Bakhshayesh, and Hossein Kazemian. 2017. Application of Zeolites for Sustainable Agriculture: A Review on Water and Nutrient Retention. *Water, Air, and Soil Pollution.*

Osorio-Celestino, Gandhi R *et al.,* 2020. Influence of Calcium Scaling on Corrosion Behavior of Steel and Aluminum Alloys. ACS Omega.

Rashid, Abdur *et al.,* 2019. Geochemical Profile and Source Identification of Surface and Groundwater Pollution of District Chitral, Northern Pakistan. *Microchemical Journal.*

Rivera-Rivera, D., M *et al.,* 2020. Identifying Key Factors of Groundwater Chemistry in Three Diverse Landscapes of Central Mexico. *Acta Ecologica Sinica.*

Scherer, Tom. 2017. Water Softening (Ion Exchange). NDSU Exention Service.

Sher, Farooq *et al.,* 2021. Removal of Micropollutants from Municipal Wastewater Using Different Types of Activated Carbons. *Journal of Environmental Management.*

Tirkey, Poonam, Tanushree Bhattacharya, Sukalyan Chakraborty, and Suman Baraik. 2017. Assessment of Groundwater Quality and Associated Health Risks: A Case Study of Ranchi City, Jharkhand, India. *Groundwater for Sustainable Development.*

Udhayakumar, R., P., Manivannan, K., Raghu, and S., Vaideki. 2016. Assessment of Physico-Chemical Characteristics of Water in Tamilnadu. *Ecotoxicology and Environmental Safety.*

Yadav, Krishna, Mohd Raphi, and Sheeja Jagadevan. 2020. Geochemical Appraisal of Fluoride Contaminated Groundwater in the Vicinity of a Coal Mining Region: Spatial Variability and Health Risk Assessment. *Chemie der Erde.*