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# THE CAPABILITY OF TULIS RIVER TO RECEIVE LIQUID WASTE FROM PRODUCTION TEST OF GEOTHERMAL WELLS AND RELATIONSHIP BY IRRIGATION IN DIENG CENTRAL JAWA

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**Key Words :** Liquid Waste, Geothermal, Treatment Plant, Boron.

## ABSTRACT

The research on Tulis River water mainly known to serve irrigational purposes is set to examine the quality and quantity as well as the capability to receive liquid waste from production test of geothermal wells.

The physical and chemical properties of the Tulis River water and the liquid waste were analyzed. The capability of the Tulis River to receive the liquid waste was determined by using the mass balance equation to each parameter that represents water quality standards, extending up to a maximum sustainable limit level at which the liquid can hold. The quality parameter to be analyzed were total dissolved solids (TDS), conductivity, Sodium Absorption Ratio (SAR), Chloride (Cl), Sulphate (SO4) and Boron (B). By using simulation and regression method the maximum discharge of the save liquid waste of each parameter to be flowed to the Tulis River can be determined.

The results of this research showed the quality of the liquid waste of the production test geothermal wells that directly or after treatment plant flow to the Tulis River belongs to group IV of liquid waste. During the dry season the Tulis River water at the upstream of the production test geothermal wells contained 1,5 mg/l higher Boron than the maximum Boron content level limit of the irrigation water / group D (Boron 1 mg/l). In the rainy season, the quality of the Tulis River water – seemed to be suitable for irrigation water. Boron material had been found to originate from young volcanoes activity, which eventually produced Borate acid. The quantity of Boron is the main limitation for the discharge of the liquid waste permitted to flow to the Tulis River. The discharge capability of the Tulis River to receive liquid waste is 0,067 up to 0,90 liters / minute during dry season and 33,5 up to 62,5 liters / minute during rainy season.

## 1. INTRODUCTION

Major use of geothermal resources is to generate electricity, while other alternatives such as room heating, agriculture, horticulture, and industrial processes.

Geothermal resources, which can be classified as a natural heat resource, take source beneath the earth. The process that generates geothermal resource involves the interaction between hot rock and ground water. The pre-heated solution is then trapped in reservoir rocks, which lies near the surface, so in this case the solution would have an economic value if produced further.

Geothermal system can be classified into 4 types based on its heat source, that is : hydrothermal system, hot-dry rock system, earth pressure system and magmatic system.

The most economic of them to be developed for energy source is hydrothermal system. In the hydrothermal system, its water comes from meteoric water (water existing atmospheric environment, entering into the earth to follow hydrologic cycle.

Geothermal energy manifestation in Indonesia shows to form a volcanic series extending from Sumatra, Java, Nusa Tenggara, Sulawesi, Halmahera, and part of Irian Jaya island. The earth heat fields in Java island is located in G. Salak, Patuha, Wayang Windu, Darajat, Karaha, Kamojang, Dieng, and Wilis. Dieng geothermal field is an area that is being operated individually by Pertamina. Geographically, Dieng geothermal field, which will be developed in high plain of Dieng of Central Java, in height of 2000 m – 2400 m on sea level and about 180 km western-east of Semarang city.

Currently there are 25 productive wells that has been drilled in search of steam energy in prospect areas around Sikidang-Sikunang, which eventually supplies heat energy to a Geothermal Power Plant in order to generate electricity up to 55 MW.

Liquid waste as a product from the exploitation of geothermal wells, particularly from production test activity, results in form of solution that may contain elements, such as Boron, Arsenic, Sulfur, and Hydragirum (Hg) that are hazardous to human, animal, and plants especially when not controlled further.

Tulis river water body is one of water bodies to be used for irrigation for population in high plain of Dieng, that will be used for waste disposal.

Some water pollutions, which are caused by disposal water of earth heat energy application, are :

a. Ammonia pollution is mainly caused by the presence of steam coming from geothermal fields that contains a significant concentration of ammonia.
b. Boron pollution can be caused by steam / water separation process containing boron.

c. Arsenic pollution is caused mainly if boron or arsenic concentration should exceed 90% out of the total liquid phase after steam and water separation process.
d. Heavy metal pollution can take place in geothermal field in high temperature or high salinity.

Water quality is determined by suspended sediment content and liquidized chemical material in the water. On the other hand, high sediment content will increase irrigation line shallowness and reduce land permeability. The most important irrigation water characteristics are : electric conductivity of water stated in mhos/cm, Na content stated in Sodium Absorption Ratio (SAR), poisonous elements such as chloride, sulfate, bicarbonate, and boron.

## 2. DEVELOPMENT OF THE PROPOSED MODEL

Currently, processed waste line disposal in waste receiver water body has become a common disposal method. Most rivers have certain capacity to receive waste that may need certain water quality standards as in the existing individual water body. Therefore, it is necessary to have certain requirements for the disposal flow in order for the receiver water quality to remain protected so as to be consistent with its use.

A water quality evaluation model of river flow is the mass balance equation.

$$QC = Q_0 C_0 + Q_1 C_1$$

where $Q$ = Mixture flow rate
$C$ = Mixture component
$Q_0$ = River 1 flow rate
$Q_1$ = River 2 flow rate
$C_0$ = River 1 components
$C_1$ = River 2 components

From the equation, we can calculate concentration of result of 2 combined river branches, or if there is other disposal source.

$$C = \frac{Q_0 C_0 + Q_1 C_1}{Q} = \frac{Q_0 C_0 + Q_1 C_1}{Q_0 + Q_1}$$

Parameter treatment model in a flow needs to be considered in case of measuring concentration distribution. Each particle flows in different speeds. The difference is caused by turbulence, friction with river base, curved river flow.

To make river quality model, it has not only sufficient to understand the speed of flow because relationship between each liquid of particle in average speed of flow.

Tracer experiment is an effective procedure to determine mean speed of flow and dispersion coefficient. Theoretically, distribution of tracer material concentration by Smedt (1988) is stated:

$$C = \frac{M/A}{2(\pi D t)^{1/2}} \exp\left[-\frac{(x - vt)^2}{4Dt}\right] \qquad (2.6)$$

where $C$ = Concentration, mass/volume
$M$ = Tracer mass
$A$ = Flow cross-sectional area, $m^2$
$D$ = Dispersing coefficient
$x$ = Distance, m
$v$ = Flowing velocity, m/sec
$t$ = time, sec

From the equation, there will be relationship between concentration (C) and distance (x) in constant time.

## 3. RESEARCH PROCEDURE

In this research, the materials in used was productive disposal water out of geothermal wells in Kali Tulis around Dieng Field. The major component, taken into research for Tulis river, is for quality water standard parameter of D group, including physical characteristics such as: temperature, dissolved residue and electric conductivity. Chemical characteristics include : pH, Mn, Cu, Zn, Cr, Cd, Hg, Pb, As, Se, Ni, Co, B, % Na, Sodium Absorption Ratio (SAR), in addition to $SO_4^-$ and $Cl^-$ according to chemical composition parameter for quality water irrigation.

Liquid waste, both from direct wells disposal and balong (storage pond) within the researched parameters consists of quality standard waste which includes physical characteristic parameters such as ; temperature, dissolved solids, and suspended substances. Chemical characteristics: pH, Fe, Mn, Ba, Cu, Zn, Cr, Cd, Hg, Pb, Sn, As, Se, Ni, Co, CN, H2S, F, $C1_2$, $Nh_3$, Nitrate, nitrate, BOD, DO chemical oxygen need, phenol, and several parameters consistent with irrigation waters, such as, C1, SO, SAR, and Boron.

### A. Water Physical And Chemical Analysis Methods

This research used field and laboratory equipment to analyze waste-water and Kali Tulis water chemical and physical characteristics.

1. Field research used the following tools: measurer, stopwatch, floater / dye, compass, topographic map, and sample bottle, field meter electric conductivity, thermometer, and litmus paper.
2. The laboratory research was to analyze physical and chemical characteristics as follows:
   a. Measurement of water temperature by expansion analysis method.

b. Dissolved residue was analyzed using a graphymetric analysis method.
c. Electric conductivity was analyzed using a potentiometric method.
d. PH investigation was analyzed using a potentiometric method.
e. Ammonia ($NH_3$), Arsenic (As), Iron (Fe), and sulfate were examined by the following method: spectrophotometric using certain reagents for each parameter.
f. Chloride (C1 ion) was analyzed by tetracy Mohr method.
g. Boron was as $HBO_2$ was analyzed by tetracy method in manitol and meter pH.
h. Sodium (Na), Calcium (Ca), Magnesium (Mg), Kalium (K), Manganese (Mn), Copper (Cu), Zinc (Zn), Selenium (Se), Nickel (Ni), and Cobalt (Co) ions examination by atomic absorption spectrophotometric method.

### B. Simulation Method

The prediction of the waste flow rate that may be disposed in Kali Tulis River applies for a simulation method, with use of the mass balance equation as according to fundamental theory, with parameters taken into account are the major parameters related to irrigation water quality.

Prediction method by simulation toward change in water quality occurring at connection of Kali Tulis river branch with water of Sikidang crater passing through Sikidang Pump House, in mass balance equation.

## 4. RESULTS

Kali Tulis debit is 82.7 L/minute in dry season and 926 L/minute in rainy season. Kali Tulis capability of receiving waste water simulated in one early point where the waste is disposed in Kali Tulis and combined with branch of Sikidang crater direction (early combined point). Concentration of early point was meant for estimating worse condition or dangerous concentration for irrigation if it is more than quality standard water for irrigation.

The extent of waste debit, in order for each parameter does not exceed the threshold was estimated by simulation method furthermore tabulated and debit picture of waste which would be disposed in Kali Tulis.

From the result of simulation , the most critical condition was in lowest debit if water parameter has reached the quality water standard threshold for irrigation in early combined point.

In dry season, waste critical debit is 0.09 L/minute, (direct waste of productive test wells) and 0.067 L/minute (waste of result of processing), because in the waste debit, concentration has reached 1 mg/L (threshold B = 1 mg/L) as seen ion Figure 1 and 2. While total other parameter concentration in early combined point is still in quality standard threshold for irrigation / D group. In 0.09 L debit (direct from productive test wells), concentration value of TDS = 282,46 mg/L, DHL = 391,06 mhas/minute, SAR of 0.67, chloride of 15.68 mg/L, sulfate of 50.41 mg/L. In 0.067 L/minute debit (waste of processing result), concentration value of DHL of 390.4 mhas/minute TDS of 282.9 mg/L, SAR of 0.96, chloride of 14.2 mg/L. sulfate of 50.41 mg/L.

In rainy season, waste critical debit is direct waste of 62 L/minute productive wells test and TDS parameter concentration of 180.39 mg/L, DHL of 286.83 mhas/minute, SAR of 1.48, chloride of 52.31 mg/L, sulfate of 33.5 L/minute and TDS parameter concentration of 185.99 mg/L, DHL of 284.21 mhas/minute, SAR of 1.42, chloride of 46.43 mg/L, sulfate of 47.115 mg/L.

## 5. DISCUSSION

From the result of various analysis, naturally shows that the water quality for the Kali Tulis system in research period during the dry season proves that it's unsuitable to be implemented as irrigation water. While in research of rainy season, quality water of Kali Tulis water body highly met requirement of D ground, except water from Sikidang crater. AS seen in Table 1 and 2, result of analysis on direct wastewater from wells and the processed waste included IV group. From result of observation on percentage of decrease in concentration of each parameter, actually the currently conducted process system has not reached requirement, because disposal result concentration still included IV group.

From result of simulation, really Kali Tulis in dry season only receives directly liquid waste from wells of maximum 0.09 l/minute. In rainy season, direct debit from wells that may be disposed in Kali Tulis is maximum 62 l/minute. For processed waste disposal, disposal debit in dry season was 0.067 l/minute, while in rainy season the figure was 33.5 l/minute.

## CONCLUSIONS

1. Result of chemical analysis for liquid waste of storage pond and some productive test wells, water waste includes IV group and boron elements as waste, that are most largely found, are DHL, TDS, SAR and chloride.
2. Kali Tulis capability in dry season to receive liquid waste is 0.067 – 0.9 l/minute and in rainy season is 33.5 – 62.5 l/minute.
3. Result of chemical analysis in Kali Tulis in dry and rainy seasons meets requirements of irrigation water / gold, it means that farmers must maintain plants that are sensitive to boron, such as, potato, cabbage, garlic, carrot and bean.

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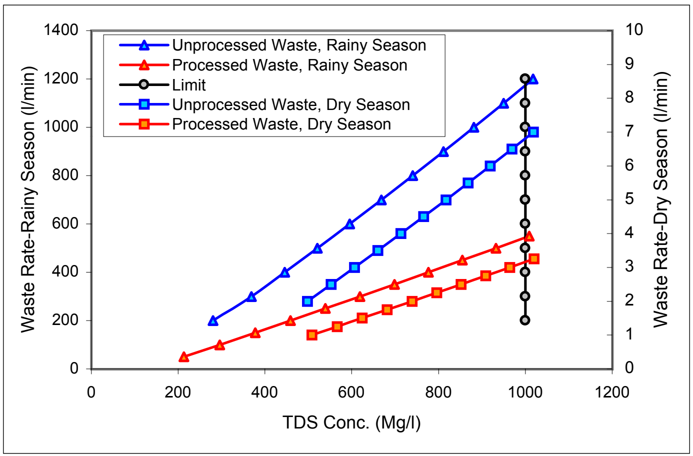


Fig. 1. Well Waste Rate (6 well)
vs. TDS (Initial Mixed)

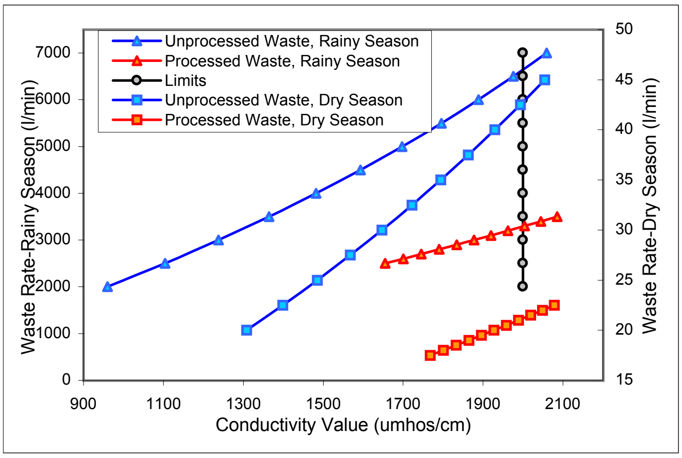


Fig. 2. Well Waste Rate (6 well)
vs. Conductivity (Initial Mixed)

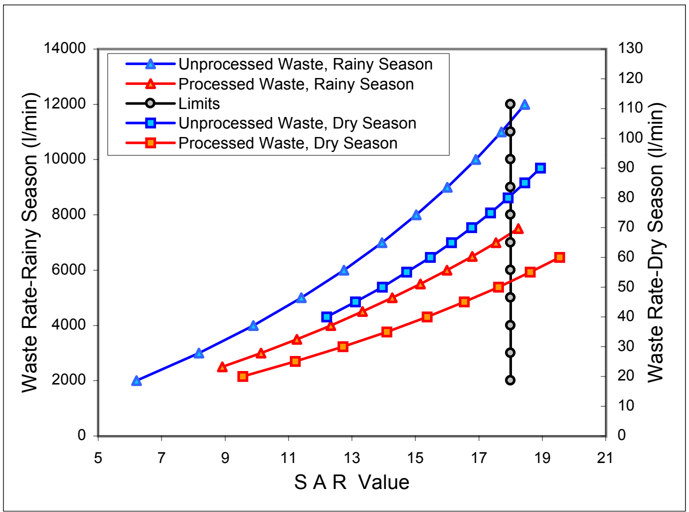


Fig. 3. Well Waste Rate (6 well)
vs. S A R (Initial Mixed)

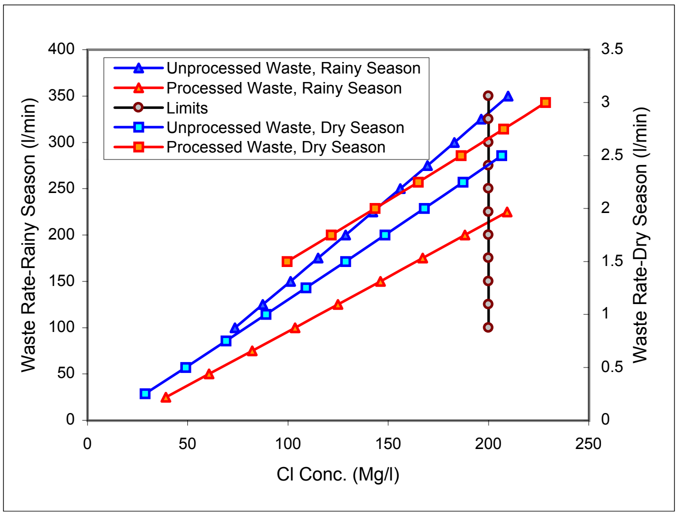


Fig. 3. Well Waste Rate (6 well)
vs. Chloride (Initial Mixed)

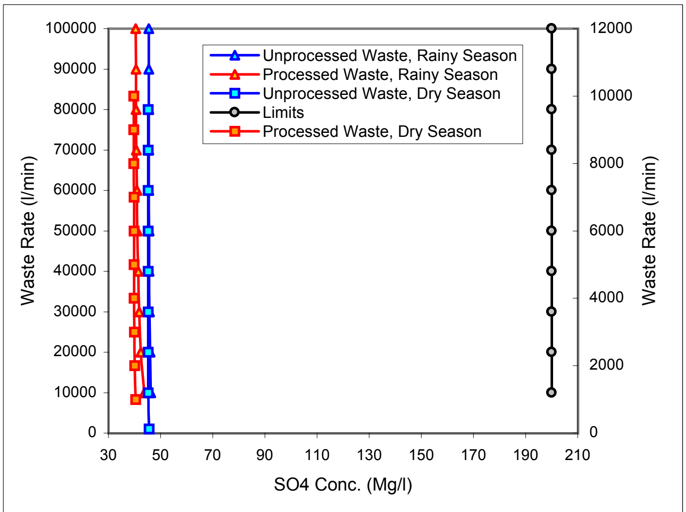


Fig. 3. Well Waste Rate (6 well)
vs. Sulfate (Initial Mixed)

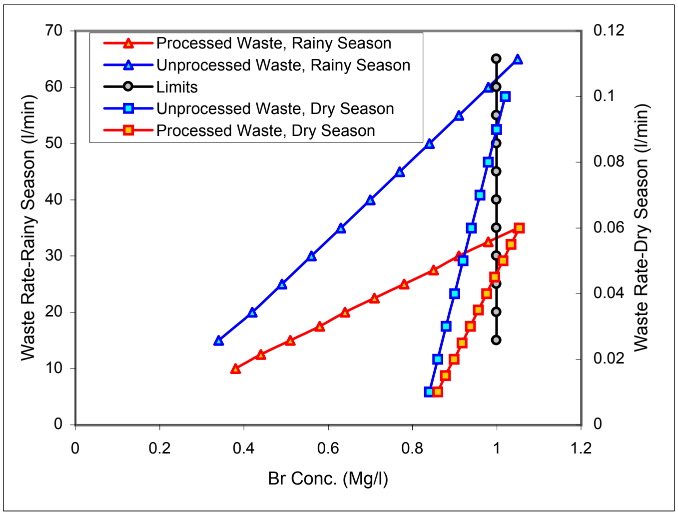


Fig. 3. Well Waste Rate (6 well)
vs. Boron (Initial Mixed)

**Table 1. Parameter Average Concentration for Simulator Rainy Season Tulis Stream**

| Parameter simulation | Conc. input area (mg/l) Sk1 | Sk2 | Sk3 | Initial Conc. at mixed (ST.2) |
|---|---|---|---|---|
| TDS | 869,0 | 119,0 | 1888,0 | 130,1 |
| Conductivity | 1630,0 | 243,0 | 2730,0 | 261,7 |
| S A R | 52,0 | 27,0 | 37,0 | 1,3 |
| Klorida | 66,0 | 17,0 | 4,0 | 17,4 |
| Sulfat | 142,0 | 46,0 | 33,0 | 47,1 |
| Boron | 0,7 | 0,1 | 0,1 | 0,1 |

**Table 2. Parameter Average Concentration for Simulator Dry Season Tulis Stream**

| Simulation Parameter | conc. input area (mg/l) Sk1 | Sk.1 | Sk.2 | Initial Conc.at mixed ST.1 |
|---|---|---|---|---|
| TDS | 371,0 | 206,7 | | 271,7 |
| Conductivity | 450,0 | 344,0 | | 385,9 |
| SAR | 1,0 | 0,9 | | 0,9 |
| Klorida | 3,8 | 11,3 | | 8,3 |
| Sulfat ) | 46,8 | 52,8 | | 50,4 |
| Boron (B) | 0,7 | 0,9 | | 0,8 |

**Table 3. Relation between rate of stream in watching station One**

| monthly rainfall (mm) | rate of flow (liter/menit) | add |
|---|---|---|
| 50 | 50 | Had been tap for 50until 120 liter/second for irigation buntu village |
| 60 | 401,48 | |
| 70 | 912,96 | |
| 80 | 1344,44 | |
| 90 | 1775,93 | |
| 100 | 2207,41 | |
| 110 | 2638,89 | |
| 120 | 3070,37 | |
| 130 | 3501,85 | |
| 140 | 3933,33 | |
| 150 | 4364,81 | |
| 160 | 4796,30 | |
| 170 | 5227,78 | |
| 180 | 5659,26 | |
| 190 | 6090,74 | |
| 200 | 6522,22 | |
| 210 | 6953,70 | |
| 220 | 7385,19 | |
| 230 | 7816,67 | |
| 240 | 8248,15 | |

**Table 4. Parameter Concentration of Simulation from Geothermal Well at Dieng Field liquid waste**

| Simulation Parameter | Geothermalwell for simulation 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| TDS (mg/l) | 132731,0 | 936,0 | 400,0 | 296,0 |
| Conductivity | 17280,0 | 610,0 | 312,0 | 300,0 |
| S A R | 436,3 | 19,5 | 6,2 | 15,3 |
| Klorida (mg/l) | 73524,0 | 133,0 | 37,7 | 2404,0 |
| Sulfat (mg/l) | 77,1 | 75,7 | 29,9 | 0,0 |
| Boron (mg/l) | 1349,0 | 108,0 | 250,1 | 13,5 |

| Simulation Parameter | Geothermal well for simulation 5 | 6 |
|---|---|---|
| TDS (mg/l) | 1560,0 | 23367,1 |
| Coductivity | 3080,0 | 11602,0 |
| S A R | 67,1 | 54,3 |
| Klorida (mg/l) | 23,6 | 13750,0 |
| Sulfat (mg/l) | 53,7 | 95,0 |
| Boron (mg/l) | 33,2 | 384,0 |

**Table 5. Average Consentration of DNG 2,8,13, 14,16 and 19**

| Simulation Parameter | Concentration simulation for 6 well |
|---|---|
| TDS (mg/l) | 9839,4 mg/l |
| DHL (μ mhos/cm) | 5121,5 (μ mhos/cm) |
| | 35,5 |
| S A R | 6766,6 mg/l |
| Klorida (mg/l) | 45,2 mg/l |
| Sulfat (mg/l) | 169,8 mg/l |
| Boron (mg/l) | |

**Table 6. Simulation Parameter Concentration from Well Liquid Waste and After Prosessing at Balong**

| Simulatio parameter | Well Mixed input balong DNG 8 & 2 | After Prosessing | Derivative Value | Irigation Limits and D Group |
|---|---|---|---|---|
| TDS (mg/l) | 23927,8 | 20057,0 | 3870,8 | 1000,0 |
| Conductivity | 11631,1 | 8300,0 | 3331,1 | 2000,0 |
| S A R | 56,2 | 45,2 | 11,0 | 18,0 |
| Klorida (mg/l) | 14056,5 | 10380,0 | 3676,5 | 200,0 |
| Sulfat (mg/l) | 94,9 | 39,6 | 55,3 | 200,0 |
| Boron (mg/l) | 388,9 | 321,3 | 67,6 | 1,0 |

**Table 7. Waste Rate (avrg. 6 Well) with Initial Mixed Conc. TDS**

| LIMIT | DRY SEASON | | | | RAINY SEASON | | | |
|---|---|---|---|---|---|---|---|---|
| | Processed waste | | Unprocessed waste | | Processed waste | | Unprocessed waste | |
| | Waste rate (lt/min) | Conc.TDS (mg/lt) | Waste rate (lt/min) | Conc.TDS (mg/lt) | Waste rate (lt/min) | Conc.TDS (mg/lt) | Waste rate (lt/min) | Conc.TDS (mg/lt) |
| 1000.00 | 1.00 | 508.05 | 2.00 | 497.60 | 50.00 | 213.37 | 200.00 | 280.32 |
| 1000.00 | 1.25 | 566.26 | 2.50 | 552.40 | 100.00 | 295.87 | 300.00 | 368.42 |
| 1000.00 | 1.50 | 624.13 | 3.00 | 606.60 | 150.00 | 377.70 | 400.00 | 445.26 |
| 1000.00 | 1.75 | 681.66 | 3.50 | 660.10 | 200.00 | 458.84 | 500.00 | 520.86 |
| 1000.00 | 2.00 | 738.85 | 4.00 | 713.10 | 250.00 | 539.32 | 600.00 | 595.26 |
| 1000.00 | 2.25 | 795.70 | 4.50 | 765.40 | 300.00 | 619.14 | 700.00 | 668.47 |
| 1000.00 | 2.50 | 852.22 | 5.00 | 817.10 | 350.00 | 698.31 | 800.00 | 740.54 |
| 1000.00 | 2.75 | 908.41 | 5.50 | 868.30 | 400.00 | 776.84 | 900.00 | 811.48 |
| 1000.00 | 3.00 | 964.27 | 6.00 | 918.90 | 450.00 | 854.73 | 1000.00 | 881.32 |
| 1000.00 | 3.25 | 1019.80 | 6.50 | 968.90 | 500.00 | 932.00 | 1100.00 | 950.09 |
| 1000.00 | | | 7.00 | 1018.31 | 550.00 | 1008.64 | 1200.00 | 1017.82 |

**Table 8. Waste Rate (avrg. 6 Well) with Initial Mixed Conc. TDS**

| LIMIT | DRY SEASON | | | | RAINY SEASON | | | |
|---|---|---|---|---|---|---|---|---|
| | Processed waste | | Unprocessed waste | | Processed waste | | Unprocessed waste | |
| | Waste rate (lt/min) | Conductivity (umhos/cm) | Waste rate (lt/min) | Conductivity (umhos/cm) | Waste rate (lt/min) | Conductivity (umhos/cm) | Waste rate (lt/min) | Conductivit (umhos/cm) |
| 2000.00 | 17.50 | 1768.11 | 20.00 | 1308.13 | 2500.00 | 1654.72 | 2000.00 | 959.64 |
| 2000.00 | 18.00 | 1800.55 | 22.50 | 1398.75 | 2600.00 | 1700.47 | 2500.00 | 1104.00 |
| 2000.00 | 18.50 | 1832.66 | 25.00 | 1485.16 | 2700.00 | 1745.59 | 3000.00 | 1238.00 |
| 2000.00 | 19.00 | 1864.45 | 27.50 | 1567.66 | 2800.00 | 1790.10 | 3500.00 | 1364.33 |
| 2000.00 | 19.50 | 1895.94 | 30.00 | 1646.49 | 2900.00 | 1834.01 | 4000.00 | 1482.30 |
| 2000.00 | 20.00 | 1927.12 | 32.50 | 1721.90 | 3000.00 | 1877.33 | 4500.00 | 1593.06 |
| 2000.00 | 20.50 | 1957.99 | 35.00 | 1794.11 | 3100.00 | 1920.07 | 5000.00 | 1697.30 |
| 2000.00 | 21.00 | 1988.57 | 37.50 | 1863.32 | 3200.00 | 1962.25 | 5500.00 | 1795.55 |
| 2000.00 | 21.50 | 1018.86 | 40.00 | 1929.70 | 3300.00 | 2003.87 | 6000.00 | 1888.32 |
| 2000.00 | 22.00 | 2048.85 | 42.50 | 1993.40 | 3400.00 | 2044.95 | 6500.00 | 1976.05 |
| 2000.00 | 22.50 | 2078.56 | 45.00 | 2054.64 | 3500.00 | 2085.50 | 7000.00 | 2059.15 |

**Table 9. Waste Rate (avrg. 6 Well) with Initial Mixed Conc. S A R**

| LIMIT | DRY SEASON | | | | RAINY SEASON | | | |
|---|---|---|---|---|---|---|---|---|
| | Processed waste | | Unprocessed waste | | Processed waste | | Unprocessed waste | |
| | Waste rate (lt/min) | Conc. SAR (mg/lt) | Waste rate (lt/min) | Conc. SAR (mg/lt) | Waste rate (lt/min) | Conc. SAR (mg/lt) | Waste rate (lt/min) | Conc. SAR (mg/lt) |
| 18.00 | 20.00 | 9.56 | 40.00 | 12.20 | 2500.00 | 8.91 | 2000.00 | 6.21 |
| 18.00 | 25.00 | 11.21 | 45.00 | 13.11 | 3000.00 | 10.13 | 3000.00 | 8.18 |
| 18.00 | 30.00 | 12.72 | 50.00 | 13.96 | 3500.00 | 11.26 | 4000.00 | 9.89 |
| 18.00 | 35.00 | 14.10 | 55.00 | 14.73 | 4000.00 | 12.33 | 5000.00 | 11.41 |
| 18.00 | 40.00 | 15.37 | 60.00 | 15.47 | 4500.00 | 13.33 | 6000.00 | 12.75 |
| 18.00 | 45.00 | 16.54 | 65.00 | 16.14 | 5000.00 | 14.27 | 7000.00 | 13.95 |
| 18.00 | 50.00 | 17.62 | 70.00 | 16.77 | 5500.00 | 15.16 | 8000.00 | 15.03 |
| 18.00 | 55.00 | 18.62 | 75.00 | 17.37 | 6000.00 | 16.00 | 9000.00 | 16.01 |
| 18.00 | 60.00 | 19.55 | 80.00 | 17.92 | 6500.00 | 16.79 | 10000.00 | 16.90 |
| 18.00 | | | 85.00 | 18.45 | 7000.00 | 17.54 | 11000.00 | 17.71 |
| 18.00 | | | 90.00 | 18.94 | 7500.00 | 18.25 | 12000.00 | 18.45 |

**Table 10. Waste Rate (avrg. 6 Well) with Initial Mixed Conc. Cl**

| LIMIT | DRY SEASON | | | | RAINY SEASON | | | |
|---|---|---|---|---|---|---|---|---|
| | Processed waste | | Unprocessed waste | | Processed waste | | Unprocessed waste | |
| | Waste rate (lt/min) | Conc. Cl (mg/lt) | Waste rate (lt/min) | Conc. Cl (mg/lt) | Waste rate (lt/min) | Conc. Cl (mg/lt) | Waste rate (lt/min) | Conc. Cl (mg/lt) |
| 200.00 | 1.50 | 99.50 | 0.25 | 28.70 | 25.00 | 39.08 | 100.00 | 73.53 |
| 200.00 | 1.75 | 121.50 | 0.50 | 48.95 | 50.00 | 60.67 | 125.00 | 87.41 |
| 200.00 | 2.00 | 143.40 | 0.75 | 69.07 | 75.00 | 82.17 | 150.00 | 101.24 |
| 200.00 | 2.25 | 165.00 | 1.00 | 89.08 | 100.00 | 103.57 | 175.00 | 115.01 |
| 200.00 | 2.50 | 186.40 | 1.25 | 108.96 | 125.00 | 124.89 | 200.00 | 128.72 |
| 200.00 | 2.75 | 207.50 | 1.50 | 128.73 | 150.00 | 146.12 | 225.00 | 142.38 |
| 200.00 | 3.00 | 228.40 | 1.75 | 148.38 | 175.00 | 167.27 | 250.00 | 156.00 |
| 200.00 | | | 2.00 | 167.92 | 200.00 | 188.32 | 275.00 | 169.53 |
| 200.00 | | | 2.25 | 187.33 | 225.00 | 209.29 | 300.00 | 183.02 |
| 200.00 | | | 2.50 | 206.64 | | | 325.00 | 196.45 |
| 200.00 | | | | | | | 350.00 | 209.83 |

**Table 11. Waste Rate (avrg. 6 Well) with Initial Mixed Conc. $SO_4$**

| LIMIT | DRY SEASON | | | | RAINY SEASON | | | |
|---|---|---|---|---|---|---|---|---|
| | Processed waste | | Unprocessed waste | | Processed waste | | Unprocessed waste | |
| | Waste rate (lt/min) | Conc. $SO_4$ (mg/lt) | Waste rate (lt/min) | Conc. $SO_4$ (mg/lt) | Waste rate (lt/min) | Conc. $SO_4$ (mg/lt) | Waste rate (lt/min) | Conc. $SO_4$ (mg/lt) |
| 200.00 | 1000.00 | 40.46 | 1000.00 | 45.61 | 10000.00 | 43.69 | 10000.00 | 46.22 |
| 200.00 | 2000.00 | 40.07 | 10000.00 | 45.26 | 20000.00 | 42.42 | 20000.00 | 45.90 |
| 200.00 | 3000.00 | 39.93 | 20000.00 | 45.24 | 30000.00 | 41.76 | 30000.00 | 45.73 |
| 200.00 | 4000.00 | 39.86 | 30000.00 | 45.23 | 40000.00 | 41.35 | 40000.00 | 45.63 |
| 200.00 | 5000.00 | 39.81 | 40000.00 | 45.23 | 50000.00 | 41.07 | 50000.00 | 45.56 |
| 200.00 | 6000.00 | 39.79 | 50000.00 | 45.22 | 60000.00 | 40.87 | 60000.00 | 45.51 |
| 200.00 | 7000.00 | 39.76 | 60000.00 | 45.22 | 70000.00 | 40.72 | 70000.00 | 45.47 |
| 200.00 | 8000.00 | 39.75 | 70000.00 | 45.22 | 80000.00 | 40.60 | 80000.00 | 45.44 |
| 200.00 | 9000.00 | 39.74 | 80000.00 | 45.22 | 90000.00 | 40.51 | 90000.00 | 45.42 |
| 200.00 | 10000.00 | 39.73 | | | 100000.00 | 40.43 | 100000.00 | 45.40 |

**Table 12. Waste Rate (avrg. 6 Well) with Initial Mixed Conc. Br**

| LIMIT | DRY SEASON | | | | RAINY SEASON | | | |
|---|---|---|---|---|---|---|---|---|
| | Processed waste | | Unprocessed waste | | Processed waste | | Unprocessed waste | |
| | Waste rate (lt/min) | Conc. Br (mg/lt) | Waste rate (lt/min) | Conc. Br (mg/lt) | Waste rate (lt/min) | Conc. Br (mg/lt) | Waste rate (lt/min) | Conc. Br (mg/lt) |
| 1.00 | 0.010 | 0.8597 | 0.01 | 0.84 | 10.00 | 0.38 | 15.00 | 0.34 |
| 1.00 | 0.015 | 0.8779 | 0.02 | 0.86 | 12.50 | 0.44 | 20.00 | 0.42 |
| 1.00 | 0.020 | 0.8984 | 0.03 | 0.88 | 15.00 | 0.51 | 25.00 | 0.49 |
| 1.00 | 0.025 | 0.9178 | 0.04 | 0.90 | 17.50 | 0.58 | 30.00 | 0.56 |
| 1.00 | 0.030 | 0.9371 | 0.05 | 0.92 | 20.00 | 0.64 | 35.00 | 0.63 |
| 1.00 | 0.035 | 0.9565 | 0.06 | 0.94 | 22.50 | 0.71 | 40.00 | 0.70 |
| 1.00 | 0.040 | 0.9759 | 0.07 | 0.96 | 25.00 | 0.78 | 45.00 | 0.77 |
| 1.00 | 0.045 | 0.9952 | 0.08 | 0.98 | 27.50 | 0.85 | 50.00 | 0.84 |
| 1.00 | 0.050 | 1.0146 | 0.09 | 1.00 | 30.00 | 0.91 | 55.00 | 0.91 |
| 1.00 | 0.055 | 1.0339 | 0.10 | 1.02 | 32.50 | 0.98 | 60.00 | 0.98 |
| 1.00 | 0.060 | 1.0533 | | | 35.00 | 1.05 | 65.00 | 1.05 |

**Table 13. Table of Water Quality Standard Group D**

| No. | Parameter | Units | Maximum Content | Analysis Method | Equipment | Note |
|---|---|---|---|---|---|---|
| | **PHYSICS :** | | | | | |
| 1 | Temperature | $^{0}C$ | Normal Temperature | Expansion | Thermometer | Matches with local condition |
| 2 | Dissolved Residue | mg/l | 1000 - 2000 | Gravimetry | Analitic scale and filter paper 0.45 µm | Dependent on the plant type |
| 3 | Electrical Conductivity | µmhos/cm ($25^{0}$ C) | 1750 - 2250 | Potensiometric | Conductivity meter | 1750 for sensitive plants. 2250 for resistant plant. |
| | **CHEMISTRY :** | | | | | |
| 1 | pH | | 5 - 9 | Potensiometric | pH meter | |
| 2 | Mangan (Mn) | mg/l | 2 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 3 | Copper (Cu) | mg/l | 0.2 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 4 | Zinc (Zn) | mg/l | 2 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 5 | Chromium($Cr^{6+}$) | mg/l | 1 | - Spectrofotometric atomic absorption | - AAS | |
| 6 | Cadmium (Cd) | mg/l | 0.01 | - Spectrofotometric atomic absorption | - AAS | |
| 7 | Hydragirum (Hg) | mg/l | 0.005 | - Spectrofotometric atomic absorption | - AAS | |
| 8 | Plumbum | mg/l | 1 | - Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 9 | Arsenic (As) | mg/l | 1 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 10 | Selenium (Se) | mg/l | 0.05 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 11 | Nickel (Ni) | mg/l | 0.5 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 12 | Cobalt (Co) | mg/l | 0.2 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 13 | Boron (B) | mg/l | 1 | - Spectrofotometric<br>- Spectrofotometric atomic absorption | - Spectrofotometer<br>- AAS | |
| 14 | Na (salt % alkaline) | mg/l | 60 | Flame Photometric | Flame Photometer | |
| 15 | Sodium Absorption Ratio (SAR) | mg/l | 10 – 18 | Calculative | Calculator | Maximum value of 10 for sensitive plant. Maximum value of 18 for less sensitive plant. |
| 16 | Residual Sodium Carbonate (RSC) | mg/l | 1.25 – 2.5 | Calculative | Calculator | Maximum value of 1.25 for sensitive plant. Maximum value of 2.5 for less sensitive plant. |

| No | Parameter | Units | Maximum Content | Analysis Method | Equipment | Note |
|---|---|---|---|---|---|---|
| | RADIOACTIVITY | | | | | |
| 1 | Total beta activity | PCi/l | 1000 *) | β counting | Geiger Muler Counter | *) Activities in the absence of Sr-90 and RA-226 |
| 2 | Strontium-90 | PCi/l | 10 | β counting | Geiger Muler Counter | |
| 3 | Radium-226 | PCi/l | 3 | α counting | α counter | |

**Table 14. Table of Water Quality Standard Group IV**

| No. | PARAMETER | Units | Categories of Waste-water Quality Standard | | | |
|---|---|---|---|---|---|---|
| | | | I | II | III | IV |
| | **PHYSICS :** | | | | | |
| 1 | Temperature | $^0C$ | 35 | 38 | 40 | 45 |
| 2 | Dissolved solids | mg/l | 1500 | 2000 | 4000 | 5000 |
| 3 | Suspended solids | mg/l | 100 | 200 | 400 | 500 |
| | **CHEMISTRY** | | | | | |
| 1 | pH | | 6 - 9 | 6 - 9 | 6 - 9 | 5 - 9 |
| 2 | Dissolved Iron (Fe) | mg/l | 1 | 5 | 10 | 20 |
| 3 | Dissolved Manganese (Mn) | mg/l | 0.5 | 2 | 5 | 10 |
| 4 | Barium (Ba) | mg/l | 1 | 2 | 3 | 5 |
| 5 | Cuprum (Cu) | mg/l | 1 | 2 | 3 | 5 |
| 6 | Zinc (Zn) | mg/l | 2 | 5 | 10 | 15 |
| 7 | Hexavalent Chromium ($Cr^{6+}$) | mg/l | 0.05 | 0.1 | 0.5 | 1 |
| 8 | Total Chromium (Cr) | mg/l | 0.1 | 0.5 | 1 | 2 |
| 9 | Cadmium (Cd) | mg/l | 0.01 | 0.05 | 0.1 | 0.5 |
| 10 | Hydragirum (Hg) | mg/l | 0.001 | 0.002 | 0.005 | 0.01 |
| 11 | Plumbum (Pb) | mg/l | 0.03 | 0.1 | 1 | 2 |
| 12 | Stanum (Sn) | mg/l | 1 | 2 | 3 | 5 |
| 13 | Arsenicum (As) | mg/l | 0.05 | 0.1 | 0.5 | 1 |
| 14 | Selenium (Se) | mg/l | 0.01 | 0.05 | 0.5 | 1 |
| 15 | Nickel (Ni) | mg/l | 0.1 | 0.2 | 0.5 | 1 |
| 16 | Cobalt (Co) | mg/l | 0.2 | 0.4 | 0.6 | 1 |
| 17 | Cyanida (CN) | mg/l | 0.02 | 0.05 | 0.5 | 1 |
| 18 | Sulfide ($H_2S$) | mg/l | 0.01 | 0.05 | 0.1 | 1 |
| 19 | Fluoride (F) | mg/l | 1.5 | 2 | 3 | 5 |
| 20 | Free Chlorine ($Cl_2$) | mg/l | 0.5 | 1 | 2 | 5 |
| 21 | Free Amoniac ($NH_3$-N) | mg/l | 0.02 | 1 | 5 | 20 |
| 22 | Nitrate ($NO_3$-N) | mg/l | 10 | 20 | 30 | 50 |
| 23 | Nitrite ($NO_2$-N) | mg/l | 0.06 | 1 | 3 | 5 |
| 24 | Biochemical Oxygen Demand (BOD) | mg/l | 20 | 50 | 150 | 300 |
| 25 | Chemical Oxygen Demand (COD) | mg/l | 40 | 100 | 300 | 600 |
| 26 | Blue Metilene Active Compound | mg/l | 0.5 | 5 | 10 | 15 |
| 27 | Fenol | mg/l | 0.01 | 0.5 | 1 | 2 |
| 28 | Vegetable Oil | mg/l | 1 | 5 | 10 | 20 |
| 29 | Mineral Oil | mg/l | 1 | 10 | 50 | 100 |
| 30 | Radioactivity **) | | | | | |
| 31 | Pesticide including PCB ***) | | | | | |

Note : *) Waste material content which fulfills waste-water quality standard requirements must not be a product of liquidification process which water is directly taken from a water source.
The waste material content stated above is the maximum content value allowed, except for pH value which includes a minimum content value.

**) Radioactivity content follows the rules currently approved.

***) Pesticide waste originating from industries which formulates or runs production, and also those from consumers currently making use of it as an agricultural component and others, should be strictly prohibited to cause water pollution which can eventually disturbs its consumption.