

Construction of Control Charts for Drinking Water Treatment in Medani Station of Water Purification, Gezira State, Sudan

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Abstract

Water is one of the important natural resources of the earth, one of these resources is surface water. The objective of this study is to construct variable control charts, on data from Wad Medani Station for Water Purification (WSWP), to test the quality of five properties of tap water namely, pH, turbidity, total hardness, residual chlorine and Total Dissolved Solids (TDS). The samples were selected randomly to cover all the year days. Variable control charts (\bar{X} charts and \bar{R} charts) were constructed for the five properties, and then fresh 20 samples were taken and analysed, and then plotted on the charts. The average of pH was 8.1, one point of the pH was above the action limit in pH \bar{X} charts, two points were located below the lower limit, and five points were located above and below the warning limits and the other points were located within the stable limits. The average of turbidity was 35, in turbidity \bar{X} chart, it was found that the turbidity values varied by an unexpected amount, The average of residual chlorine was 0.2, one point of the residual chlorine was above the action limit in \bar{X} charts, two points were located above the warning limit and all the other points were located within the stable limits, this indicates that the process is under control. The average of TDS was 170, in \bar{X} Chart for TDS, most of points were located between upper and lower warning limits, three points were located above the warning limit and two points were located below warning limit, so the process is considered under control. The average of Total Hardness was 130, two points of the Total Hardness was above the action limit in \bar{X} charts, two points were located below the warning limit and the other points were located between upper and lower warning limits, so the process is considered under control. The study recommends the use of quality control charts beside the laboratories tests to monitor the process and study the seasonal change of the quality of the water in the untreated water from the river to the sedimentation basin.

Key words: Control Charts, Quality, Water Treatment, Surface Water.

1. Introduction:

Water is an important natural resource of the earth and has been essential for the existence of all living things, one of these sources is surface water, and this source is easily contaminated by animal and human wastes (*Imafuku, 1999*). Control charts are usually used quite extensively at the beginning of a new program, process or product, for all important operations and processes. Charts are removed as they are found to be unnecessary or the process stabilizes. Control charts are examples of the primary techniques of statistical process control (*Oakland, 2003*). Control charts (also called process chart or quality control chart) are graphs that show whether a sample of data falls within the common or normal range of variation. The objective of this study is to construct variable control charts, on data from Wad Medani Station for Water Purification (WSWP), to test quality of five properties of tap water namely, pH, turbidity, total hardness, residual chlorine and Total Dissolved Solids (TDS). (Control charts are used to control the water treatments process so as of not to be produce water that is not conforming with standards of good quality water) conforming water by controlling the treatment A control chart is a graph that contains a centreline, upper and lower control limits. The centreline represents the process average. The control limits represent the upper and lower boundaries of acceptability around the centreline. The horizontal axis represents sample numbers or points in time, and the vertical axis represents measurements from samples, as shown in the Fig bellow, Upper Warning Limit (UWL) and Lower Warning Limit (LWL) may also be added. Generally action is required if a result is beyond either of the control limits. The UWL and LWL are set at a level so that most of the results will fall between the lines when a system is running in control (*Walter A. Shewhart in 1920's*).

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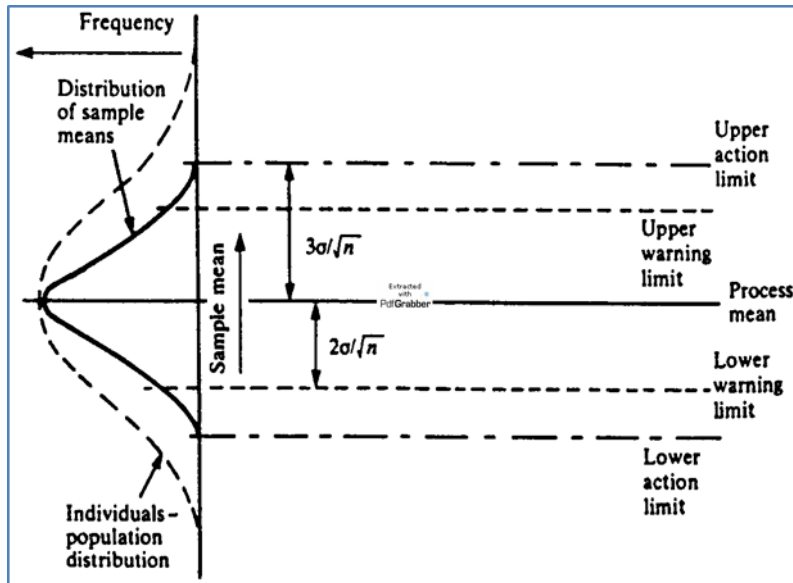


Fig (1) Statistical Basis of the Control Chart
Source :(Oakland,2003)

1.2 Uses of Control Charts:

Control charts are useful for analysing and controlling repetitive processes as they help to determine when corrective actions are needed, because they display running records of performance, control charts provide numerous types of information to management. (Montgomery, 2009). they are a useful tool for studying variation. The limits quality gives the control chart an analytical power to enable its user to determine whether a process can be considered stable and thus, predictable, or unstable, and unpredictable.

1.3 Equations Used for Construction of the Charts

1.3.1 Construction of Average charts or \bar{X} charts

Average charts are used for quantitative quality e.g. weights, volumes, compositions etc. If the measurements are normally distributed with a mean \bar{X} and standard deviation σ for a sample of (n) items then:

- Estimated Standard Deviation (S) = The Range (R)/ The factor (d_n) (1)

$$\sigma = R/d_n\sqrt{n} \quad (2)$$

- d_n is a factor which depends only on the sample size n as shown on table(2)

(For $n = 5$, $d_n=2.33$)

The limits of \bar{X} charts:

- Upper limits $\bar{X} \pm (3* \bar{R} /dn) \sqrt{n}$ (3)

- Lower limits $\bar{X} \pm (2* \bar{R} /dn) \sqrt{n}$ (4)

1.3.2 Construction of Range charts or \bar{R} charts

The limits of \bar{R} charts

- Upper control limits $\bar{R}*.D_{0.999}$ (5)

- Lower control limits $\bar{R} .D_{0.001}$ (6)

- Upper warning limits $\bar{R} .D_{0.975}$ (7)

- Lower warning limits $\bar{R} .D_{0.025}$ (8)

The multiplier D is obtained from samples table (2). There are tables of pairs of values $D_{0.999}, D_{0.001}, D_{0.975}, D_{0.025}$

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Table (1) Fresh 20 samples for the Five Properties of the Tap
Water Collected from Wad Medani Station of Water Purification

Samples No.	pH	Turbidity	Residual Chlorine	TDS	TH
1.	8.30	33	0.12	180	115
2.	8.25	35	0.20	179	130
3.	8.20	37	0.25	168	100
4.	8.30	33	0.58	16	110
5.	8.25	98	0.15	187	128
6.	8.42	37	0.20	184	138
7.	8.15	27	0.34	154	110
8.	8.20	18	0.28	167	147
9.	8.07	26	0.08	146	121
10.	8.16	28	0.09	199	150
11.	7.75	31	0.22	180	148
12.	8.00	31	0.29	160	100
13.	7.83	30	0.21	161	110
14.	7.85	29	0.10	195	147
15.	8.18	29	0.17	175	137
16.	8.00	32	0.20	156	157
17.	7.99	29	0.10	169	146
18.	7.96	30	0.06	147	144
19.	7.95	45	0.10	160	145
20.	7.65	36	0.36	165	143

Table (2) Relationship between Standard Deviation and Range and Control Chart Limits for Sample Range

Source: (Oakland, 2003)

Sample size (n)	For lower limits		For upper limits		Sample size N	Factor d_n
	$D_{0.001}$	$D_{0.025}$	$D_{0.975}$	$D_{0.999}$		
2	0.00	0.04	2.81	4.12	2	1.13
3	0.04	0.18	2.17	2.98	3	1.69
4	0.10	0.29	1.93	2.57	4	2.06
5	0.16	0.37	1.81	2.36	5	2.33
6	0.21	0.42	1.72	2.21	6	2.53
7	0.26	0.46	1.66	2.11	7	2.70
8	0.29	0.50	1.62	2.04	8	2.85
9	0.32	0.52	1.58	1.99	9	2.97
10	0.35	0.54	1.56	1.94	10	3.08

2.0 Materials:

In this study a 25 and 50 ml burettes, were used graduated in 0.1ml .25ml Conical flask 250 ml.,100 ml graduated cylinder. ,Wash bottle with distilled water., in this study also used the chemicals and reagents, were mainly brought from central laboratory of Medani Station for Water Purification and they are, Potassium chromate indicator solution., Standard silver nitrate titrant., Standard EDTA titrant., buffer solution., Ammonia NH_3 , Ammonium pupurate (murexide).,Erio Chrome Blank T (ECB), and ammonium chloride.

2.1 Apparatus:

pH meter [HACH (2000)], Turbidity meter [HACH (2100 N IS)], and TDS meter [HACH (2000)] were used in this study .

2.2 Methods:

The data of five properties of tap water namely pH, Turbidity, Residual chlorine, Total Hardness, TDSs were collected from (WSWP), the sample size was equal to 5 observed data and the subgroups were equal to 10.

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Variable control charts (\bar{X} charts and \bar{R} charts) were constructed for the five properties, and fresh 20 samples were taken and analysed, then plotted on the charts, using Mat lap software program. The charts were used to observe and evaluate the behavior of the process overtime and corrective action taken if necessary.

The methods include measurement of properties which were chosen for the study and the experimental work was carried out in central laboratory of Wad Medani Station for Water Purification (WSWP), The methods are explained below:

2.2.1 Total Hardness test:

25 ml of sample was put in 50 ml graduated cylinder and diluted to a total volume of 50ml, then the sample was poured into 250ml conical flask, and 1ml of the pH buffer solution was added to the sample and adjusted to 10 with ammonium chloride/hydroxide solution **eriochrome** black was added as indicator and a red color resulted followed by titration versus EDTA disodium salt and the end point the color changed from red to blue, the volume of EDTA used to reach the end point was recorded, then the result in mg /l calcium carbonate was recorded.

2.2.2 Chlorine Test:

For chlorine test, 1ml of potassium chromate indicator solution was to the **sample** added and titrated with standard silver nitrate titrant to a pinkish yellow as the end point then the volume of silver nitrate was recorded.

2.2.3 Turbidity Test:

The method of analysis of turbidity was done using HACH (2100 N IS) turbidity meter and the results were reported in nephelometric turbidity unit (NTU).

2.2.4 pH and TDS Tests:

The pH and TDS tests of water sample were measured using pH and TDS mrters.

3.0 Results and Discussions:

The tables below show the control chart limits for \bar{X} and \bar{R} charts which were calculated from equations in section 1.3

Table (3) The Control Chart Limits which were used to construct the charts Calculated by Equations shown in section (3)

	The Average (X)	The Range (R)	Standard Deviation (S)	UCL	LCL	UWL	LWL
pH	8.09	0.45	0.191	1.05	0.07	0.81	0.17
Turbidity	35.20	15.67	6.73	36.98	2.50	28.36	5.97
Residual chlorine	0.20	0.33	0.012	0.78	0.05	0.59	0.12
Total dissolved solid	168.40	40.80	17.5	96.28	6.53	73.85	15.09
Total hardness	132	38.57	16.55	91.00	6.17	69.80	14.27

	UCL	LCL	UWL	LWL
pH	9.25	8.73	8.99	882.00
Turbidity	44.22	26.18	41.22	29.18
Residual Chlorine	0.34	0.07	0.29	0.12
Total Dissolved Solid	191.92	144.90	233.08	103.77
Total Hardness	154.20	109.70	146.80	117.19

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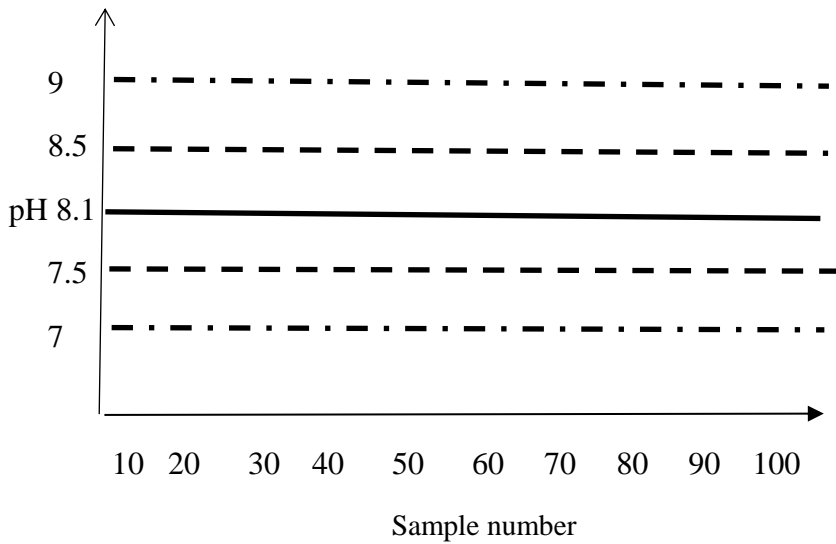


Fig (3.1): \bar{X} Chart for tap water pH

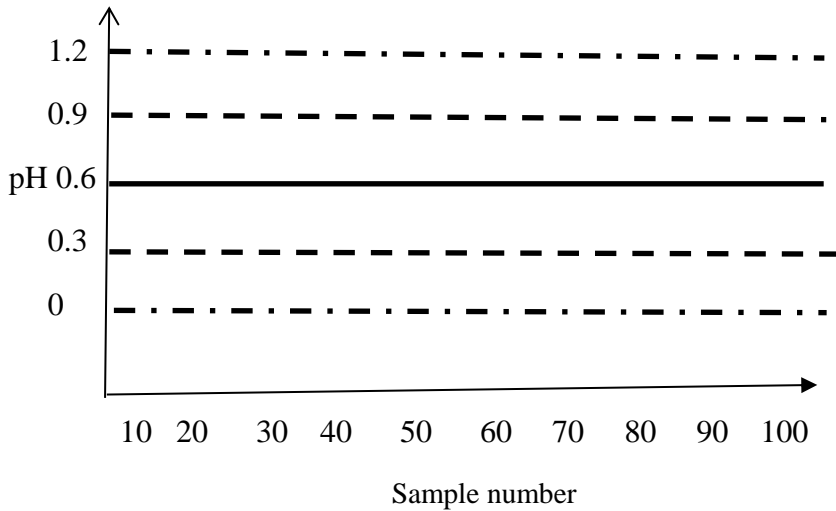


Fig (3.2) : \bar{R} Chart for tap water pH

Source: Own calculations based on secondary sample from (WSWP)

One point of the pH was above the action limit in pH \bar{X} charts, two points were located below the lower limit, five points were located above and below the warning limits and the other points were located within the stable limits. This means the cause for violation points must be searched for, then must check the process line shift to find out the reason behind this deviation and must be removed.

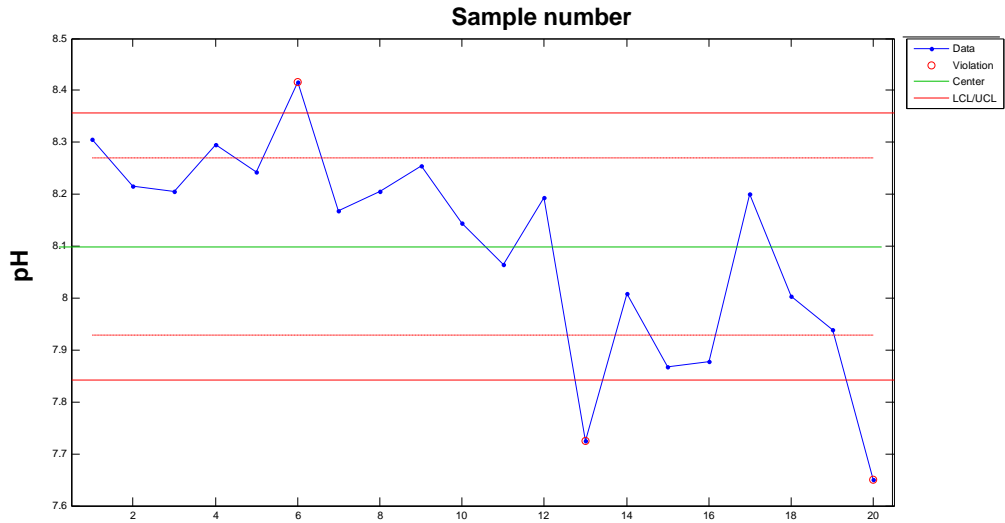


Fig (3.3) \bar{X} chart of pH for Tap water
Source: Own experimental work

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Control charts for Turbidity of Tap Water:

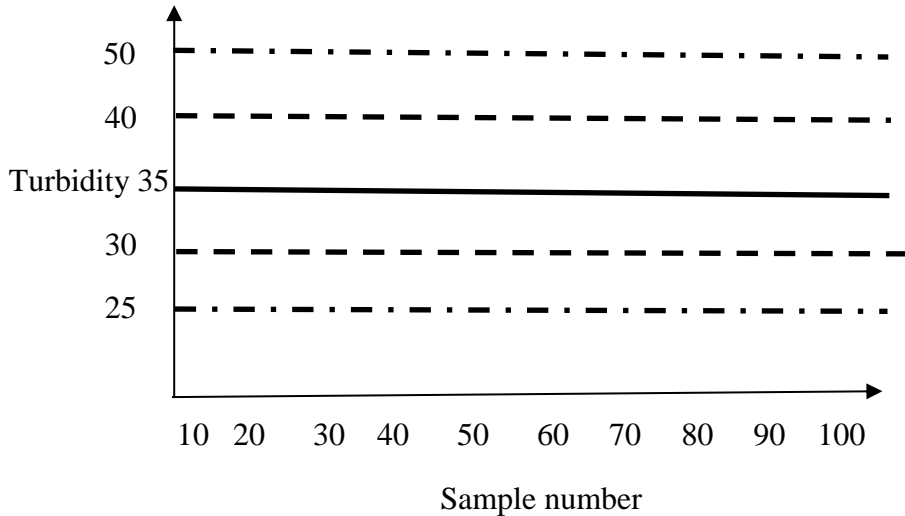


Fig.(3.4): \bar{X} Chart for tap water turbidity

Source: Own calculation based on secondary sample from (WSWP)

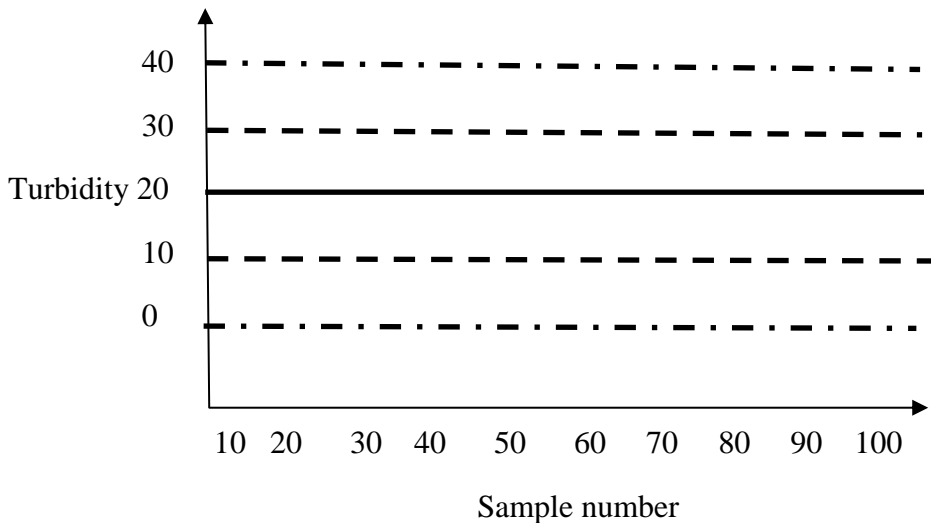


Fig.(3.5): \bar{R} Chart for tap water turbidity

Source: Own calculation based on secondary sample from (WSWP)

In turbidity \bar{X} chart, it was found that the turbidity values have been varied by an unexpected amount.

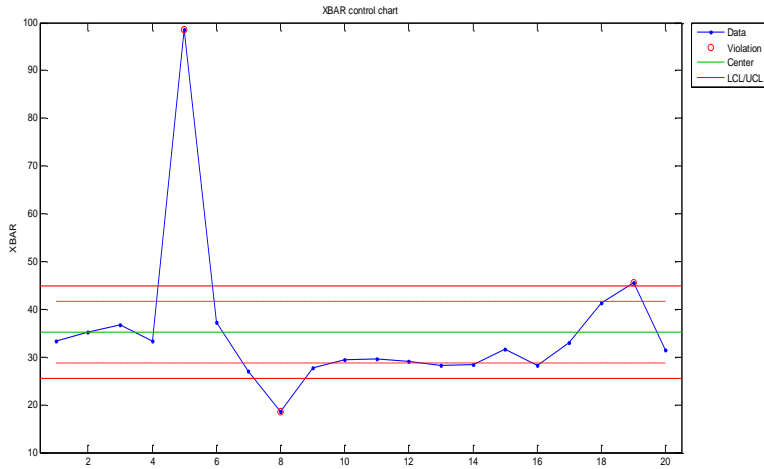


Fig (3.6) \bar{X} chart of Tap water turbidity

Source: Own experimental work

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Control charts for Residual Chlorine:

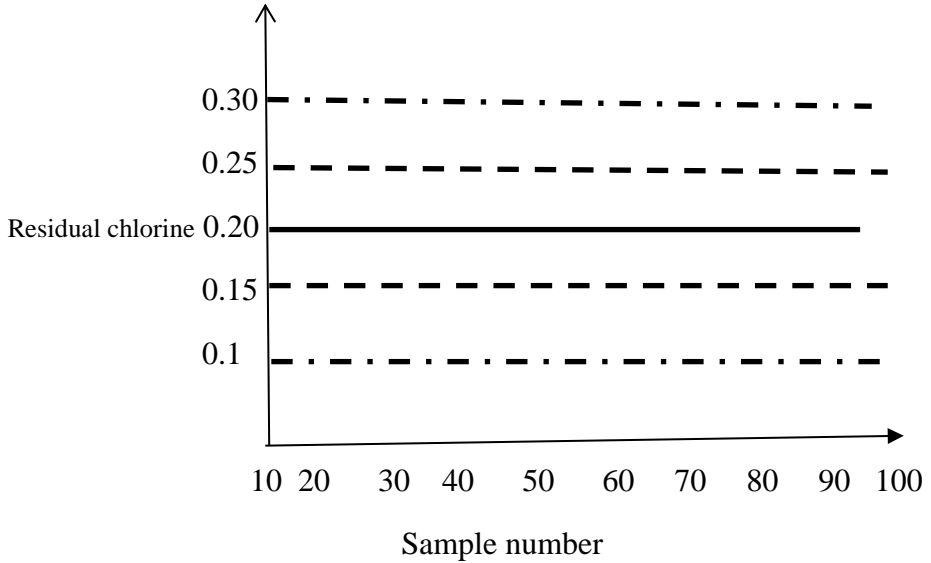


Fig.(3.7): \bar{X} Chart for residual chlorine

Source: Own calculation based on secondary sample from (WSWP)

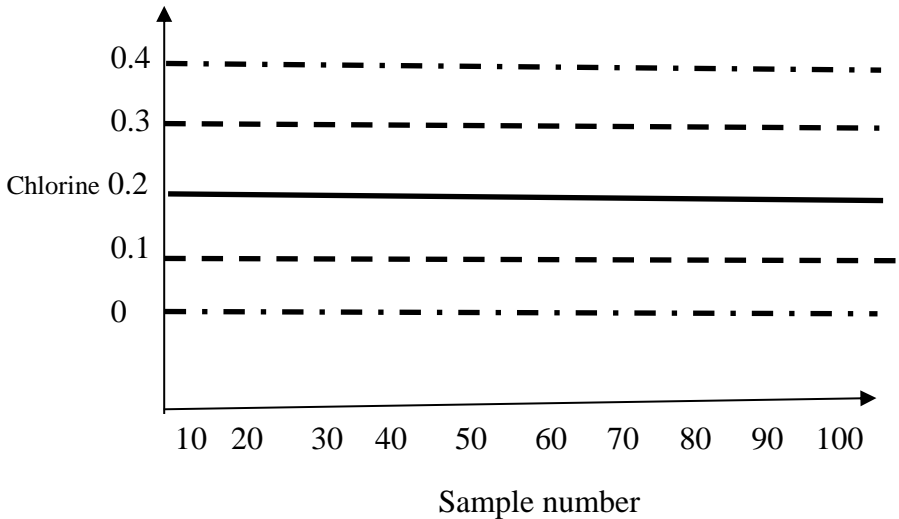


Fig.(3.8): \bar{R} Chart for tap water chlorine

Source: Own calculation based on secondary sample from (WSWP)

One point of the residual chlorine was above the action limit in residual chlorine \bar{X} charts, two points were located upper the warning limit and all the other points were located within the stable limits this indicates that the process is under control.

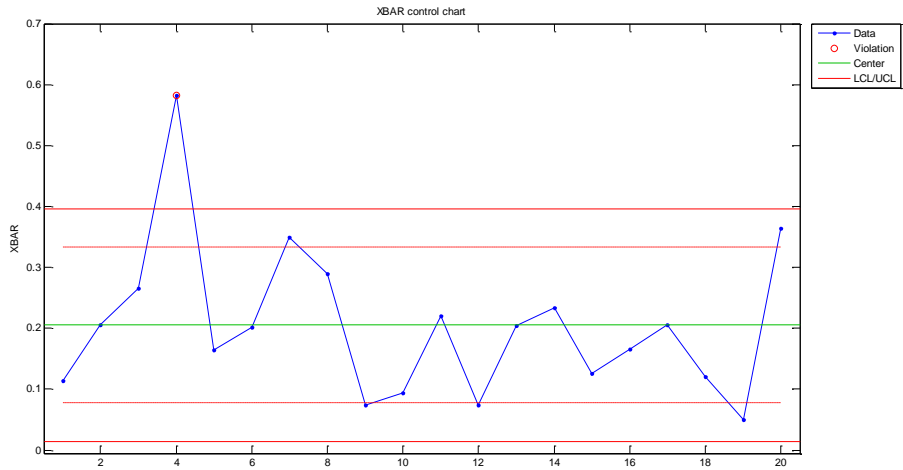


Fig (3.9) \bar{X} chart of Residual Chlorine

Source: Own experimental work

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Control charts for Total Dissolved Solids (TDS):

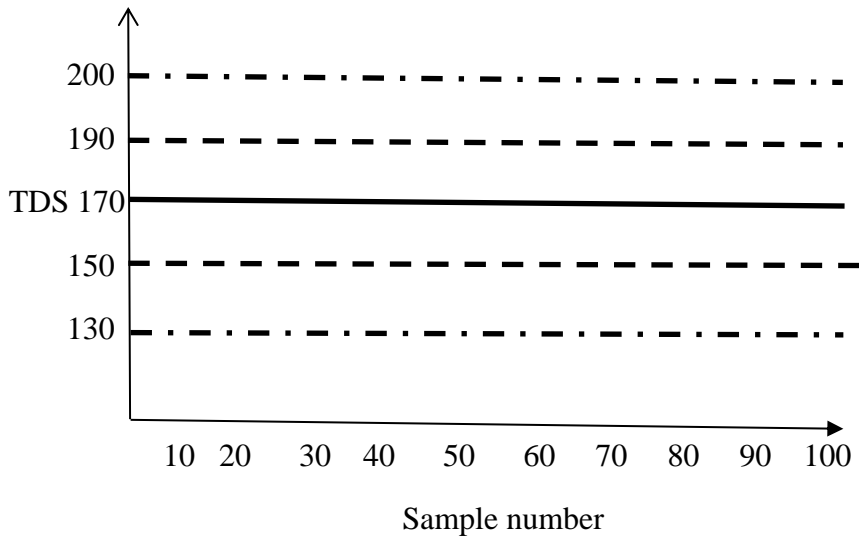


Fig.(3.10): \bar{X} Chart for TDS

Source: Own calculation based on secondary sample from (WSWP)

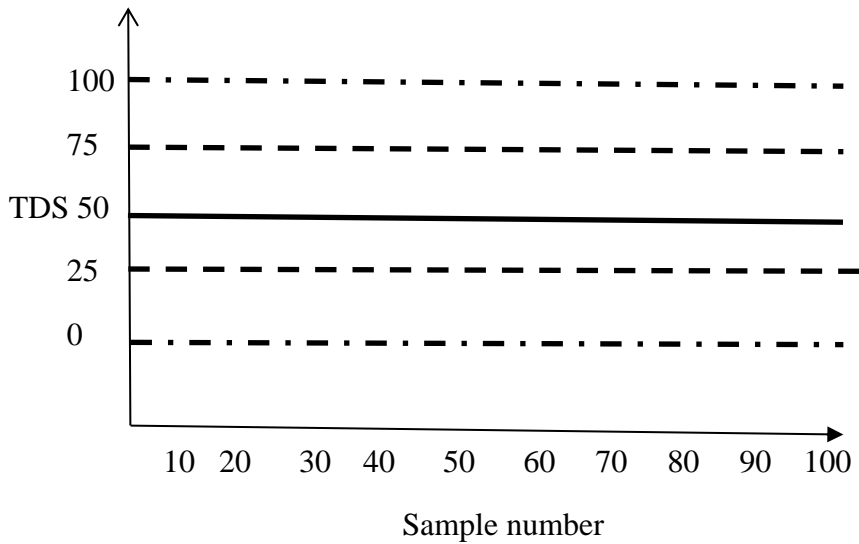


Fig.(3.11): R Chart for TDS

Source: Own calculation based on secondary sample from (WSWP)

In \bar{X} Chart for TDS, most of points were located between upper and lower warning limits, three points were located upper the warning limit and two points were located below warning limit, so the process considered under control.

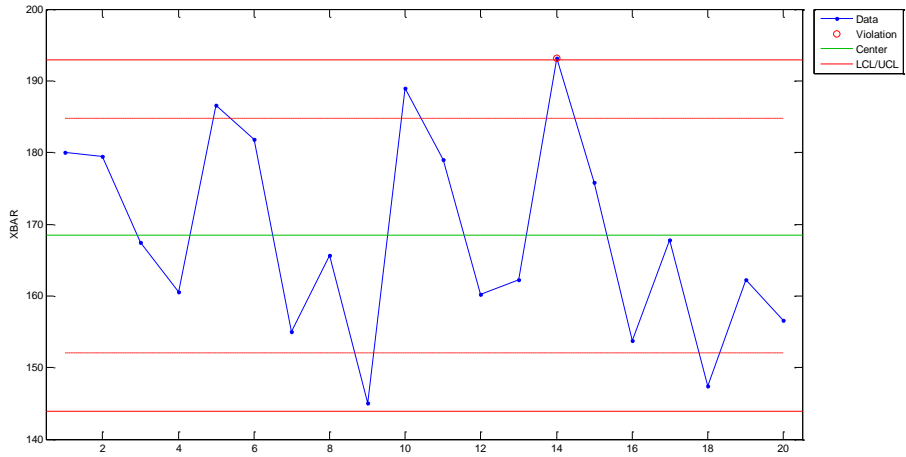


Fig (3.12) \bar{X} chart of TDS
Source: Own experimental work

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Control charts for Total Hardness:

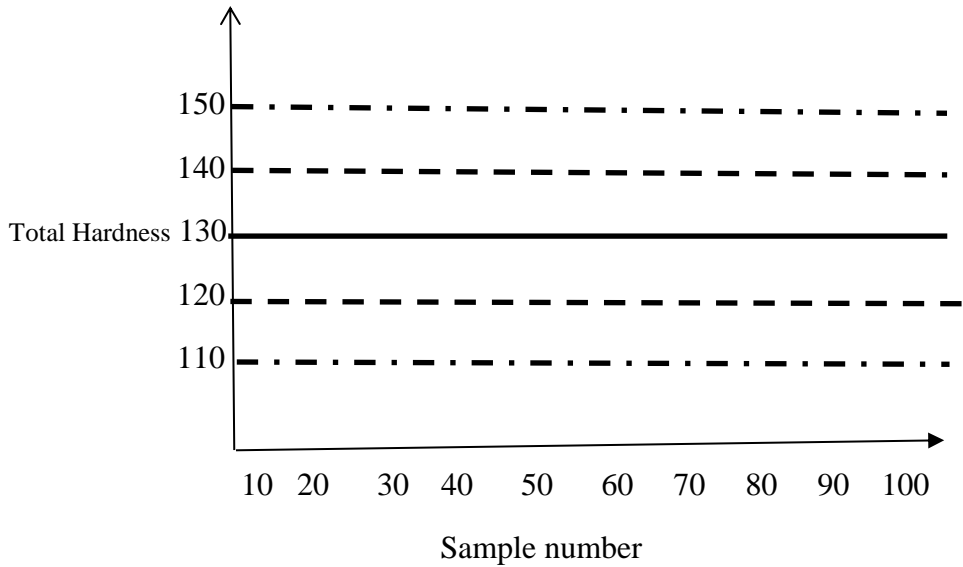


Fig.(3.13):X̄ Chart for total hardness

Source: Own calculation based on secondary sample from (WSWP)

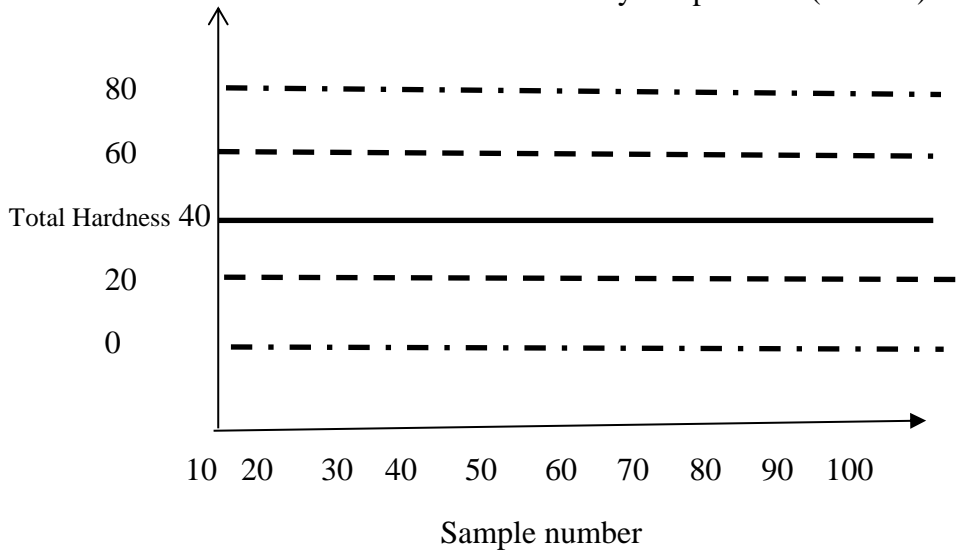


Fig.(3.14):R̄ Chart for Total Hardness

Source: Own calculation based on secondary sample from (WSWP)

Two points of the Total Hardness was above the action limit in Total Hardness \bar{X} charts, two points were located below the warning limit and the other points were located between upper and lower warning limits, so the process considered under control.

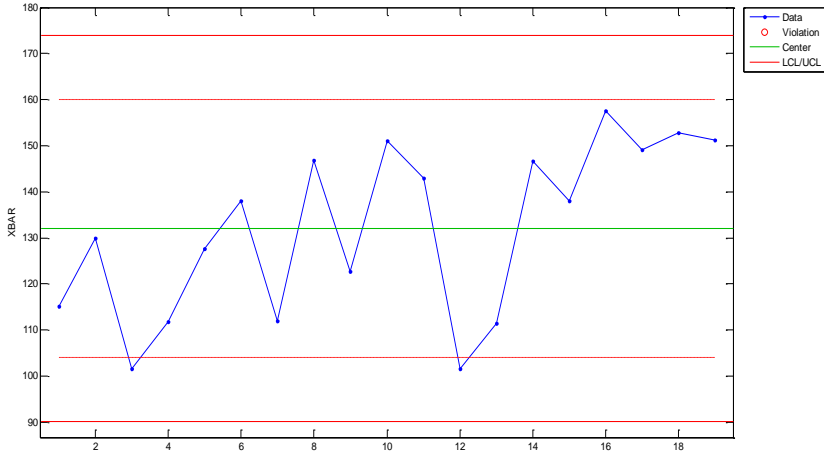


Fig (3.15) \bar{X} chart of Total Hardness
Source: Own experimental work

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