Sampling Frequency determination in water quality monitoring stations with attitude to consumption patterns reform to reduce costs

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Abstract: Consumption patterns reform means applying correct way of using resources. Due to the excessive use of chemicals for measurement of physicochemical parameters of water, the high volume of wastewater, environmental pollutions, Selection of quality parameters and the sampling frequency for water quality analysis are important for the reform of consumption. A large amount of water quality monitoring network costs is due to sampling sequence. Also usability of the collected data are depends on the sampling frequency. In water resource monitoring programs, the number of hourly and seasonal sampling are determined according to qualitative and quantity parameter type, characteristics of water source and sampling frequency. The number of parameters and sampling at each station was determined using the formulas presented. Given the above analysis of the physicochemical parameters significantly reduced, which reduces costs and less time to spend.

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Introduction

The consumption patterns reform means applying correct way of using each country resources, cause promotion in life indexes and reduce costs. In other hand, necessity of the best use, cause a scientific improvement in designing equipment equal to the high standard and it is an opportunity for the best distribution. The consumption patterns reform need a permanent acculturation and this in turn need techniques to obligate people of society to have correct consumption and make it as a stable behavior in all of scopes [1, 2].

Many factors influence the health of aquatic ecosystems and the plant and animal life that depend on them. These factors include physical habitat, riparian function, water quantity, watershed health, and water quality. This guidebook focuses on methods for monitoring water quality. Monitoring involves a series of observations, measurements, or samples collected and analyzed over time [3] . Water quality varies naturally with location and time. Pollution can be defined as the fouling or making unclean air or water which harms beneficial uses. Water pollution is generally characterized as originating from either "point" or "nonpoint" sources. Point source pollution is associated with a particular site on a stream and typically involves a known quantity and type of pollutant that can be controlled at the site. An example of point source pollution is effluent from a factory outlet (an endof- pipe discharge) delivered directly to a stream [4-6].

Many reasons exist for monitoring water quality. Monitoring can be used to identify areas w here water quality standards are not being met and resources such as salmon and trout are being impaired. Monitoring can also be used to identify the sources and loads of pollutants that are causing these declines [7]. Once the areas and causes of these water quality problems have been identified, then monitoring can be used to measure the overall effectiveness of the water quality protection efforts and individual practices. Monitoring is also important when know ledge of the effects from past restoration treatments or past management practices are desired in order to help design future management actions. Resource managers need monitoring data to improve practices and to better protect fish and fish habitat. The monitoring process and the data generated can also provide a valuable educational tool for a wide variety of user groups, such as watershed councils, school groups, researchers, and other interested people [8, 9]. Main Features of the Monitoring Station are:

Integrated

One terminal for all sensors and interfaces.

Plug & Measure

Just connect the local waterpipe, switch on the power, and start to measure.

Cost Efficient

No reagents. No replacement parts except membranes of the ISEs. Manual or automatic cleaning. Minimum maintenance hours.

Most Comprehensive Contamination Warning System
Inline with EPA Guidance on Planning for Contamination Warning System Deployment, May 2007.
Modular
Select any modules/parameter combination you need. A solution for every budget. Simply add more modules whenever you need to.
Minimal Maintenance
The maintenance interval of a station is dependent on its weakest link. We just do not allow any weak link. Remote maintenance reduces field visits to a minimum. 1 visit/month is sufficient for many applications.
Reduces complexity to an absolute minimum
One software, one user interface, one data format, one remote access tool for an unbelievable range of parameters.
Compact
The most compact station for analytical parameters in the world.
Bypass Line
Service any sensor without interrupting the flow.
Minimises the need for local infrastructure
No need anymore to build houses, chambers or containers. Just put your modules into a waterproof cabinet. Requires only 10% of the space of conventional analyser stations.

Attach the modules on a flat wall, around the corner, put them in a cabinet or install them in a field enclosure
Uniform Flow-Through Cells
Allows simple and fast ordering, exchange and maintenance of sensors [10-13].

Due to the excessive use of chemicals for measurement of physicochemical parameters of water, the high volume of wastewater, environmental pollutions, Selection of quality parameters and the sampling frequency for water quality analysis are important for the consumption patterns reform. Confidence interval (CI) formula is:

$$CI = 2 \times Z\alpha/2 \times \delta/\sqrt{n} \quad (1)$$

Which $Z\alpha/2$ and n are 1.96 and number of samples in a year, respectively [14, 15].

Method
Selection of water quality parameters

Selecting water quality is one of the most important steps for designing and exploiting of water quality monitoring network. Water quality is usually specified by physical, chemical and biological parameters. These are corrected and determining their relations is complicated. However these are necessary for specified of water source butt measuring all of them is not economical, so they should be Classification spatial and temporal and some of them should be selected for sampling. Multi-criterion analysis is a classification method for determining quality parameters priority. Accidental changes of temporal and spatial water quality parameters is a one of the problems for selecting water quality parameters economically, and there aren't enough information because of discontinuous measuring. Index parameters should be selected by study of relationship between system's qualitative and quantitative parameters. Can be estimated as parameters that not measured by using the measurements of index parameters and the correlation between quality parameters. The following table show general classification for selecting quality parameters in monitoring network by "Sanders and et al" (1987). In this structure several levels have been suggested for selecting quality parameters and this selection is done according to sampling costs and samples analysis and a temporal and spatial correlation between water quality parameters.

Table 1. Classification quality parameters systems for monitoring water

Type of variable	Profile	Description
First stage parameters	Basic variables	The parameters are a function of profile hydraulic system Including flow, water level and flow rate
second stage parameters	Basic water quality parameters	Temperature, pH, Turbidity, BOD, COD, Cation, Anion, Electrical conductivity and Chlorides
Third stage parameters	Secondary qualitative parameters	Qualitative variables that are specific side effects, including Radioactive materials, Suspended solids, Dissolved Minerals and etc
Fourth stage parameters	More detailed classification of the qualitative parameters	Combined effects of certain compounds that can be effective such as minerals in water turbidity (Iron oxide, Manganese compounds, Aluminum and etc)

Localization of water qualitative monitoring stations

Localization in monitoring stations for preparing waters` good samples has a special importance. Criteria which are effective for determining qualitative monitoring station's localization; are very different in running waters and underground water resources.

In running water resources a river length is an important index, while in the underground water resources a sampling depth is one of the main parameters [16].

Sampling sequence determination in water qualitative monitoring stations

In some monitoring programs, different sequences of sampling are determined according to pollution resources, index`s qualitative parameters, the goals and importance of project and existent equipment.

Seasonal monitoring (four times sampling in a year) or monthly monitoring (one sample in one month) four majority of water qualitative control projects are traditional in Iran. One reason for selecting seasonal sequence is a necessity to study four season`s effects on pollutants density changes. A large amount of monitoring costs is due to sampling sequence. Usability of the collected data is connected with sampling sequence too [17].

There are different criteria to determine sampling sequence, and among them, fiscal restraints and an engineering judgment are important parameters. In water resource monitoring programs, the number of hourly and seasonal sampling are determined according to qualitative and quantitative variable type, water resource properties and sampling sequences.

Hourly to daily sampling:

according to input flow changes and river basin expanse; discharge of river at the time of torrent is usually measured by hourly to daily sequence. Also, some factors which have effect on biological activities such as soluble oxygen density and etc maybe measured hourly or daily according to hourly changes in temperature and input pollutants.

Daily to monthly sampling:

parameters which their changes are dependent to climatic change or agricultural and industrial periodic activity are sampled or measured with several days or several months sequence. For example if it has stability or hasn`t many changes, for determining sediment amount, the pollutants density are sampled or measured with several days or several months sequence.

Rear sampling:

Some changes are due to human long-term activities that affect water resources that are usually measured with yearly sequence. Mean (μ) is a general statistical parameter for measuring water quality parameters. A main goal in selecting sampling sequence is to give proper estimate of mean (μ). For determining sampling sequence, a confidence interval should be determined around mean. By this way water quality changes connection to sampling sequence is determine. Confidence interval 100 (1- α) percentages around population mean (μ) is defined as:

$$[\overline{X} - Z_{\alpha/2}.\mathrm{var}(\overline{X})^{0.5}, \overline{X} + Z_{\alpha/2}.\mathrm{var}(\overline{X})^{0.5}] \quad (2)$$

Which $Z_{\alpha/2}$ Standard normal distribution sequence coefficient for $\alpha/2$ increase probably. For example for 95 percent confidence interval we have $Z_{0.025} = 1.96$. If samples be independent, so

$$\mathrm{var}(\bar{x}) = \frac{\sigma}{n} \quad (3)$$

In above equation, n and σ^2 are sample number and population variance, respectively. So 95 percent confidence interval around mean is:

$$\overline{X} - 1.96\frac{\sigma}{n}, \overline{X} + 1.96\frac{\sigma}{\sqrt{n}} \quad (4)$$

A confidence interval with low width shows uncertainty in mean estimate. In above mention relation σ^2 there is population variance and network designer that never can change it. $1-\alpha$ Confidence balance should be selected according to fiscal restraints and needed caution. In simple words sampling sequence`s goal in selecting "n" is that it gets acceptable width for confidence interval around population mean according to monitoring network's goals. Selecting sampling sequence need some information about random variable behavior. In most methods, some information about density changes variance or parameters quantity are needed. A monitoring network designer maybe encounter with three kinds of information:

1. There are good qualitative and quantitative information about a river or a studied territory.
2. There is no information about our river but there are quantitative and qualitative information about another or near rivers of region with similar properties.
3. There are no information or they are not confidence.

If there is not enough information about river, at first it is necessary to design a short-term monitoring program according to river condition and pollutant entrance area, so necessity to continue this program should be studied, then data should be analysis and its future sampling sequence should be determined. After data analysis, sampling sequence maybe decreased. In other worlds, data are collected at the first step and the main monitoring program is designed at the second step.

Sampling sequence in one station and one variable mode

If samples be independent with attention to below equations, sampling numbers are as:

$$n \geq [\frac{Z_{\alpha/2}.\sigma}{\mu - \overline{X}}] \quad (5)$$

Commonly population variance σ^2 is not usually definite but it can be estimated from data. If standard deviation (s) be used in above equation as estimation of α, so is used in $t_{\alpha/2}$ instead of $Z_{\alpha/2}$. If the difference between population mean and sample mean ($\mu - \overline{X}$) called (E) error, so

$$n \geq [\frac{t_{\alpha/2}.S}{E}]^2 \quad (6)$$

In above equation it is necessary to determine $1-\alpha$ confidence balance an error (E) according to needed caution and fiscal condition by network designer. S2 is another quantity which be calculated from previous measurements and observation. In above equation if (S) be used in lieu of (σ), degree of freedom (t) which is a function of (n) is determined by trial and error. If number of samples be very much, population variance (σ^2) can be estimated from (S2). This matter don`t provide high error in sampling sequence determination. If we have 30 samples or more, the number of them is high, but variable distribution function should not be very different from normal distribution. If the sample numbers be more than 50, the random variable distribution shape has a low effect on samples mean distribution, so the above mentioned condition can be ignored. According to quantitative and qualitative information about river or studied area, sampling sequence in one station with one variable with attention to chemo-physics parameters has been determined by use of the following formula.

$$\text{Confidence interval width (CIW)} = 2 \times Z_{\alpha/2} \times \frac{\sigma}{\sqrt{n}} \quad (7)$$

$n = [2\times1.96]^2\ \sigma^2\ /\ \text{CIW}$

Which $Z_{\alpha/2} = 1.96$, **n** is number of sample in a year and CIW is equal Maximum value of parameter - Minimum value of parameter.

Result and discussion

According to Eq 7 calculation to determine the frequency of samples related to the physicochemical parameters in the raw water and treated water were calculated that these results are shown in Table 3. Based on these results number of samples needed to measure in year (n) was determined. That n for NO_2^-, TOC, THM, Mn, Na and Cu is equal to 4, for Zn and Cr is 3 and for NO_3^- and NH_3 is 2 samples in year.

Table3. Number of sample for each parameter in a year

Parameter	Confidence interval width (CIW)		Standard deviation (SD)		Number of raw water parameter measurements in a year	Number of treated water parameter measurements in a year	Number of samples needed to measure in year (n)
	Raw water	Treated water	Raw water	Treated water			
Nitrate (NO_3^-)	20	17.75	6.495	5.504	1.62	1.47	**2**
Nitrite (NO_2^-)	0.01	0.005	0.004	0.002	3.41	3.84	**4**
Ammonia (NH_3)	0.03	0.01	0.008	0.003	1.29	1.93	**2**
Total organic carbon (TOC)	2.3	2.2	1.090	1.053	3.45	3.52	**4**
Trihalomethanes (THM)	25	27	11.199	12.019	3.08	3.04	**4**
Manganese (Mn)	0.01	0.004	0.005	0.002	3.93	3.84	**4**
Sodium (Na)	17	11	7.088	5.802	2.67	4.27	**4**
Zinc (Zn)	0.03	0.03	0.012	0.014	2.67	3.13	**3**
Copper (Cu)	0	2.4	0	1.304	4.54	4.54	**4**
Chromium (Cr)	0.01	0.005	0.004	0.001	2.78	2.12	**3**

According to figures 1 and 2, it is possible to decrease physico-chemical parameters measurement (%25 to %96.2) therefore chemical material costs are decreased and monetary costs and human resources which are involved decline very much too.

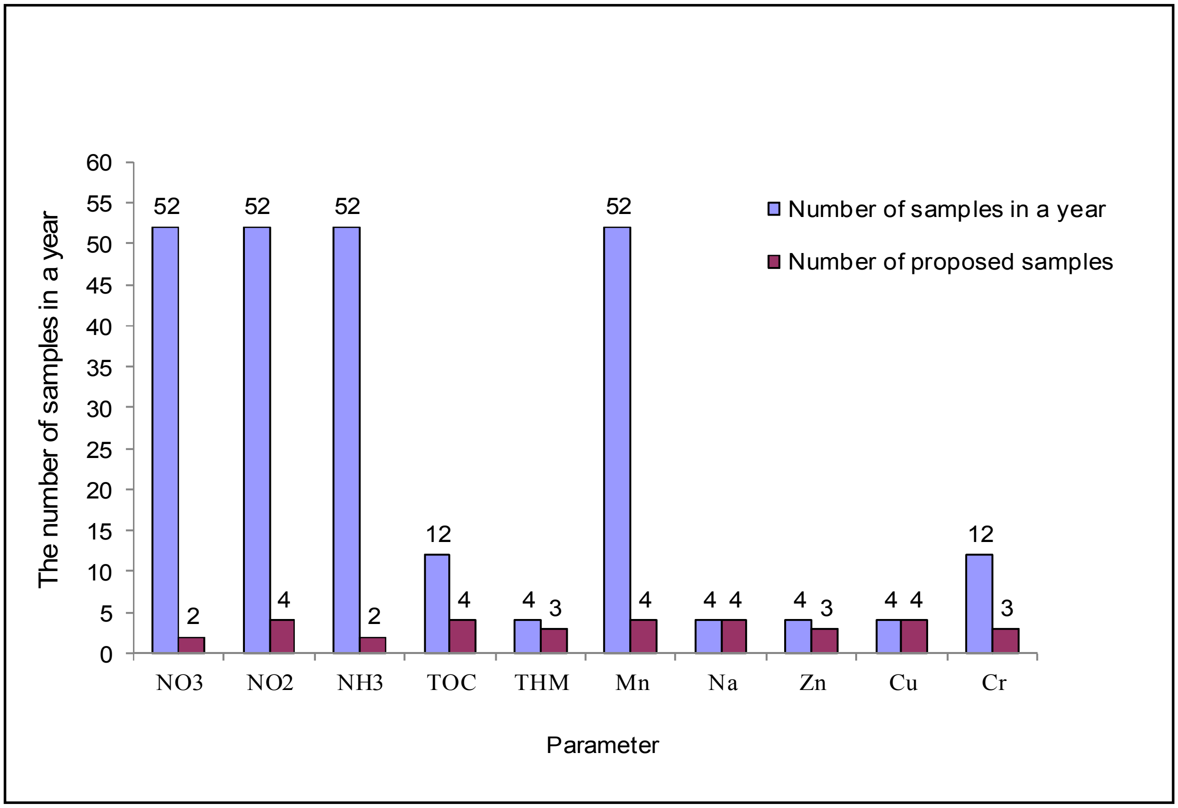

Fig 1. Compare the number of tests done in a year with the number of proposed experiments

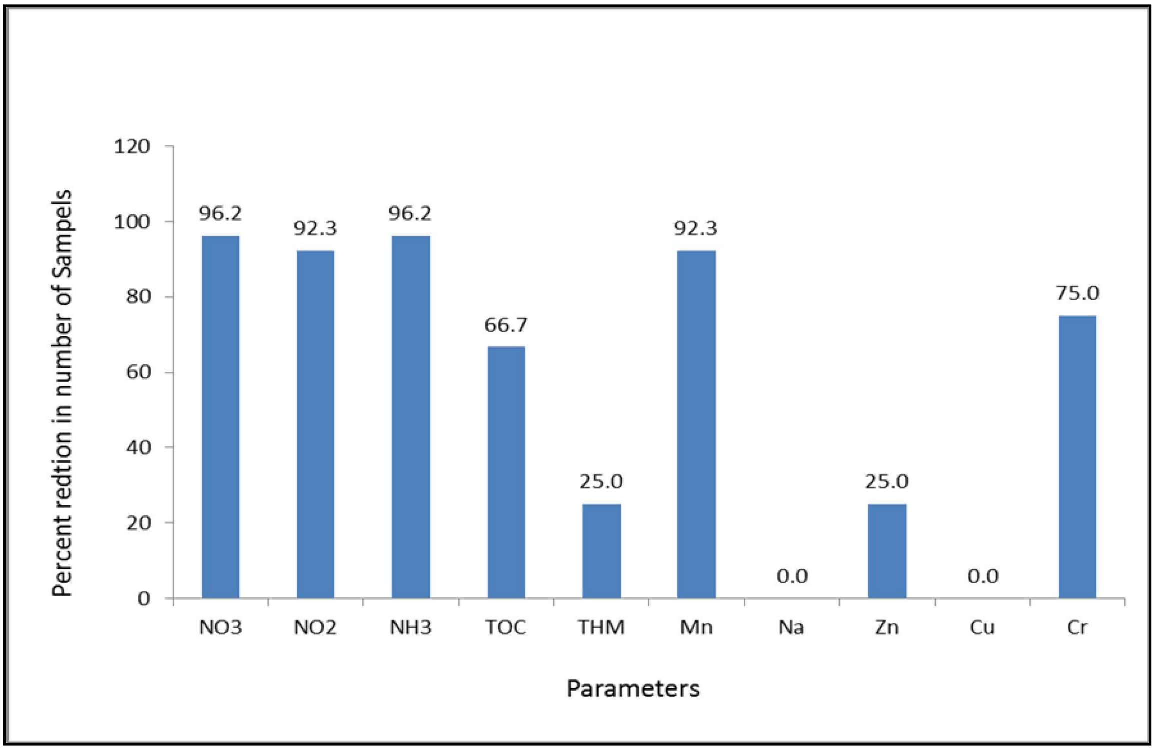

Fig 2. Percent reduction of the number of experiments

Conclusions

Answering certain questions requires that sampling intervals be as short as possible to maximize the utility and representativeness of the data. In some cases, weekly, bi-weekly or monthly sampling frequencies are most typical, while in other situations, sites may not be accessible at all times of year. Sampling locations and frequencies are mostly driven by the questions to be answered. Water quality varies naturally with location and time. The number of parameters and sampling at each station was measurement. Based on these results, the physicochemical parameters significantly reduced

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