Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Deli River Water Quality Control in Medan City Using Statistical Methods Quality Control

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Received: February 15, 2024. Accepted: March 25, 2024. Published: March 30, 2024

Abstract: Clean water is a water-based resource of good quality and is commonly used by humans for consumption or daily activities. Clean water quality that meets standards/quality is uncompromising to obtain because river water quality has been polluted by various kinds of waste from various human activities, so the potential impact on river quality decreases in quantity and quality. 70% of the Deli River pollution is solid and liquid waste, domestic waste, and industrial waste, and along the Deli River, it has affected river water quality. The statistical quality control method can be used to identify air quality quantitatively. Statistical quality control is a collection of strategies, techniques, and actions taken to ensure that they produce a quality product. This research aims to determine the control of the water quality of the Deli River in Medan City using Statistical Quality Control. Based on the data obtained, the water quality standards of the Deli River in the Sumatra II River Basin Agency from January 2023 to December 2023 have not been statistically controlled because several data samples are out of control. Then, Deli River water quality control was carried out based on graphic control using SQC (Statistical Quality Control). The results of quality control using SQC show that SQC provides different controls because, in SQC, TDS controls data on controlled 3 times, while the $\bar{X}$ and R data on DO, the $\bar{X}$ and R data on and $\bar{X}$ And R data for fatty oil are controlled.

Keywords: Control; Quality; River Water; Statistical Quality Control.

Introduction

Rivers are a type of surface water that is a water source for life; the role of rivers is significant, so they must be adequately maintained [1]. Clean water is a type of water-based resource that is of good quality and is commonly used by humans for consumption or in carrying out daily activities. Clean water quality that meets standards/quality is uncompromising to obtain because the quality of river water has been polluted by various kinds of waste from various human activities, so the potential impact on the quality and quantity of river natural resources (SDA) has decreased both in terms of quantity. as well as quality [2].

The Deli River is one of the main rivers that cross the city of Medan. The development of industry and settlements and the pollution of the Deli River can already be felt through the brownish water, with scattered rubbish piling up from the edge to the river flow, seen from the silting that occurs at several [3]. 70% of the Deli River pollution is caused by solid and liquid waste, domestic waste, and industrial waste, and along the Deli River, it has affected the river water quality. The decline in water quality is characterized by changes in water color to brown and smelly [4].

Looking at the Deli River pollution problem, management efforts need to be made to ensure the water quality is following its intended purpose [5]. In quality management, there are methods or tools used to control the implementation of a process so that it runs according to specifications. The statistical quality control method can be used to identify water quality quantitatively. Statistical Quality Control is a system developed to maintain uniform production quality standards. Statistical quality control is a set of strategies, techniques, and actions to ensure the strategy produces a quality product [6].

In SQC, seven tools can be used, including (1) Pareto Diagram, (2) Cause and Effect Diagram, (3) Scatter Diagram, (4) Check Sheet, (5) Control Chart (variables and attributes), (6) Histogram, (7) Flowchart. Researchers will use a control chart with variable types [7]. Using a variable-type control chart is essential because, in this research, the object under study has continuous dimensions and unlimited possibilities. Measurements carried out in variable control charts include using X-chart and R-chart [8].

In the era of statistical quality control, the Inspection Department was equipped with statistical tools to detect deviations in product attributes produced by the production process [9]. Production attributes are inspected by the Inspection Department and included in the statistical quality control chart. If they are still within the control limits (between the upper and lower control limits), the attribute deviations that occur are coincidental. Hence, there is no need to make corrections to the production system and process [10].

SQC analysis is a control chart used to determine quality control limits. The control chart is used to determine the level of defects in a product if there is something outside the Upper Control Limit (UCL) and Lower Control

How to Cite:
Rizkina, M., Siregar, M. A. P., & Batubara, A. U. (2024). Deli River Water Quality Control In Medan City Using Statistical Methods Quality Control. *Jurnal Pijar Mipa*, *19*(2), 372–379. https://doi.org/10.29303/jpm.v19i2.6591

Limit (LCL) lines [11]. In the quality control process, various types of specified defects may occur. Some types of defects can be tolerated, and some cannot be tolerated. Conditions like this make it necessary to classify the types of defects based on their weight using the control chart method [12].

Based on several previous studies, it turns out that research on the quality of a product using Statistical Quality Control (SQC) is considered quite effective in finding the sources of problems regarding the quality control of a product [13]. This research aims to determine the control of the water quality of the Deli River in Medan City using Statistical Quality Control [14].

Research Methods

This type of research is quantitative research. Quantitative research is the numerical or numerical type of research, using statistical data that can be measured or calculated directly as numeric or numerical variables. The data source used in this research is secondary data. Secondary data is a data source obtained by researchers as a second party. It is not obtained directly but is based on existing agency data. The data source used comes from the II River Region Hall.

Statistical Quality Control (SQC) is a static quality controller that uses a control chart approach to make strategic decisions on quality improvement proposals. In this SQC, the average UCL and LCL values are used to conclude whether a product, especially in this research on water quality, has data deviations and problems with the quality of the water produced, which is still within the tolerance value or not [15]. The water quality is very reasonable if it is within the tolerance limit. In contrast, if it has exceeded the UCL or LCL tolerance limit, then SQC shows data on what variables must be controlled and what efforts will be taken to improve the water quality.

Factors that influence the reduction of water quality consist of TDS (Total Dissolved Solid), DO (Dissolved Oxygen), BOD (Biological Oxygen Demand), TSS (Total Suspended Solid), and fatty oils. So, in this study, the following variables were used [16]:

1. x_1 : TDS (*Total Dissolved Solid*)
2. x_2 : DO (*Dissolved Oxygen*)
3. x_3 : BOD (*Biological Oxygen Demand*)
4. x_4 : TSS (*Total Suspended Solid*)
5. x_5 : fatty oil
6. y : River Water Quality

The implementation procedures used to achieve the research objectives are as follows:

1. Conduct a literature study that supports the issue of Statistical Quality Control for improving river water quality
2. Field studies on river water quality control processes
3. Collecting data on river water quality and factors that influence it
4. Data processing by calculating control chart boundaries
   a. Create $\bar{X}$ and R control charts
   b. The causal analysis of the control data map is beyond the control limits
5. Conclusions and recommendations.
6. Finished.

Table 1. Quality Standards for River Water Quality [17]

NO.	Parameter	Maximum Quality Standards	Unit
1	TDS	1000	mg/L
2	DO	6	mg/L
3	BOD	2	mg/L
4	TSS	50	mg/L
5	Fat Oil	1000	mg/L

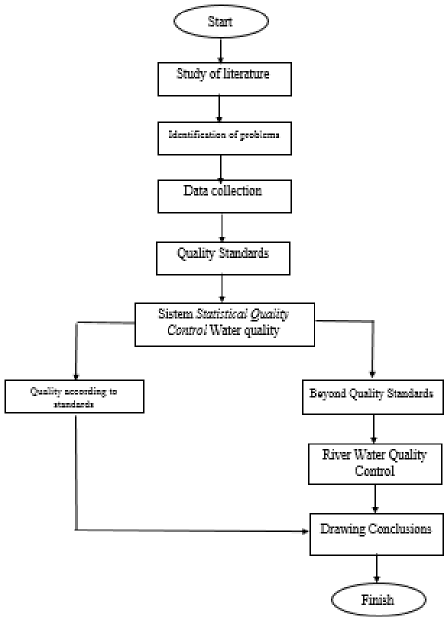


Figure 1. Research Framework

Results and Discussion

In analyzing the problems in controlling the water quality of the Deli River at the Sumatra River Regional Office II this was done by making graphs on the variables TDS (Total Dissolved Solid), DO (Dissolved Oxygen), BOD (Biological Oxygen Demand), TSS (Total Suspended Solid) and Fatty Oil.

TDS (Total Dissolved Solid)

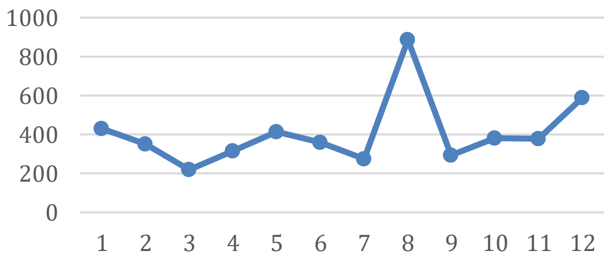


Figure 2. Average TDS graph

Based on the TDS graph for Deli River Water, the average TDS is less than 1000 mg/L, and no data is outside the quality standard limits. Based on the standards set by BWS, the maximum TDS value is 1000 mg/L.

DO (Dissolved Oxygen)

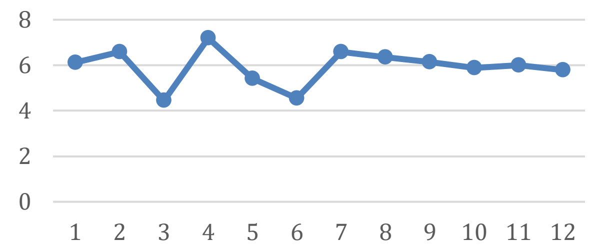


Figure 3. Average DO graph

Based on the Deli River Water DO graph, the average DO is 5.92, and some data is outside the normal limits, namely January, February, April, July, August, September, and November, based on the standardization set by BWS, namely River Water DO Deli maximum 6 mg/L.

BOD (Biological Oxygen Demand)

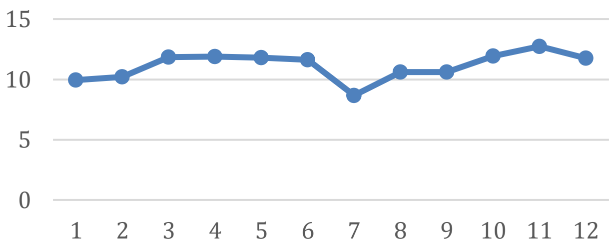


Figure 4. Average BOD graph

Based on the Deli River BOD graph, the average BOD is 11.10. Some data is outside the limits, namely in January, February, March, April, May, June, July, August, September, October, November, and December, based on The standardization set by BWS, is a maximum of 2 mg/L.

TSS (Total Suspended Solid)

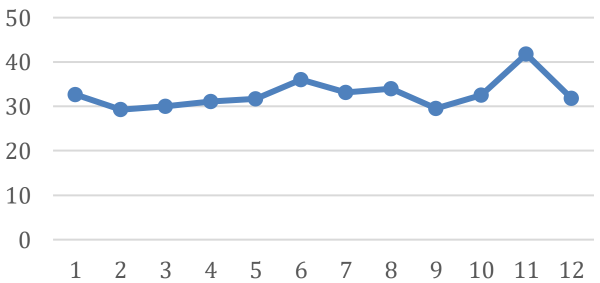


Figure 5. Average TSS graph

Based on the Deli River Water TSS graph, the average TSS is 32.89, and no data is outside the normal limits based on the standards set by BWS; namely, the maximum TSS of Deli River Water is 50 mg/L.

Fat Oil

Fatty Oil is 3.44, and there is no data outside the limits based on the standardization set by BWS. Maximum Fatty Oil is 1000 mg/L.

Control chart analysis is used to control process performance using statistical methods. The control chart has an upper control limit line (UCL) and a lower control limit line (LCL). These two lines determine the control limits for quality content in statistical calculations. The following are the steps for creating. $\bar{X}$ And R control charts for TDS, DO, BOD, TSS, and Fat Oil.

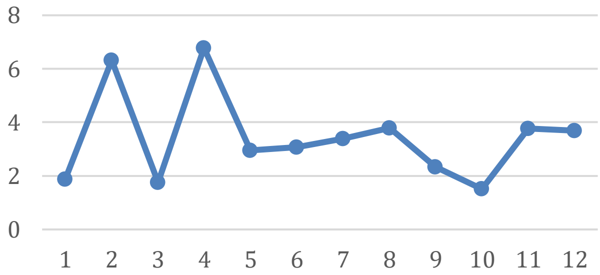


Figure 6. Average Fat Oil Graph

Based on the Deli River Fatty Oil graph, the average

Map $\bar{X}$ and R Map for TDS (Total Dissolved Solid)

Before determining the control chart $\bar{X}$, the step that must be taken is to determine $\bar{X}$ On the same date every month. To determine $\bar{X}$ The data must be divided into 12 groups. After that, $\sum R$ The total number of all groups determines it.

$\sum R_1 \quad = TDS(1\,Januari) + TDS(1\,Februari) + \cdots + TDS(1\,Desember)$

$\sum R_1 \quad = 435 + 149 + 362{,}2 + 118 + 204{,}8 + 232{,}7 + 201{,}7 + 274{,}6 + \quad 252{,}2 + 137 + 107 + 368$

$\sum R_1 \quad = 284{,}2$

$\sum R_2 \quad = TDS(2\,Januari) + TDS(2\,Februari) + \cdots + TDS(2\,Desember)$

$\sum R_2 \quad = 357 + 359 + 205{,}1 + 150 + 0 + 378 + 342 + 270{,}1 + 268 + 128 + \quad 100 + 283{,}3$

$\sum R_2 \quad = 2859$

$\sum R_3 \quad = TDS(3\,Januari) + TDS(3\,Februari) + \cdots + TDS(3\,Desember)$

$\sum R_3 \quad = 170{,}8 + 154{,}8 + 130 + 108 + 0 + 0 + 261{,}1 + 0 + 183{,}8 + 330 + \quad 148 + 478$

$\sum R_3 \quad = 1964{,}5$

Next, $\bar{X}$ is obtained from $\sum R_1$, which is divided by the total number of groups in the data, with the number of groups in this research data being 12.

$$\bar{X}_1 = \frac{\sum R_1}{12}$$

$$\bar{X}_1 = \frac{2842{,}2}{12}$$

$$\bar{X}_1 = 236{,}85$$

$$\bar{X}_2 = \frac{\sum R_2}{12}$$

$$\bar{X}_2 = \frac{2859}{12}$$

$$\bar{X}_2 = 238{,}25$$

$$\bar{X}_3 = \frac{\sum R_3}{12}$$

$$\bar{X}_3 = \frac{1964{,}5}{12}$$

$\bar{X}_3 = 163{,}70$
This continues until March, April, May, June, July, August, September, October, November and December.
Next, to calculate R for each data, use the following formula:
$R = max - min$
R is the daily average value.
$R_1 = 435 - 107$
$R_1 = 328$
$R_2 = 378 - 100$
$R_2 = 278$
$R_3 = 478 - 108$
$R_3 = 370$
The calculation results $\sum R$,$\bar{X}$ And R from 1st – 31st is displayed in the following table 2. To determine CL, UCL, and LCL from the $\bar{X}$, control chart, the following calculations are used:

Table 2. $\sum R$,$\bar{X}$ and R on the same date every month (mg/L)

Date	$\sum R$	$\bar{X}$	$R_{(\max-\min)}$
1	2842.2	236.85	328
2	2859	238.25	278
3	1964.5	163.7083	370
4	2302.7	191.8917	430
5	2147.5	178.9583	273
6	2861.4	238.45	413
7	2506	208.8333	355
8	2637	219.75	1002
9	2847	237.25	546
10	4952	412.6667	701.2
11	3565.8	297.15	471.2
12	3338	278.1667	757
13	1984	165.3333	560
14	1705	142.0833	162.2
15	1902	158.5	320.2
16	3817	318.0833	637.6
17	4013.6	334.4667	389.4
18	22934	191.1167	541.2
19	3522	293.5	660
20	5186	432.1667	698
21	5131.5	427.625	547
22	3193.9	266.1583	515.2
23	2741.8	228.4833	556
24	2842.6	236.8833	685
25	2999.8	249.9833	305.2
26	3844.8	320.4	306.2
27	4284.5	357.0417	369.5
28	3116.8	259.7333	154.6
29	2279	189.9167	417
30	3088.883	257.4069	406.6
31	3144	262	393.5
$\sum$	95913.68	7992.807	14548.8

$$CL = \frac{7992{,}87}{31}$$
$CL = 257{,}83$
$$R = \frac{R_{(\max-\min)}}{n}$$
$$R = \frac{14548}{31}$$
$R = 469{,}31$
Then :
$UCL_{\bar{X}} = \bar{\bar{X}} + A_2R$
$UCL_{\bar{X}} = 257{,}83 + 0{,}266 \times 469{,}31$
$UCL_{\bar{X}} = 382{,}67$

$LCL_{\bar{X}} = \bar{\bar{X}} - A_2R$
$LCL_{\bar{X}} = 257{,}83 - 0{,}266 \times 469{,}31$
$LCL_{\bar{X}} = 132{,}99$

UCL is the lower average limit value, and LCL is the upper average limit value.
Next, the CL, UCL, and LCL limit values are made into a graph which produces the $\bar{X}$, control chart in Figure 7.

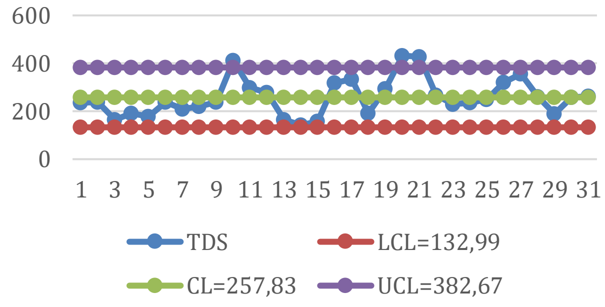


Figure 7. $\bar{X}$ TDS Control Map

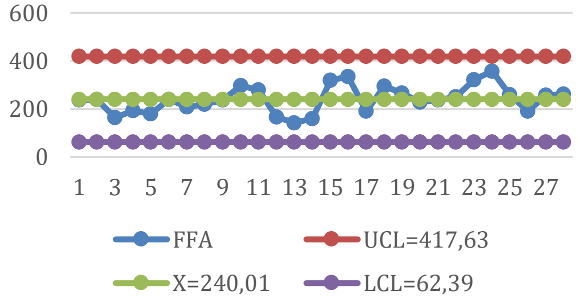
Based on Figure 7, some data is outside the control limits, namely data on the 10th, 20th, and 21st, which exceed the control limits, so in the $\bar{X}$ (control chart), the data needs to be revised by discarding out-of-control data.
The calculation for the revision of the $\bar{X}$ The TDS control chart is as follows :
$$\bar{\bar{X}} = \frac{\bar{X} - Xd}{g - gd}$$
$$\bar{\bar{X}} = \frac{7992{,}80 - 412{,}66 + 432{,}16 + 427{,}62}{31 - 3}$$
$\bar{\bar{X}} = 240{,}01$
$R = 469{,}31$
$$\sigma_0 = \frac{R}{d_2}$$
$$\sigma_0 = \frac{469{,}31}{3{,}25}$$
$\sigma_0 = 144{,}405$
Maka, $UCL_x = \bar{\bar{X}} + A \times \sigma_0$
$UCL_x = 240{,}01 + 1{,}23 \times 144{,}405$
$UCL_x = 417{,}63$

$LCL_x = \bar{\bar{X}} - A \times \sigma_0$
$LCL_x = 240{,}01 - 1{,}23 \times 144{,}405$
$LCL_x = 62{,}39$

Next, to determine UCL_x and LCL_x The formula is used
$\sigma_0 = \frac{R}{d_2}, d_2 = 3{,}25$
$R = 469{,}31$
$$\sigma_0 = \frac{R}{d_2}$$

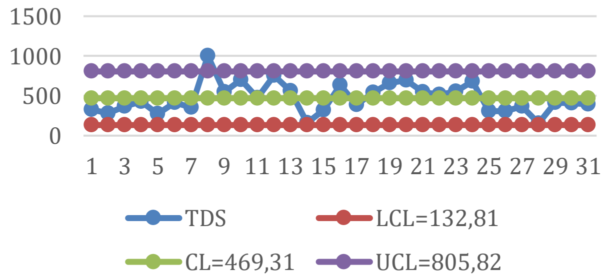
$$\sigma_0 = \frac{469{,}31}{3{,}25}$$
$$\sigma_0 = 144{,}405$$
Maka, $UCL_x = \bar{\bar{X}} + A \times \sigma_0$
$$UCL_x = 240{,}01 + 1{,}23 \times 144{,}405$$
$$UCL_x = 417{,}63$$

$$LCL_x = \bar{\bar{X}} - A \times \sigma_0$$
$$LCL_x = 240{,}01 - 1{,}23 \times 144{,}405$$
$$LCL_x = 62{,}39$$



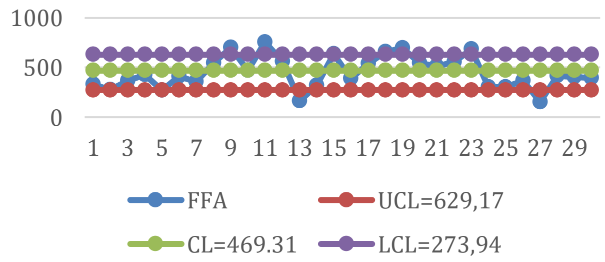
Where :
the horizontal axis is days, the vertical axis is TDS
Figure 8. Revision of $\bar{X}$ TDS Control Map

The calculation is then carried out to determine CL, UCL, and LCL. To determine CL, UCL, and LCL from the R control chart, the CL value is the same as the R-value, namely 469.3. Next, the CL, UCL, and LCL limit values are made into a graph, which produces the R control chart in Figure 9.



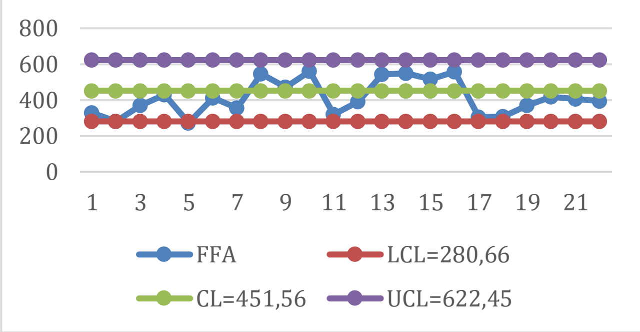
Where :
the horizontal axis is days, the vertical axis is TDS
Figure 9. R TDS Control Map

Based on Figure 9, some data exceeds the control limits on the control chart R; the data is defective on the 8th, so it needs to be revised by discarding out-of-control data.



Where :
the horizontal axis is days, the vertical axis is TDS
Figure 10. Revised R TDS Control Map

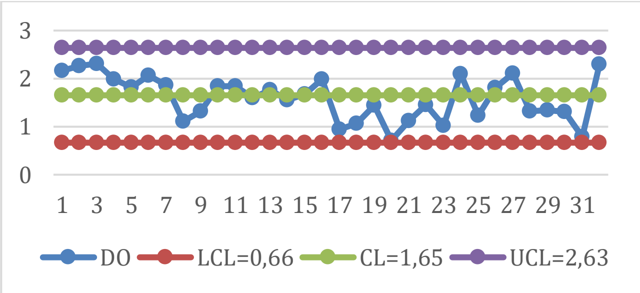
Based on Figure 10, some data exceeds the control limits, namely data on 9, 11, 13, 15, 18, 19, 23, and 27, so the data in the R control chart contains defective data and must be revised.



Where :
the horizontal axis is days, the vertical axis is TDS
Figure 11. Revised R TDS Control Map

Based on Figure 11, no data exceeds the limit, so the data in the R control chart is not defective and does not need to be revised.

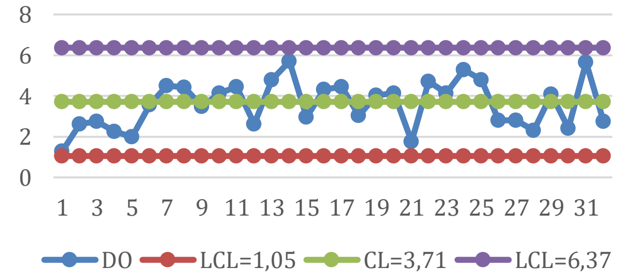
Map of $\bar{X}$ and R for DO (Dissolved Oxygen)



Where :
the horizontal axis is days, the vertical axis is DO
Figure 12. $\bar{X}$ DO Control Map

Based on Figure 12, no data is outside the control limits and exceeds the control limits, so the data on the $\bar{X}$, control chart does not need to be revised.

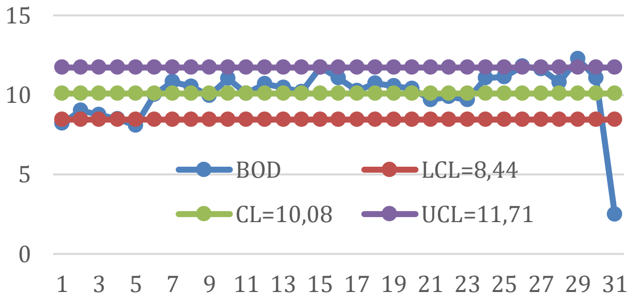
To determine CL, UCL, and LCL from the R control chart, the CL value is the same as the R-value, 3.70. Next, the CL, UCL, and LCL limit values are made into a graph, which produces a control chart R, as shown in Figure 4.13.



Where :
the horizontal axis is days, the vertical axis is DO
Figure 13. R DO Control Map

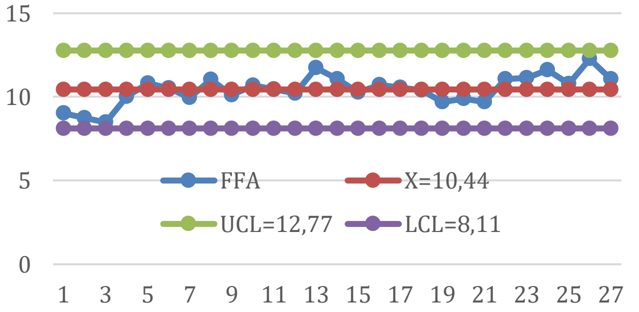
Based on Figure 13, no data exceeds the control limits. There is no defective data in the R control chart, so the data has not been revised.

$\bar{X}$ and R map for BOD (Biological Oxygen Demand)

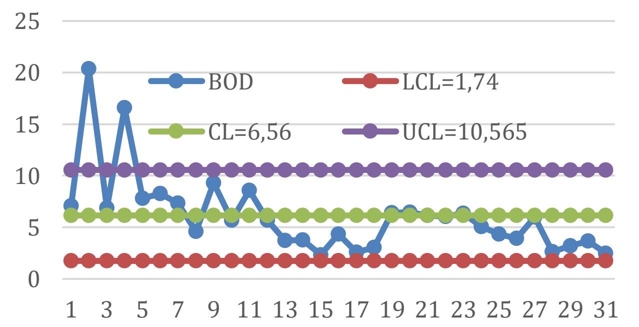


Where :
the horizontal axis is days, the vertical axis is BOD
Figure 14. $\bar{X}$ BOD Control Map

Based on Figure 14, some data is outside the control limits, namely on the 1st, 5th, 26th, 29th, and 31st, which exceed the control limits, so the data on the $\bar{X}$, control chart, the data must be revised.

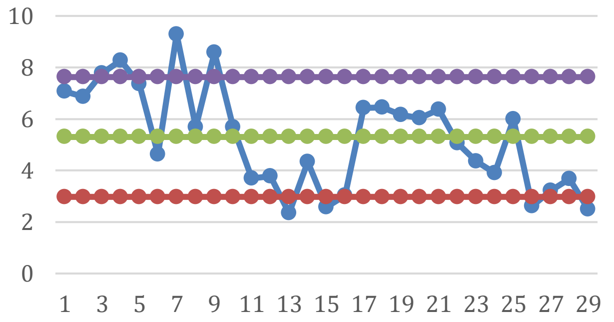


Where :
the horizontal axis is days, the vertical axis is BOD
Figure 15. Revised $\bar{X}$ BOD Control Map



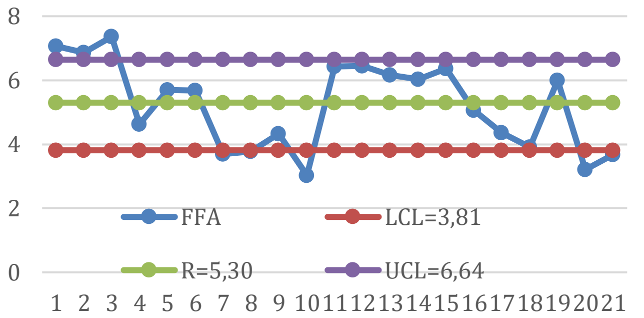
Where :
the horizontal axis is days, the vertical axis is BOD
Figure 16. R BOD Control Map

Based on Figure 16, some data exceeds the control limits, namely data on the 2nd and 4th, so the data in the R control chart contains defective data and needs to be revised.



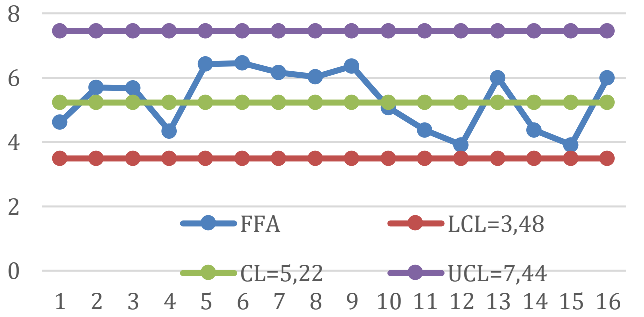
Where :
the horizontal axis is days, the vertical axis is BOD
Figure 17. Revised R BOD Control Map

Based on Figure 17, some data exceeds the control limits, namely data on the 3rd, 4th, 7th, 9th, 13th, 15th, 26th, and 29th, so the data in the R control chart contains defective data and must be revised.



Where :
the horizontal axis is days, the vertical axis is BOD
Figure 18. Revised R BOD Control Map

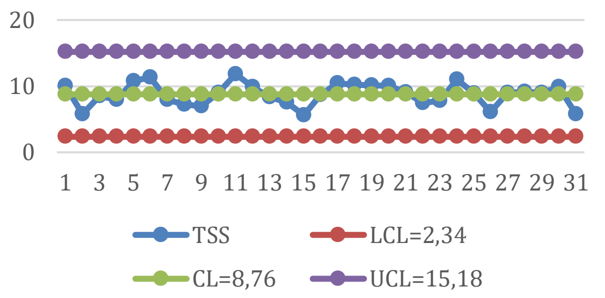
Based on Figure 18, some data exceeds the control limits, namely data on the 1st, 2nd, 3rd, 7th, 8th, 10th, 20th, and 21st, so the data in the R control chart contains defective data and must be revised.



Where :
the horizontal axis is days, the vertical axis is BOD
Figure 19. Revised R BOD Control Map
After the revision is carried out, the data is under control.

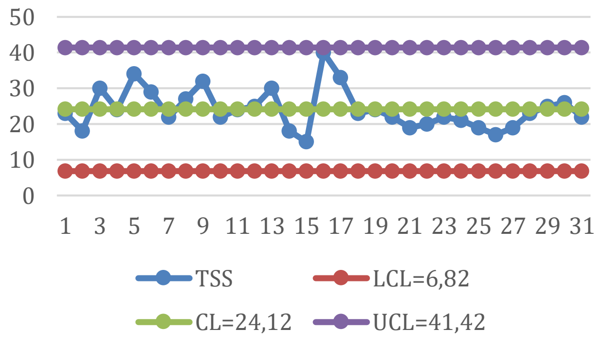
$\bar{X}$ and R maps for TSS (Total Suspended Solid)

Based on Figure 20, no data is outside the control limits, and that exceeds the control limits, so the data on the X¯ control chart does not need to be revised.



Where :
the horizontal axis is days, the vertical axis is TSS

Figure 20. $\bar{X}$ TSS Control Map

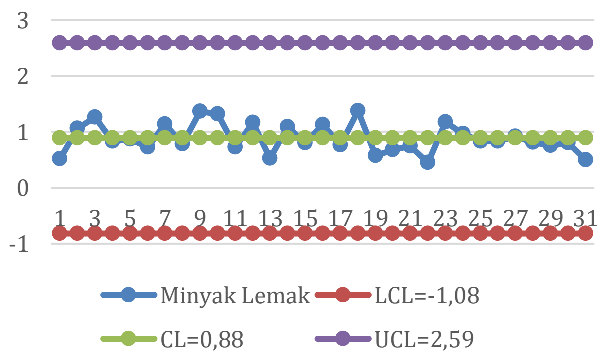


Where :
the horizontal axis is days, the vertical axis is TSS

Figure 21. R TSS Control Map

Based on Figure 21, no data exceeds the control limits, so the data in the R control chart does not contain defective data and does not need to be revised.

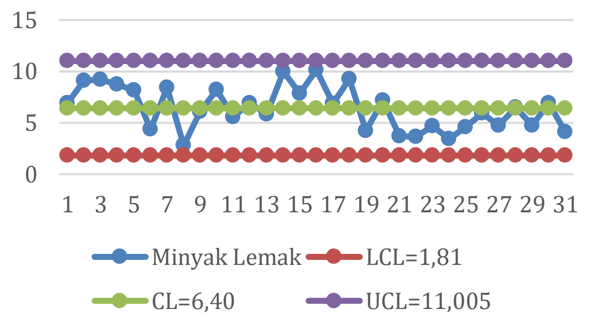
$\bar{X}$ and R maps for Fat Oil



Where :
the horizontal axis is days, the vertical axis is fat oil

Figure 22. Control Map $\bar{X}$ Fat oil

Based on Figure 22, no data is outside the control limits and exceeds the control limits, so the $\bar{X}$, control chart data does not need to be revised.



Where :
the horizontal axis is days; the vertical axis is fatty oil

Figure 23. Control map R Fatty oil

Based on Figure 23, no data exceeds the control limits, so there is no defective data and no need for revision.

Based on the results of quality control using SQC (Statistical Quality Control), it can be seen that SQC provides different analytical controls because in SQC the control of $\bar{X}$ TDS (Total Dissolved Solid) is controlled by 3 data, namely data on the 10th, 20th, and 21st, on R TDS data is controlled 2 times, the first control is data on the 8th, and the second control is controlled by 8 data, namely data on 9, 11, 13, 15, 18, 19, 23 and 27. At $\bar{X}$ BOD (Biological Oxygen Demand) is controlled by 4 data, namely data on the 1st, 5th, 26th, and 31st, and in R BOD, the data is controlled 3 times, the first control is controlled by 2 data, namely the data on the 2nd and 4th, the second control is controlled by 8 data, namely the data on the 3rd, 4th, 7th, 9, 13, 15, 26 and 29, and the third control is controlled by 8 data, data on dates 1, 2, 3, 7, 8, 10, 20 and 21.

From the analysis of the data above, TDS and BOD experienced control or revision due to unstable and fluctuating data, which was caused by the TDS and BOD content increasing due to the area around the source having lots of plants, then naturally forming humus compounds due to the weathering process or plant residues, which have been killed by microorganism activity, high mineral content, industrial waste pollution, and soil erosion. So, many solid substances are dissolved in the water [18].

The TDS and BOD values have decreased due to the addition of Ca(OCl)2 chlorine, which acts as an oxidizer to remove iron and manganese compounds dissolved in water [19]. Therefore, the more dissolved iron and manganese oxidized, the lower the TDS and BOD levels in the water [10]. So, indirectly, the increase or decrease in TDS and BOD values is directly proportional to the increase or decrease in the content of organic matter dissolved in water. Meanwhile, the $\bar{X}$ and R data on DO (Dissolved Oxygen), the $\bar{X}$ and R data on TSS (Total Suspended Solid) and the $\bar{X}$, and R data on fatty oil are under control.

Conclusion

Based on the data obtained, the water quality standards of the Deli River in the Sumatra II River Basin Agency from January 2023 to December 2023 have not been statistically controlled because several data samples are out of control. Then, the Deli River water quality is controlled based on the control chart using SQC (Statistical Quality Control). The results of quality control using SQC show that SQC provides different controls because in SQC, the TDS (Total Dissolved Solid) controls on times, the 1st control is data on the 8th, and the 2nd control is controlled by 8 data, namely data on 9, 11, 13, 15, 18, 19, 23 and 27. At $\bar{X}$ BOD (Biological Oxygen Demand) is controlled by 4 data, namely data on the 1st, 5th, 26th, and 31st, and in the R BOD, the data is controlled 3 times; the 1st control is controlled by 2 data, namely the data on the 2nd and 4th, the 2nd control is controlled by 8 data, namely the data on the 3rd, 4th, 7, 9, 13, 15, 26 and 29, and the third control is controlled by 8 data, data on dates 1, 2, 3, 7, 8, 10, 20 and 21. Meanwhile the $\bar{X}$ and R data on DO (Dissolved Oxygen), $\bar{X}$ and R data on TSS (Total Suspended Solid) and $\bar{X}$, and R data for fatty oil are under control.

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