Chemical Characteristics of Irrigation Water and its Suitability for Soil and Agricultural Crops in Singosari District, Malang Regency, East Java, Indonesia

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ABSTRACT

The irrigation water should be available not only in adequate quantity but also of good quality. The quality of irrigation water is as important as soil fertility. The aim of this research is to characterize irrigation water based on chemical aspects and its suitability for soil and agricultural crops. Water chemical characterization was carried out using the Piper Trilinear Diagram model. Assessment of the suitability of irrigation water use for soil and crops is carried out using the Irrigation Water Quality Index model. The chemical characteristics of irrigation water at the research location are that it has a soil alkali content exceeding the alkali content, a weak acid content exceeding the strong acid content, and a carbonate hardness of more than 50%. The irrigation water quality index value is in the range of 70–85 with a low water use restriction category. Irrigation water in this category can be used on soil with a light texture/medium permeability and should be avoided on crops that are sensitive to salt.

Keywords: *chemical characteristics, crop, irrigation, soil, water quality.*

INTRODUCTION

Malang Regency has an area of 3,530.65 km^2, of which 3.98% of the total area is agricultural land. Agricultural land in Malang Regency covers 45,851 ha of rice fields, 100,691 ha of dry fields/gardens, and 26,534 ha of plantation areas. The agricultural sector is a mainstay sector in the economy of Malang Regency. To support agricultural efforts, a number of irrigation network facilities have been built to meet the irrigation needs of 45,851 ha of rice fields. Most of the irrigation network is technical irrigation that irrigates 28,393 ha (61.10%) of rice fields, while for semi-technical irrigation 11,593 ha (24.94%) and simple irrigation 6,479 ha (13.94%) (BPS-Statistics of Malang Regency, 2021[a]).

Singosari District is one of the districts in Malang Regency. Astronomically, Singosari District is located between 112.3795° to 112.4416° E and 7.5472° to 7.5162° S. The area of Singosari District is 113.74 km^2 (11,374 ha) or around 3.98% of the total area of Malang Regency (BPS-Statistics of Malang Regency, 2021[b]). The area of rice fields in Singosari District is 1,322 ha, where based on the type of irrigation, all of the rice fields are irrigated rice fields. The harvested area of rice fields in 2020 reached 3,598 ha with production reaching 25,596 tons (BPS-Statistics of Malang Regency, 2021[a]). Seasonal vegetables and fruits cultivated locally include shallots, garlic, scallion, cabbage, mustard green, long beans, chayote, chili, pepper, tomato, eggplant, string bean, cucumber, water spinach, spinach, dan cauliflower (BPS-Statistics of Malang Regency, 2021[b]). Based on the irrigation operation scheme map in the Singosari area made by the Malang Regency Water Resources Public Works Service, in the Singosari District area there are at least 10 weir buildings used to meet irrigation water needs.

The Irrigation water obtained from the dam intake should be available not only in adequate quantity but also in good quality. The quality of irrigation water is as important as soil fertility (Singh & Khare, 2008). Water quality can be assessed based on its chemical characteristics. The presence of dominant ions, both cations and anions dissolved in water, determines the chemical type of the water (Srinivas *et al*., 2014). The suitability of water quality for irrigation can be determined based on the level of salinity hazard, the level of alkalinity hazard, and the level of toxicity hazard (Khan *et al*., 2014). Considering the important role of irrigation water as one of the determining factors for the success of farming efforts in order to support food security, it is necessary to conduct a study on the chemical characteristics of irrigation water and the suitability of its quality to agricultural land (soil and crops).

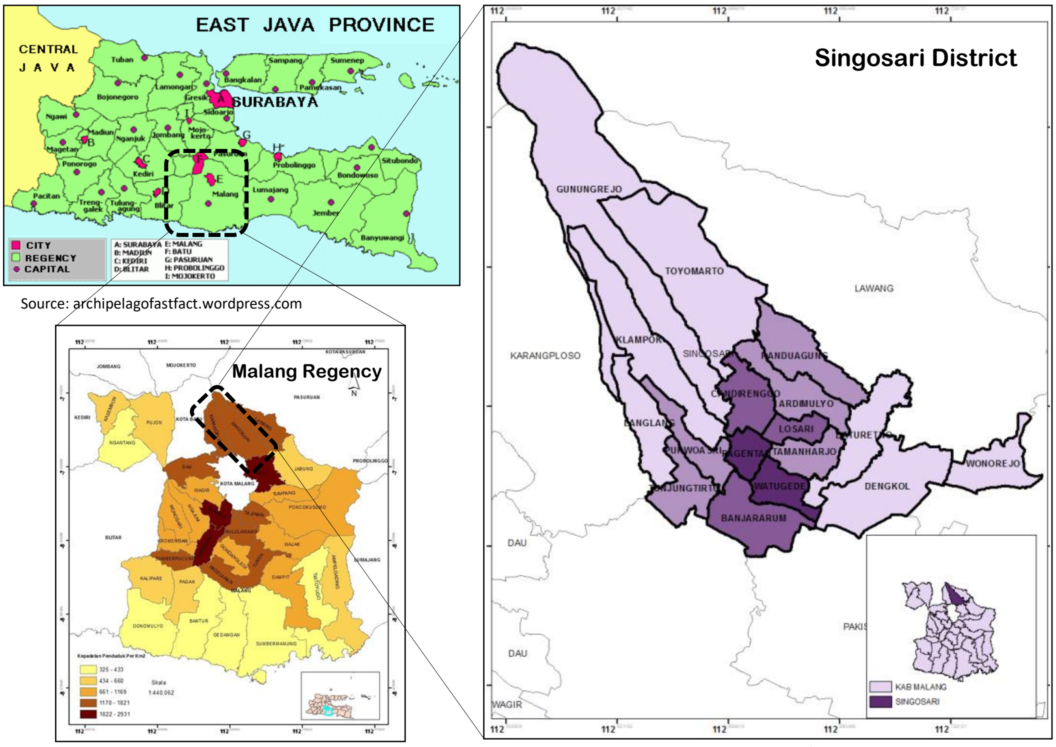
Determination of the chemical characteristics of water can be done using the Piper Trilinear Diagram Model (Piper, 1944) with the aim of identifying the dominant cation and anion types, the dominance of alkali or alkaline earth, the dominance of strong or weak acids, and the carbonate or non-carbonate hardness contained in the water. Assessment of the suitability between irrigation water quality and agricultural land (soil and crops) can be done using the Irrigation Water Quality Index (IWQI) model. The IWQI model was proposed by Meireles *et al*. (2010) based on physico-chemical parameters including: Electrical Conductivity (EC), Sodium ion concentration (Na^+), Chloride ion concentration (Cl^-), Bicarbonate ion concentration (HCO_3^-), and adjusted Sodium absorption ratio (SAR_{adj}) in irrigation water. The IWQI value reflects the danger of salinity and alkalinity of irrigation water to the soil, as well as the danger of toxicity to crops. The index value is a representation of the level of suitability of irrigation water quality to soil and crops. The IWQI model has been used in a number of studies in several countries to determine irrigation water quality index values (Khalaf & Hassan, 2013; Al-Mussawi, 2014; Omran *et al*., 2014; Siswoyo *et al*., 2016; Abdulhady *et al*., 2018; Siswoyo *et al*., 2020[a]; Siswoyo *et al*., 2020[b]; Siswoyo & Kurniawan, 2021).

The purpose of this study was to hydrochemically characterize the water from the weir intake used as a source of irrigation water and its suitability for agricultural land (soil and crops). The targeted innovation in order to support development in the agricultural sector, especially to realize food security, is to obtain a model to determine the type of high economic value agricultural crops that can be cultivated on agricultural land based on the quality of water used as a source of irrigation water. The results of this modeling are expected to be used as a reference or guideline for farmers to determine the types of crops with high economic value that can be cultivated on their agricultural land.

MATERIAL AND METHODS

This research was conducted in the Singosari District, Malang Regency, East Java Province. The sample of this research was water from the weir intake which is used as a source of irrigation water in the

Singosari District. This research was conducted for a period of 5 months, starting from April to September 2022. Water sample testing was carried out at the Environmental Laboratory of Perum Jasa Tirta 1. The study area map is shown in Figure 1, while the description of the research sample is shown in Table 1.



Source: archipelagofastfact.wordpress.com

Source: BPS-Statistics of Malang Regency (2021[a])

Source: BPS-Statistics of Malang Regency (2021[b])

Fig. 1. Map of the study area.

Table 1. Description of the research samples

Weir name	Latitude, longitude, and altitute	Sample ID
Mondoroko weir	7°54’37.48” S, 112°39’51.05” E, +463 m a.s.l.	AP-01
Damean weir	7°53’47.62” S, 112°40’46.24” E, +497 m a.s.l.	AP-02
Gondorejo weir	7°53’52.15” S, 112°40’58.37” E, +488 m a.s.l.	AP-03
Dengkol weir	7°54’00.65” S, 112°42’05.80” E, +499 m a.s.l.	AP-04
Klampok III weir	7°53’24.65” S, 112°39’24.77” E, +493 m a.s.l.	AP-05
Pasrepan I weir	7°53’25.15” S, 112°38’31.45” E, +518 m a.s.l.	AP-06
Tunjungtirto weir	7°53’37.93” S, 112°38’39.34” E, +491 m a.s.l.	AP-07
Kendedes weir	7°52’58.98” S, 112°39’37.37” E, +515 m a.s.l.	AP-08

The equipment used in this study includes: GPS to obtain the coordinates of the location and elevation of water sampling, thermometer (Digital Thermometer TP 3001) to measure water temperature, pH meter (Pen type pH-02) to measure water pH, conductivity meter (µSiemen digital conductivity tester) to measure EC, 1 liter polyethylene bottle used as a container for water samples, styrofoam box for sample bottles. The materials used in this study were water samples taken from the weir intake used as a source of irrigation water at the research location. The number of water samples studied was 8 samples taken during the dry season.

Water sampling was carried out using a container in the form of a bottle made of polyethylene plastic. Preservation of water samples was carried out physically by cooling the water sample at a temperature of 4˚C ± 2˚C (National Standardization Agency, 2008). The parameters observed in this study include temperature, pH, EC, and the content of dissolved ions in water samples (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}). Parameters that are easily changed in value such as temperature, pH, and EC are measured directly in the field. Analysis of the content of dissolved ions in water samples was carried out at the Environmental Laboratory of Perusahaan Umum Jasa Tirta 1.

Analysis of the chemical characteristics of water was carried out using the Piper Trilinear Diagram Model (Piper, 1944) based on input values including the concentration of dissolved cations in water (Na^+, K^+, Mg^{2+}, Ca^{2+}), the concentration of dissolved anions in water (HCO_3^-, CO_3^{2-}, SO_4^{2-}, Cl^-), and total dissolved solids (TDS). The concentration of CO_3^{2-} anions was calculated based on the value of HCO_3^- concentration and pH value measured according to the theory of CO_2–HCO_3^-–CO_3^{2-} species distribution in water (Manahan, 1994). The TDS value was calculated based on the equation of the relationship between TDS and EC (Hanson, 2006). The completion of the analysis of water chemical characteristics using the Piper Trilinear Diagram Model was carried out with the help of the GW_Chart computer program version 1.30.0.0 (Winston, 2000; Winston, 2020). Analysis of the water quality index for irrigation was carried out using the IWQI Model (Meireles *et al*., 2010).

RESULTS AND DISCUSSION

Water samples were taken from 8 locations of weir intakes located in Singosari District, Malang Regency. The results of field measurements and laboratory tests on water samples taken from weir intakes are shown in Table 2. The chemical characteristics of water from weir intakes were determined using the Piper Trilinear Diagram Model as shown in Figure 2.

Table 2. Physico-chemical characteristics of water samples from the weir intakes

Sample ID	pH	EC (µS/cm)	t (°C)	Concentration of ions (mg/L)						
				Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-	SO_4^{2-}	Cl^-
AP-01	7.8	333.3	23.5	1.14	2.54	2.99	27.57	215.10	15.06	15.30
AP-02	7.6	385.3	22.7	3.44	2.52	2.52	27.00	197.50	16.48	40.90
AP-03	7.5	424.3	22.7	3.87	2.78	2.97	28.90	207.90	17.59	55.20
AP-04	7.5	258.3	24.0	< 0.0053	3.72	0.89	16.17	185.70	9.11	16.80
AP-05	7.5	299.0	24.1	< 0.0053	1.95	1.57	24.53	220.20	7.41	14.30
AP-06	7.8	305.3	23.8	< 0.0053	1.12	1.16	23.25	258.40	11.60	12.80
AP-07	7.7	298.7	24.1	< 0.0053	1.50	1.27	20.90	219.70	12.52	11.30
AP-08	6.8	314.3	26.1	< 0.0053	1.62	0.19	21.40	184.10	5.21	13.80

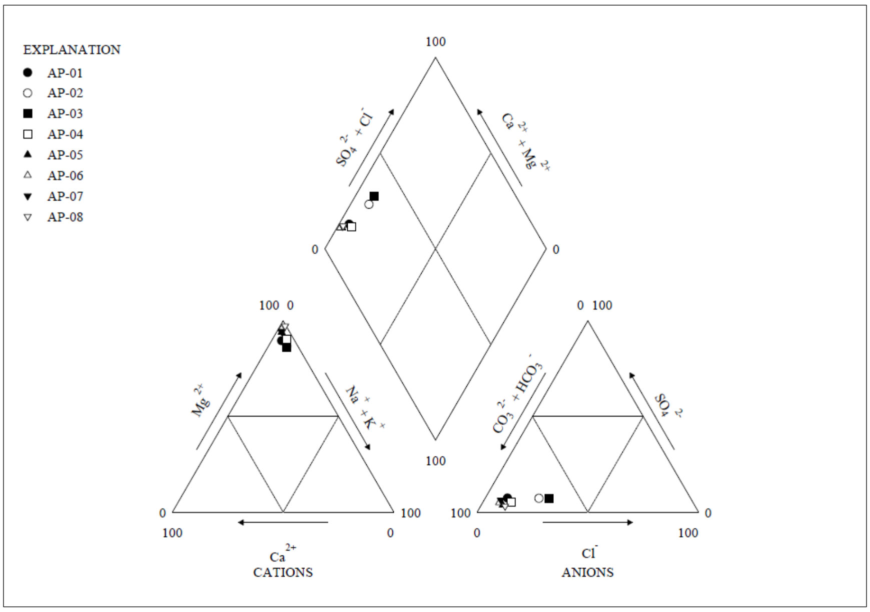


Fig. 2. Piper Trilinear Diagram of water samples from the weir intakes

Based on the modeling results using the Piper Trilinear Diagram Model, it can be stated that the chemical characteristics of water in the study area are that it has an alkaline earth content exceeding its alkali content, a weak acid content exceeding its strong acid, and carbonate hardness (secondary alkalinity) of more than 50%, the chemical properties of water are dominated by alkaline earth and weak acids. The dominant cation type is the Magnesium type, while the dominant anion type is the Bicarbonate type. Irrigation water in the study area is generally water with the chemical type Mg^{2+}–HCO_3^-.

The results of the IWQI value calculation are shown in Table 3. Based on the calculation results using the irrigation water quality index model, it can be shown that the irrigation water quality index value at all water sampling locations is in the range of 70 – 85. Irrigation water with an index value in this range is in the category of irrigation water with low usage restriction. Water for irrigation in this category can be used on soil with light texture / medium permeability and its use should be avoided on crops that are sensitive to salt (Meireles *et al*., 2010).

Table 3. IWQI value calculation results

Sample ID	IWQI	Water use restriction
AP-01	79.00	Low restriction
AP-02	78.22	Low restriction
AP-03	77.34	Low restriction
AP-04	80.43	Low restriction
AP-05	79.30	Low restriction
AP-06	78.24	Low restriction
AP-07	79.37	Low restriction
AP-08	80.21	Low restriction

The crops that are suitable for cultivation on agricultural land in the study area are crops that are moderately sensitive, moderately tolerant, and tolerant to salt (Ayers & Westcot, 1994). The crop categories moderately sensitive, moderately tolerant, and tolerant to salt (Ayers & Westcot, 1994) which can be adapted to rice crops and non-rice agricultural crops with high economic value (Haryono *et al*., 2009), and has been commonly cultivated in the Singosari District, Malang Regency (BPS-Statistics of Malang Regency, 2021[a]), such as: paddy *(Oryza sativa)*, corn *(Zea mays)*, peanuts *(Arachis hypogaea)*, sweet potatoes *(Ipomoea batatas)*, tomatoes *(Lycopersicon lycopersicum)*, eggplant *(Solanum melongena)*, cabbage *(Brassica oleraceae* var *capitata)*, and sugar cane *(Saccharum officinarum)*.

CONCLUSION

The irrigation water in the study area is generally water with the chemical type Mg^{2+}–HCO_3^-. Irrigation water in the study area can be used on soil with light texture/moderate permeability and its use should be avoided on plants that are sensitive to salt. Types of agricultural crops that can be cultivated in the study area according to the quality of irrigation water include: paddy *(Oryza sativa)*, corn *(Zea mays)*, peanuts *(Arachis hypogaea)*, sweet potatoes *(Ipomoea batatas)*, tomatoes *(Lycopersicon lycopersicum)*, eggplant *(Solanum melongena)*, cabbage *(Brassica oleraceae* var *capitata)*, and sugar cane *(Saccharum officinarum)*.

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