Journal of
Chemical Engineering Research & Reviews

Akbari MR. J Chem Eng Re Rev: JCERR-103
Doi.org/10.47378/JCERR/2023.1.100103

Research Article Open Access

Dilution or Mixing Degree Determination in Drinking Water Distribution Network. Conductivity Equation

***Spec. Juan Daniel Ruiz Diaz director LABQUIAM-FACENA UNNE**
Assoc Prof. Analytical Chemistry, The Overall Analytical Process Associate Professor; FACENA-UNNE Environmental Chemistry Laboratory Director
**Veterinary Doctor Laura Mariel Vazquez, Food Technology Chair- Veterinary Sciences School - UNNE
***Dr. Francisco Antonio Vazquez Technical director COVESA Paso de la Patria Corrientes Argentina
Full Professor of Analytical Chemistry and Regular Professor of The Overall Analytical Process. -Retired from UNNE Argentina. Category II Investigator Coneau Argentina.

***Corresponding author:** Juan Daniel Ruiz Diaz, Assoc Prof. Analytical Chemistry, The Overall Analytical Process Associate Professor; FACENA-UNNE Environmental Chemistry Laboratory Director. Email: jdrdiaz@yahoo.com

Citation: Diaz JDR (2023) Dilution or Mixing Degree Determination in Drinking Water Distribution Network. Conductivity Equation. J Chem Eng Re Rev: JCERR-103.

Received Date: April 14, 2023; **Accepted Date:** April 21, 2023; **Published Date:** April 25, 2023

Summary-Abstract
A method was developed to manage the quality and quantity of drinking water distribution to the community of Paso de la Patria-Corrientes, Argentina, based on household water conductivity measurements. The method allows deciding (operating) on the relative mixing degree of supply water quantities, from the supply sources of the company rendering the service: surface water (Paraná River) treatment plant and two groundwater boreholes of lower quality due to their high saline and iron content. An equation that links the conductivities of the treatment plant water and the water from the borehole that simultaneously feeds the distribution network was designed. Thus, determining the mixing degree (in %) at each point of the distribution network.

Keywords: Conductivity, Quality, Drinking water, Supply.

Introduction

Since time immemorial, the dilemma of the sanitation agencies responsible for drinking water supply has been the resolution of the "demand satisfaction based on the premises of quality and quantity" controversy. This paper is an effective contribution to solving this controversy. Based on a case study, Paso de la Patria, Corrientes, Argentina.

It is evident that the importance of having water for the supply of communities, even today, continues to pose challenges to meeting the provision of such a precious commodity for human sustenance with suitable quality.

Supplying enough water with suitable quality characteristics is almost always a challenge. The common drawbacks are the need to treat the available resources to bring them into compliance with the above-mentioned requirements.

There are many treatment mechanisms and they range in complexity of physicochemical principles and operating costs. Thus, surface water can be treated through conventional mechanisms to adapt its nature to the suitability standards for human consumption; in the same way, a groundwater source can also be treated by physicochemical procedures to meet drinking water requirements.

It is common knowledge that surface water (river, stream, lake, etc.) cannot be distributed without prior treatment. In the case of groundwater, with very few exceptions, it must also be treated, in the best of cases, only for disinfection and in most cases to reduce its saline content or to eliminate undesirable dissolved substances (in our area, iron is a very frequent case).

The water distribution management agency often encounters the need to prioritize water quality over quantity to satisfy the needs and demands of the population served, which requires sufficient water with acceptable quality within drinking water standards.

Supply sources available to the Paso de la Patria, Corrientes, Argentina community: a conventional physicochemical treatment system based on coagulation with aluminum sulphate, sedimentation, and filtration, with final disinfection, using fresh water from the Paraná River. It also has two water wells that supply water distributed at times of very high demand in an attempt to meet population needs. These boreholes deliver water that does not meet the quality requirements due to its high saline content (high conductivity) and iron content in an amount that turns it unsuitable, which although it may be tolerable, confers unpleasant colour and taste properties.

Based on the principles of chemistry, mainly analytical chemistry, using its laws, standards, and rules of mass and stiequiometric balance and its mixtures rules, a method is developed for the management of solutions concentrations that do not involve chemical reactions in themselves but govern the properties of mixtures and dilutions.

This paper presents the physicochemical characteristics of the raw or fresh water from the Paraná River, the water resulting from the treatment performed at the COVESA treatment plant, which supplies water for consumption by the Paso de la Patria population, and the water characteristics of two wells, located at opposite ends of the distribution network of about 10 km in length, used to supplement the water supply to the population when demand warrants it. Tables 3-4-5-6. Studies show the composition of the two boreholes that are used only when demand requires it and there is no other alternative due to the water resource scarcity.

These two boreholes are located at the ends on both sides of the distribution network, one in the Pescadores neighbourhood and the other in the Judiciales neighbourhood.

For example, Paso de la Patria is a major tourist center, the biggest in the Corrientes province, which twice a year, once in August during the national Dorado fishing season and again during the summer months, welcomes tourists who increase its population four or fivefold, which means that there is a shortage of water during these months. Consequently, the water supply agency (COVESA) is forced to choose the quantity-quality of the water and its supply to the population served, by enabling the boreholes whose water quality is deficient even though considered suitable according to the current standards.

Therefore, this tool offers COVESA, the producer and distributor, the possibility to determine the quality of the entire distribution network by simply measuring water conductivity. This tool involves an equation based on the conductivity values at three different locations, the water conductivity at the treatment plant, the water conductivity at the well feeding the network area under study, and the water conductivity at the home/network site under consideration. With this information, it is thus possible to decide whether or not to alter the ratios or mixing degree of the water supplied by modifying the flow rates to the network from the water treatment plant, to meet the seasonal demand with the best quality, by regulating as much as possible the mixing degree of the water from the plant with that from the wells to attenuate by dilution the undesirable characteristics of the water from the wells.

The study aimed to identify the parameters that affect electrical conductivity and evaluate the percentage contribution of these parameters. The correlation matrix shows that colour, total dissolved solids (TDS), chloride (Cl), fluoride (F), total phosphorus (TP), total alkalinity (TA), calcium (Ca), magnesium (Mg), sodium (Na), and dissolved oxygen (DO) have a significant effect on the electrical conductivity (EC). Among these parameters, TDS has the highest contribution (39.65%) followed by total alkalinity (23.5%), total hardness (19.9%), chlorine (6.5%), and calcium (5.5%) ions, respectively. However, colour, TP, fluoride, and DO have almost 1.45% contribution to the electrical conductivity. (Arun Kumar Shrestha and col. 2018)

Several water quality indices are used to evaluate water suitability for potable use; however, every index has strengths and weaknesses which limits the applicability and ease of use. There is a need to develop a universally accepted water quality index (WQI) which is flexible enough to represent drinking water suitability all over the world. (Arun Kumar Shrestha and col. 2019)

In this case, the developed and proposed method is not a quality index and does not qualify as such. Drinking water quality is one of the greatest factors affecting human health. However, drinking water quality in many countries, especially in developing countries is not desirable and poor drinking water quality has induced many waterborne diseases. This special issue of Exposure and Health was edited to gain a better understanding of the impacts of drinking water quality on public health so that proper actions can be taken to improve the drinking water quality conditions in many countries. This editorial introduction reviewed some latest research on drinking water quality and public health, summarized briefly the main points of each contribution in this issue, and then some research fields/directions were proposed to boost further scientific research in drinking water quality and public health. (Arun Kumar Shrestha and col. 2019)

The RWQI (Raw Water Quality Index) was developed in compliance with deterministic models, in order to assess the treatability of natural waters for human consumption by means of conventional process, based on the similar procedure of the well-known Water Quality Index developed by the National Sanitation Foundation (WQI NSF). The RWQI, however, seemed to require further adjustments regarding mainly rating criteria. In order to find a non-deterministic model that would allow handling uncertainties, the non-linearity of the parameters, and the knowledge of the specialists, the Fuzzy Logic was used in a new approach to the RWQI. In this context, the new index (named Raw Water Quality Index Fuzzy - RWQIF) was applied to data set of 24 water sources in Brazil evaluating the correlations with the RWQI, the WQI CETESB, treated water turbidity, and coagulant dose. The inverse correlation between the RWQIF with coagulant dose and treated water turbidity was obtained. However, the low intensity of these correlations indicated that there are other intervening factors in this relation. Finally, this research points out the RWQIF as a suitable support decision-making tool that allows managers to prioritize watershed protection actions in the short, medium, and long-term, aiming at minimizing the water treatment costs and improving the treated water quality. (Mariângela Dutra de Oliveira and Col. 2019).

Although these findings are taken into account at the time of applying conventional treatment to water from the Paraná River, this method cannot be considered as a quality index, as already stated earlier.

In the 1980s, steady-state and dynamic models of water quality in distribution systems were developed. The 1990s saw the development of EPANET as a research tool and the basis for most of the commercial models in use today. Other developments included modeling chlorine and trihalomethanes in the distribution system, modeling water quality in tanks, and design of chlorine booster systems. Water quality models were used in hindcasting to assess water quality contamination events in distribution systems and legal cases resulting from groundwater contamination. In the 21st century, water security became a major driver in much of the research related to water quality modeling in distribution systems. The development of EPANET-MSX facilitated modeling of multiple interacting species. Real-time water quality modeling looms as an important direction for future water quality modeling. (Walter M. Grayman, 2018)

Materials and methods

Quality control laboratory of the COVESA drinking water treatment plant in Paso de la Patria. Simple basic laboratory materials, plus a portable conductivity meter and a portable Hach turbidimeter. The laboratory test was carried out by standard procedures (APHA methods), With the application of chemistry concepts, principles, laws, and theories, mainly those related to analytical chemistry, and especially those related to solution concentrations and their mixture rules, in cases where only dilutions are involved. And in cases where chemical reactions are involved, the fundamental laws of conservation of matter plus those of stoichiometry arising from chemical reactions must also be considered.

A simple laboratory test has been designed and implemented to confirm the original speculation of the proportional variation of conductivity with the degree of dilution. Determining the mixture ratios of waters with different salt content and their respective conductivity to elucidate the equation that governs this process.

Although it can be a prior stated that the conductivity value of the mixture varies linearly according to the degree of mixing, in this case, given the characteristics of the mixed waters, however, both mixtures were tested independently at the COVESA plant laboratory: first, plant water with well water from the Pescadores neighbourhood Table 1, Figure 1; and then, plant water mixed with well water from the Judiciales neighbourhood Table 2, Figure 2. Thus, any uncertainty due to possible variations caused by the interaction of different water compositions coming from different sources is ruled out.

The laboratory test is simple and requires preparing mixtures of the water treated at the plant with the water from each well one at a time, increasing ratios, and measuring their conductivity. At the extremes of this function (straight line) you have, on one end, pure plant water (lower conductivity) and at the other end, pure well water (higher conductivity).

The intermediate mixtures are arranged on a straight line according to their relative ratios between the two aforementioned endpoints. From this chart (straight line), the resulting equation can be calculated to determine the degree of mixing by simply measuring the conductivity of household water supplied.

Determination of the mixing degree between treatment plant-produced water and water supplied by boreholes.

$$y = aX + b$$

$$X = \frac{(Y - b)}{a}$$

Y = network sample conductivity
X = well water percentage
***b** = plant-produced sample conductivity*
a = (well water conductivity - plant water conductivity) / 100
a = (Y - b) / X given a numerical value (slope of the straight line).

Some examples applied to the Judiciales neighbourhood:

Plant: 58 µS/cm - Well: 284 µS/cm-a = (284 -58) / 100 = 2.26

1.- Street water tap - Virgen de Itati: 206 µS/cm
2.- Punta arena beach: 60 µS/cm
3.- Jardin Hotel: 60 µS/cm
4.- Jorge Lopez: 58 µS/cm

Mixing degree of well water at the Judicial neighbourhood
1.- (206 – 58) / 2.26 = 65.5 % well water
2.- (60 – 58) / 2.26 = 0.9 % well water
3.- 0.9 % well water
4.- 0.0 % well water

Borehole in Pescadores neighbourhood			
	% Plant Water	**% Well water**	**Conductivity µS/cm**
1	100	0	58
2	90	10	100
3	80	20	142
4	70	30	185
5	60	40	227
6	50	50	269
7	40	60	311
8	30	70	353
9	20	80	396
10	10	90	438
11	0	100	480

Table 1: mix from the water treatment plant and the Pescadores neighbourhood water well.

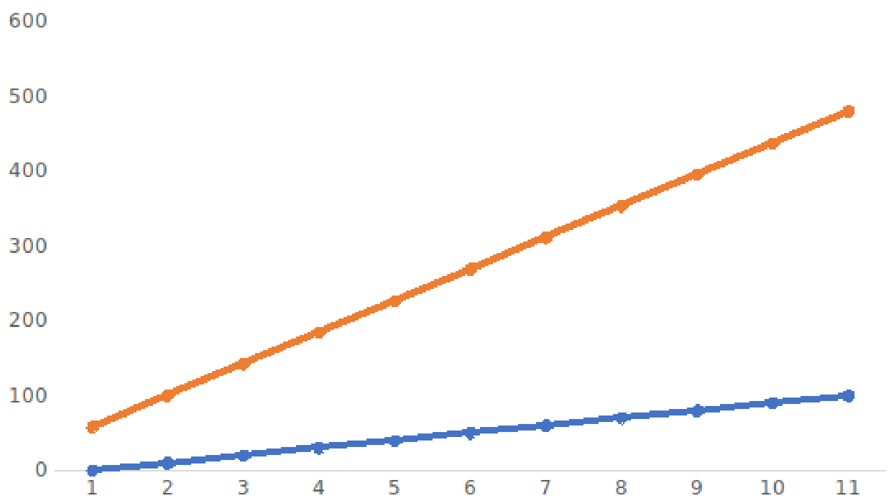

Figure 1: water mix from the plant - from the Pescadores neighbourhood water well.

Ref: red line conductivity vs. mixture percentage and blue line well water percentage from

Borehole in Judiciales neighbourhood			
	% Plant Water	**% Well water**	**Conductivity µS/cm**
1	100	0	58
2	90	10	77
3	80	20	96
4	70	30	116
5	60	40	135
6	50	50	154
7	40	60	173
8	30	70	192
9	20	80	212
10	10	90	231
11	0	100	250

Table 2: mix from the water treatment plant and the Judiciales neighbourhood water well.

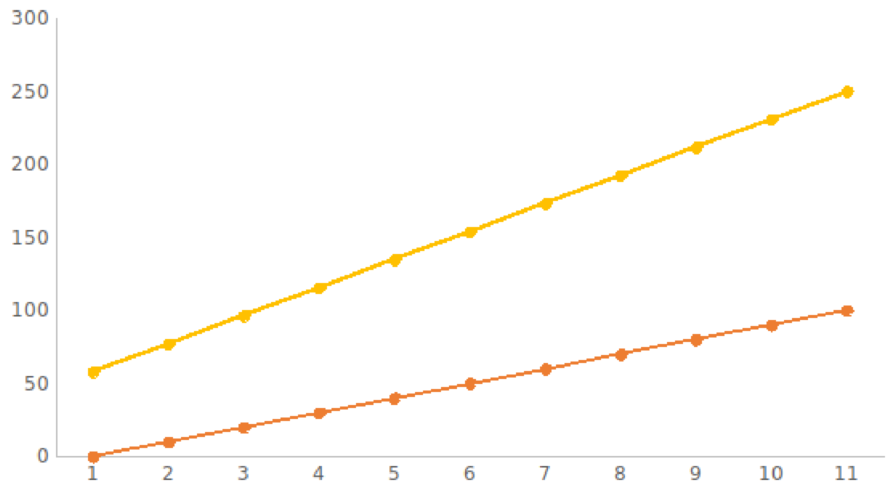

Table 2: mix from the water treatment plant and the Judiciales neighbourhood water well.

Ref: Yellow line conductivity vs. mixture percentage and red line well water percentage

Remarks: the tests are performed on the same day, therefore, plant conductivity and both well water conductivities are as shown in the tables and charts. Given that conductivity varies from time to time, especially plant water conductivity. This is considered in the equation, by calculating the value of a (slope of the straight line) when the mixing degree determinations are made and with the corresponding values for both water wells located at the Judiciales and Pescadores neighbourhoods, respectively.

Brief (short) water analysis results.

Requested by: COVESA
Scope: Potability

Label: **Type:** Water
Origin: Pescadores Nbhd **Reference:**
Extraction site: Well **Extraction Date:** 11/12/2019
Water temperature (ºC): **Time:**

PHYSICOCHEMICAL ANALYSIS

			REFERENCE (CAA)
COLOUR		**< 2**	**< 5**
TURBIDITY	**UNT**	**1.10**	**< 3**
CONDUCTIVITY	**µS/cm**	**480**	
pH		**6.8**	**6.5-8.5**
HARDNESS	**mg/L**	**76**	< 400
CHLORIDES	**mg/L**	**53**	**< 350**
ALKALINITY	**mg/L**	**240**	
Iron	**mg/L**	**1.1**	

Table 3. Pescadores neighbourhood well water analysis

Label: **Type:** Water
Origin: Rio Paraná **Reference:**
Extraction site: **Extraction Date:** 11/12/2019
Water temperature (ºC): **Time:**

PHYSICOCHEMICAL ANALYSIS

			REFERENCE (CAA)
COLOUR		**4**	**< 5**
TURBIDITY	**UNT**	**12**	**< 3**
CONDUCTIVITY	**µS/cm**	**68**	
pH		**7.10**	**6.5-8.5**
HARDNESS	**mg/L**	**12**	< 400
CHLORIDES	**mg/L**	**8**	**< 350**
ALKALINITY	**mg/L**	**24**	

Table 4. Rio Paraná water analysis

Label: **Type:** Water
Origin: Water well in Judiciales neighbourhood
Reference:
Extraction site: **Extraction Date:** 11/12/2019
Water temperature (ºC): **Time:**

PHYSICOCHEMICAL ANALYSIS

			REFERENCE (CAA)
COLOUR		**< 2**	**< 5**
TURBIDITY	**UNT**	**< 1.0**	**< 3**
CONDUCTIVITY	**µS/cm**	**250**	
pH		**6.8**	**6.5-8.5**
HARDNESS	**mg/L**	**30**	< 400
CHLORIDES	**mg/L**	**28**	**< 350**
ALKALINITY	**mg/L**	**112**	
Iron	**mg/L**	**0.76**	

Table 5. Judiciales neighbourhood well water analysis

Label: **Type:** Water
Origin: Water Treatment Plant
Reference:
Extraction site: **Extraction Date:** 11/12/2019
Water temperature (ºC): **Time:**

PHYSICOCHEMICAL ANALYSIS

			REFERENCE (CAA)
COLOUR		**< 2**	**< 5**
TURBIDITY	**UNT**	**0.5**	**< 3**
CONDUCTIVITY	**µS/cm**	**58**	
pH		**7.10**	**6.5-8.5**
HARDNESS	**mg/L**	**8**	< 400
CHLORIDES	**mg/L**	**4.3**	**< 350**
ALKALINITY	**mg/L**	**14**	
Iron	**mg/L**	**< 0.10**	

Table 6. Treatment Plant water analysis

Conclusions

A specific decision-making tool was designed for management decisions related to the quality of water collected, treated, and distributed to a very prominent tourist community in Corrientes, Argentina, based on expertise in chemistry, particularly analytical chemistry, proven through a very simple conductivity measurement exercise in the COVESA Paso de la Patria treatment plant's quality control laboratory. Thus, it is possible to decide the mixing ratio of plant water with well water to be supplied, managing the feed and pumping flow to the distribution network, and therefore regulating the relative mixing degree to be distributed to the community based on the demand, with the best possible quality.

$$Y = a X + b \qquad X = (Y - b) / a$$

Y = network sample conductivity
X = well water percentage
b* = *plant-produced sample conductivity
***a* = (well water conductivity - plant water conductivity) / 100**

Acknowledgment
A very special thanks to the goodwill and cooperation of COVESA Paso de la Patria - Corrientes - Argentina authorities for allowing us to use the Plant's facilities and equipment for conducting this research exercise.

References

1. Dutra de Oliveira Mariângela, Teixeira de Rezende Oscar Luiz, Freitas Ramos de Fonseca Juliana, Libânio Marcelo. "Evaluating the surface Water quality index fuzzy and its influence on water treatment". Journal of Water Process Engineering 32 (2019) 100890. journal homepage: www.elsevier.com/locate/jwpe. Elsevier
2. Grayman Walter M., "HISTORY OF WATER QUALITY MODELING IN DISTRIBUTION SYSTEMS". 1st International WDSA / CCWI 2018 Joint Conference, Kingston, Ontario, Canada – July 23-25, 2018
3. Peiyue Li and Jianhua Wu, "Drinking Water Quality and Public Health". Exposure and Health https://doi.org/10.1007/s12403-019-00299-8 © Springer Nature B.V. 2019
4. Shrestha Arun Kumar and Basnet Nabin, "The Correlation and Regression Analysis of Physicochemical Parameters of River Water for the Evaluation of Percentage Contribution to Electrical Conductivity" Hindawi Journal of Chemistry Volume 2018, Article ID 8369613, 9 pages.
5. https://doi.org/10.1155/2018/8369613
6. Shrikant Mukate a, Vasant Wagh a, Dipak Panaskar a, James A. Jacobs b, Akash Sawant c, "Development of new integrated water quality index (IWQI) model to evaluate the drinking suitability of water" Ecological Indicators 101 (2019) 348–354, journal homepage: www.elsevier.com/locate/ecolind