PARTICLE COUNTING IN RIYADH WATER DISTRIBUTION NETWORK

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ABSTRACT: Particle counting is considered a good and sensitive indicator of drinking water quality and its changes. In this study, particle counting was evaluated in Riyadh Water Distribution Network. Results indicated that small size particles ($\leq$ 1.0 μm) are the dominant. Counts for sizes $\geq$ 25 μm were almost negligible ($\leq$ 1.0 NP/ml). The average system total particle counts, turbidity, and total dissolved solids were found to be 12928 NP/ml, 0.38 NTU, and 290 mg/l with maximums of 15835, 2.12, and 476 and minimums of 3190, 0.0, and 228, respectively. No sign of significant water quality deterioration was detected. Particle size distribution, however, was nearly identical with wide variation among sample counts.

1. INTRODUCTION

Particle counters are instruments that enumerate and size particles in water and other process fluids. Their basic components are the sensor and a data processing device called counter. They employ light scatter, obscuration, or electrical resistance measuring systems to analyze one particle at a time [1]. Most instruments can be used to analyze individual samples or installed on-line for real time monitoring of continuously flowing process streams.

Particle counting is a two-dimensional measurement established technology commonly used in medicine, oceanography, manufacturing processes and electronics. Particle counts and size distribution data have broad applicability for use in water treatment process control, design and selection, as well as monitoring of water quality. It is a sensitive indicator of water quality that has been used successfully in drinking water treatment processes [1-4]. Particle counting provides more information with greater sensitivity because particles are individually sized and enumerated. It can measure water clarity and its nature can be related to the quantity of present particles or their sizes, shapes, and chemical nature. Turbidity, however, is a one dimensional measure of water clarity that has been used as measure of water quality for many years. It is caused by the interaction between light and particles with sizes ranging between 1 nm to 1 mm, where its sensitivity depends on the type of instrument used. Good correlation between these two parameters (particle counts and turbidity) have been reported mainly for on-line sampling of particles greater than or equal to 1 μm [5].

Particulate matter in water distribution systems may result from incomplete removal of particles during treatment, pipe material itself, and system line repair. Particles may interfere with disinfection by protecting viruses and bacteria within the treatment plant or in the distribution system [6]. Water quality, in terms of total particle counts (TPC), was also reported to degrade as water within the distribution system moves across the network with

reported to degrade as water within the distribution system moves across the network with the assumption that the longer it is held in distribution lines the greater the potential for increased bacterial counts, turbidity, particles, and decrease or total loss of chlorine residual. The Riyadh Water Distribution Network (RWDN), with its nearly 9000 Km of pipes varying in age, size, and type of used materials, is expected, to a certain extent, to have changes in its water quality. Factors that are expected to cause such changes include pipe condition and water scheduling. Studies have indicated that gross leakages in the RWDN varied from 9 to 67% of the total water supplied through the network where the highest level belonged to the oldest and most developed areas of the city [7].

The continuous increase in water demand has necessitated its scheduling across the city districts. The water is interrupted within the distribution network sections for periods up to 3 days during Summer. In 1993, the average daily water consumption of the city was 1.15 Mm^3, 65% of which was desalinated sea water and the remaining 35% was treated groundwater. As water is fed to the distribution system, its quality meets the local and international standards due to the different types of treatments it receives.

The objective of this paper is to present the results of the preliminary first work in its kind to be carried out on particle counting and distribution in RWDN.

2. MATERIALS AND METHODS

A total of 20 locations were sampled within the RWDN representing different districts of the city, Figure 1. The samples were collected from lines leading to home water meters and public buildings during normal operating periods. For particle analysis, samples were collected in 300 ml particle-free glass, while the other parameters were collected in 300 ml plastic bottles. At each location, water was allowed to flow for 5 min before samples were collected.

Particles were counted with a Hiac/Royco Model 9064 Particle Size Analyzer (Pacific Scientific, Menlo Park, Co.) equipped with a Hiac/Royco HRLD Sensor. The size range of particles that can be counted with this sensor is 0.5 to 350 μm. Twenty five ml of the sample were allowed to flow through the sensor. All analyses were done in triplicate and the average values are reported. Ten particle size ranges were selected as follows: 0.5-1, 1-2, 2-4, 4-6, 6-8, 8-10, 10-20, 20-30, 30-40, and 40-50 μm; giving an average value of 0.75, 1.5, 3, 5, 7, 9, 15, 25, 35, and 45 μm each, respectively. A calibrated HACH 2100P turbidimeter was used for turbidity measurements. Total dissolved solids were determined according to standard methods [8].

3. RESULTS AND DISCUSSION

3.I Particle counts and size distribution

Detailed results of turbidity, TDS, and TPC obtained from samples collected from the designated locations are shown in Table 1. The average, maximum, and minimum TPCs are plotted against the particle arithmetic mean size for samples collected from those locations, Figure 2, recording some total counts of 12928, 15835, and 3190 number of particles/ml (NP/ml), respectively. The minimum value was for a sample collected from Alakeek district in the far north side of the city, while the maximum was for a sample collected from Salah-Aldeen district north of the city center.

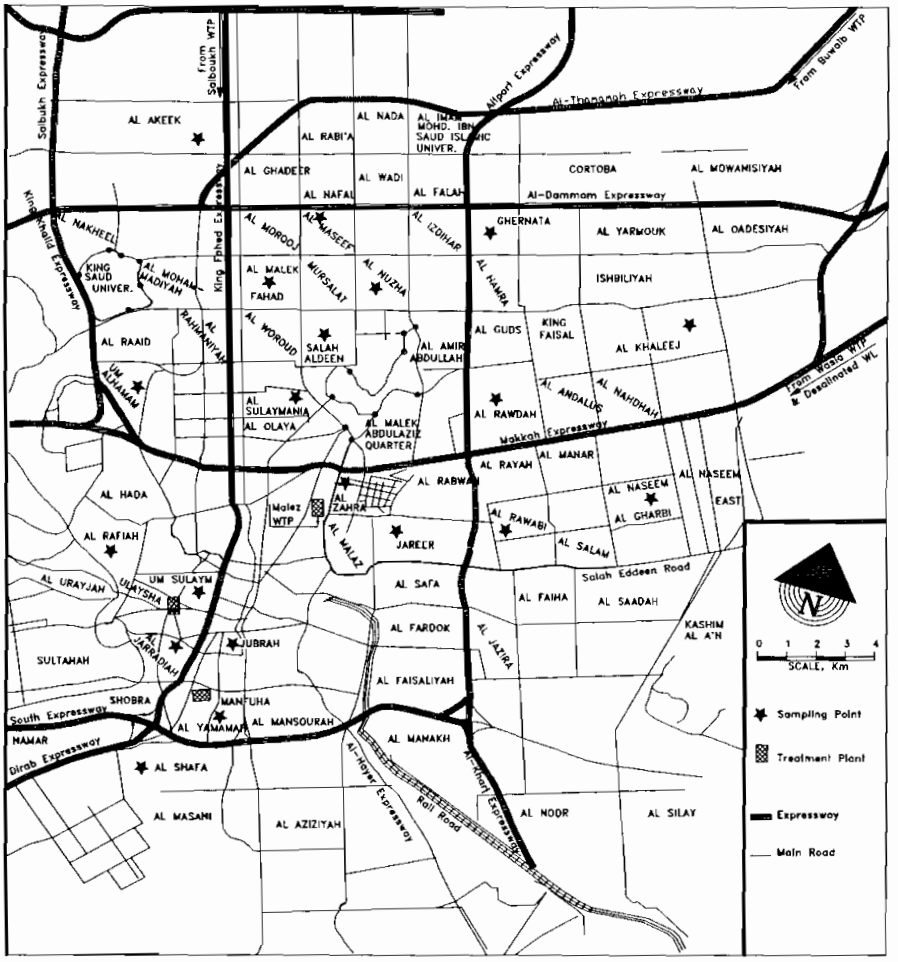

Figure 1: Distribution of sample locations within Riyadh city.

The general trend of particle counts is skewed to the left as distributed within the network. As can be noted, there is a clear indication that small size particles are higher in number than the larger ones. The number of particles whose sizes are between 3-7 μm is in the hundred counts; while those whose sizes are between 9-15 μm constitute around 10 NP/ml. Sizes >15 μm were almost negligible (below 1 NP/ml). In general, there is a wide variation between sample particle counts (from 3190 to 15835 NP/ml) that might be associated with the nature of source waters and the network condition.

The cumulative total NP/ml less than or equal to a particular size for all collected samples is shown in Figure 3. As shown, 50% of the samples have a TPC $\geq$ 14000 NP/ml while none has exceeded 15835 NP/ml. In an on-line study of similar nature conducted on the municipality drinking waters of Los Angeles (LA) and Hollywood (HYW) counties, in south California, results have shown an average, maximum, and minimum TPCs of 98085,

Table 1. Detailed results of TDS, turbidity and TPC from sample locations.

Location	Turbidity, NTU	TDS, mg/L	TPC, NP
Ghernata	0.27	270	8211
Al Akeek	0.00	312	3190
Al Maseef	0.17	268	11903
Al Nuzha	0.15	260	14879
Al Sulaymania	0.18	262	6915
Salah Aldeen	0.41	270	15835
Almalek Fahad	0.26	282	15117
Um Alhamam	0.29	324	14411
Al Jarradia	0.13	476	9165
Um Sulaym	0.29	432	11813
AL Shafa	0.24	256	15246
Al Yamamah	0.40	260	13557
Jubrah	0.27	260	12925
Al Rafia	0.32	258	15586
Al Zahra	0.23	280	14189
Jareer	0.25	260	15221
Al Rawabi	0.98	282	14692
Al Naseem Algharbi	2.12	276	15645
Al Rawdah	0.50	228	15385
Al Khaleej	0.24	274	14701

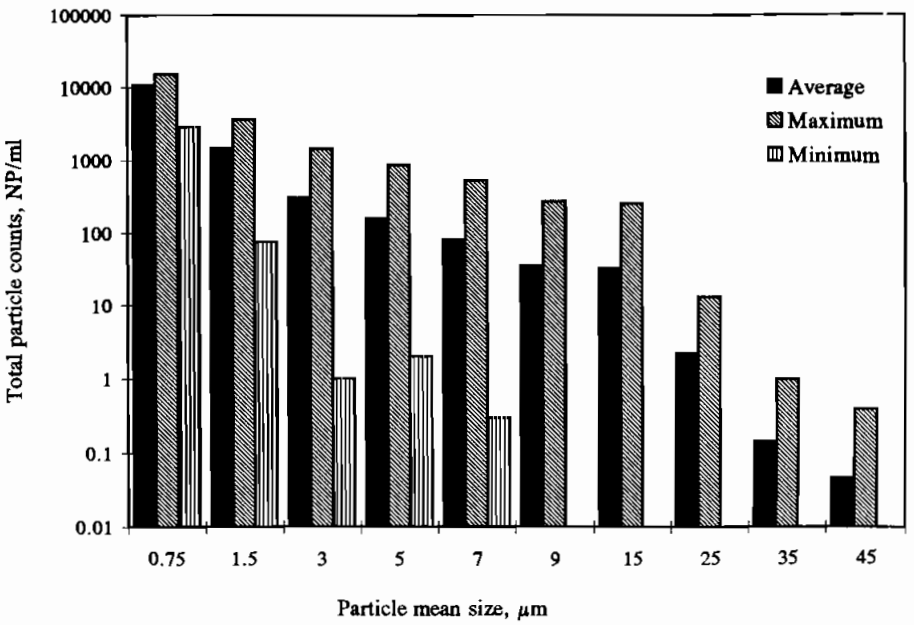

Figure 2: Samples particle counts distribution in Riyadh Water Distribution Network.

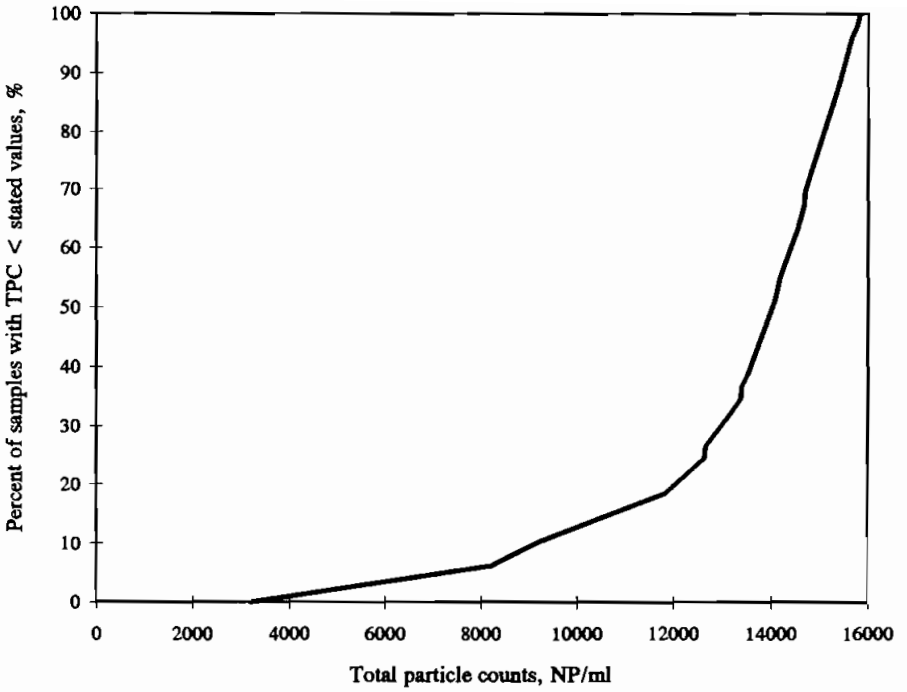

Figure 3: Cumulative distribution of total particle counts in Riyadh Water Distribution Network.

185758, and 52688 NP/ml for LA and 63352, 114895, and 42359 for HYW, respectively. As compared to Riyadh municipal water supply, these counts are very much higher than even the maximum counts of 15385 recorded in the present study. These high counts were attributed to the intermittent short events occurring in south California municipal water supply [6].

Summary of statistical analysis for samples mean value of TPC, turbidity, and TDS is given in Table 2. On the basis of these results TDS levels in RWDN are far below the maximum contaminant levels (MCLs) set by the Saudi Standard Organization (SASO), World Health Organization (WHO), and the United States Environmental Protection Agency (USEPA). The mean recorded TDS value in the network was 290 mg/l. Turbidity values were also below the MCLs set by the 3 agencies; with the exception of only one sample which recorded a turbidity value 2.12 NTU (exceeding USEPA standards of 1.0 unit). This means that, the quality of supplied water in RWDN meets local and international standards with respect to turbidity and TDS. Correlation between particle counts and turbidity proved to be unsatisfactory (R^2=0.119) for particles $\geq$ 0.5 μm. Good correlations between the two fore mentioned parameters have been obtained in studies conducted in California, USA. However, unlike the present study, good correlations were obtained from fixed same locations with time as being the variable.

Table 2. Summary of statistical analysis for samples average value of total particle counts, turbidity, and TDS collected from RWDN.

Parameter	MCL SASO	MCL WHO	MCL EPA	Avg. value	Max. value	Min. value	SD
Total Particles, $NPml^{-1}$	___	___	___	12928	15835	3190	3465
Turbidity, NTU	5-25	1-5	1	0.38	2.12	0.0	0.45
TDS, mgl^{-1}	1500	1000	500	290	476	228	60.2

Max. : Maximum Min. : Minimum SD : Standard Deviation

4. CONCLUSION

The mean TPC within RWDN was found to be 12928 NP/ml with a nearly identical size range distribution in all sampled sections of the network with a wide variation among total counts. Comparison of sample particle counts and size ranges showed that counts are increasing with decreasing sizes and no sign of significant water quality deterioration was detected. This is due to the fact that samples were collected during normal operating conditions. More than 50% of the samples have a TPC $\geq$ 14000 NP/ml.

Based on the results of this preliminary study detailed research should be conducted on water quality as it enters the distribution network as well as the effect of water distribution scheduling on water quality changes.

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