IMPLEMENTATION OF A WATER MONITORINGPLAN BASED ON RISK ASSESSMENT APPROACH

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ABSTRACT

Within the area of water, risk is defined as the analysis and prioritization of the combined probability of water contamination, consumer exposure and the size of the anticipated public health impact of specific chemical, microbiological and/or other hazards related to water. Sub consequently, itrepresents the probability that a hazard may occur in a water product which can result on human health exposure to hazardous elements(Codex Alimentarius, 2001)(Kapaj, S., 2006). This work represents an additional effort fordeveloping and implementinga national monitoring plan for major drinking water health risk based on a standard risk assessment approach using a semi-quantitative method and taking into account the regulatory requirements. The developed monitoring plan can be used by the researcher community, stockholders and related governmental entities as a predicting tool for determining the prevalence that may be present in the drinking water and to predict early warnings. The main advantage of such method is that it allows classifying the risk in a structured way according to its probability and / or its impact (gravity) to increase the efficiency of monitoring and to decrease inspection costs, both in practice and from theoretical calculations (Presi et al., 2008). The samples number to be analyzed is determined according to the prevalence level according to the severity of danger (PL) and the confidence level (CL). For the determination of CL, three parameters are taken into account; (1). Harmful effect of hazard, (2) the occurrence and (3) the contribution. For each parameter, a score was assigned ranging from 1 to 4. For the model validation, an example was proposed which calculates the number of samples per risk type; i.e. the presence of E. coli bacteria.

Keywords: monitoring plan; drinking water; risk assessment; major health risks.

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1 INTRODUCTION

Ranking of health risks related to water safety is generally recognized as the basis for risk-based priority setting and resource allocation. It permits governmental and regulatory organizations to allocate their resources efficiently to the most significant public health problems (J. P. Maudoux, 2016).

The main objective of this paper is to develop a monitoring plan based on major health risks in drinking water system. This tool can be used to define appropriate monitoring frequency, to assist in determining regulatory requirements and prevent human health risks through drinking water, to unify technical implementation modalities and to automate control and monitoring processes in all stages of drinking water supply system from water plant to consumers.

The national monitoring plans check the synthetic tool role to prove compliance and continuously detect anomalies in early stage of water supply system. The development of these monitoring plans requires a proved and justified approach.

2 MATERIALS AND METHODS

Recently, various risk ranking methods are available that prioritize water safety risks (Van Asselt et al., 2012). Methods vary from qualitative, through semi-quantitative, to quantitative methods (Cope et al., 2010).Most methods are based on the 'technical' concept of risk being a function of presence of the hazard and severity of its impact on human health. However, the follow method involve other metrics, which may be considered in decision making, e.g., the contribution of water to the total ingestion contamination reflect the potential exposure to the spread or impact of the disease (H. J. Van der Fels-Klerx et al, 2017)(Presi, P., 2008). This method is based on semi-quantitative scoring of both exposure and effect of the hazard on human health (Alfred Bernard, 2002).

2.1 Monitoring plan development

The process of implementing the monitoring plan described in "Fig. 1" consists of identifying the hazard, defining the risk problem, describing the stages of the risk pathways, collecting data and information, including uncertainty and variability and finally combining information logically. The main advantage of such risk assessment method is that it allows classifying the risk in a structured way according to its probability and / or its impact (gravity).

The monitoring plan development process consists of the following six steps:

1) Identify the hazard of undesirable substances and prohibited substances and pathogens with potential toxicity,
2) For each parameter to be analyzed, define the prevalence of contamination,
3) Calculate the number of analyzes to be performed to detect the studied parameter (endangered),
4) Divide analysis number in the risk matrix,
5) For the multiannual program,we can adjust the matrix from one year to another,
6) Establish the monitoring plan.

In this regard, the more hazard was severe, faster it was detected with a sufficient confidence level.

2.2 Risk assessment approach

In order to determine the corresponding risk assessment (RA) approach, three criterions are taken into account by using the function expressed in equation 1and for each criterion; a score is assigned from 1 to 4 as follows:

1) Criterion 1/the harmful effect of hazard (in terms of toxicity, virulence): score 1 (not harmful or negligible) to 4 (very harmful).
2) Criterion 2/the occurrence in terms of the estimated contamination prevalence in water; Score 1 (very low prevalence, low analytical detection, and not exceeded) to 4 (high probability of prevalence, frequent analytical detections and exceeding standards).
3) Criterion 3/ the contribution of water to the total ingestion contamination reflect the potential exposure to the spread or impact of the disease: score 1 (limited contribution) to 4 (very important contribution).

For each population (e.g. natural mineral waters) the scores of the three parameters (adverse effect, occurrence, and contribution) are attributed according to the type of risk (e.g. E.coli).

After calculation of the risk assessment, a risk matrixwas drawn up as shown in "Fig. 2".

2.3 Determination of the confidence level

As it is show in "Fig. 2", each risk matrix value corresponds to a confidence level "CL" (90%, 95%, 99%) as follows:

- CL90% for risk assessment ranging from 2 to 6 (e.g. low toxicity, reduced contamination),
- CL95% for risk assessment ranging from 7 to 12 (e.g. average toxicity, average contamination),
- CL99% for risk assessment ranging from 13 to 20 (e.g. highly hazardous contaminant and water being a major source of contamination).

2.4 Determination of the prevalence level

The prevalence level is attributed according to the hazard gravity. The lower score corresponds to the highest prevalence. So that, we apply for the score from 1 to 4 respectively, a prevalence level "PL" 10%, 5%, 2.5% and 1%.
The prevalence level to be controlled is based on the hazard score as presented in "Table1".

2.5 Determination of samples number

The samples number to analyze depends mainly on the precision and the confidence level to be attained as presented in "Table 2". Therefore, at a given confidence level, the higher the accuracy required of the valid prevalence, the higher the samples number required.
The samples number to analyze is carried out by using a statistical application. The following parameters are necessary to perform the calculation:

– The population size (drinking water): is generally considered infinite
– The prevalence level to control.
– The confidence level

Samples number to analyze "N" is taken using the eq. (3)

3 EQUATIONS

RA= Harmful Effect + (occurrence × contribution) (1)

RA = score criterion 1 + (score criterion 2 × score criterion 3) (2)

$$N = \frac{Z^2 \times \alpha \times (1-\rho) \times \rho}{\Delta^2} \quad (3)$$

With;

- Z^2: defined from the table of the reduced normal centered law corresponding to the desired confidence level α,
- p: the estimated prevalence of the concerned variable (ex E. coli),
- α: the desired confidence level,
- Δ: acceptable or tolerated error margin.

4 TABLES

Table 1.The prevalence level to control

Hazard score	Prevalence level
Not harmful = 1	10 %
Probably harmful = 2	5 %
harmful = 3	2,5 %
Very harmful = 4	1 %

Table 2. The prevalence level to control

PL			
10%	22	29	44
5%	45	59	90
2,5 %	91	118	182
1%	230	298	458
	90%	95%	99%	CL

5 FIGURES

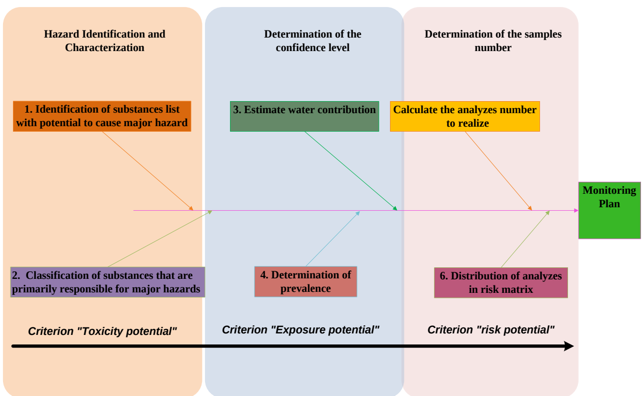

Figure 1 . Identification of the major health risks process

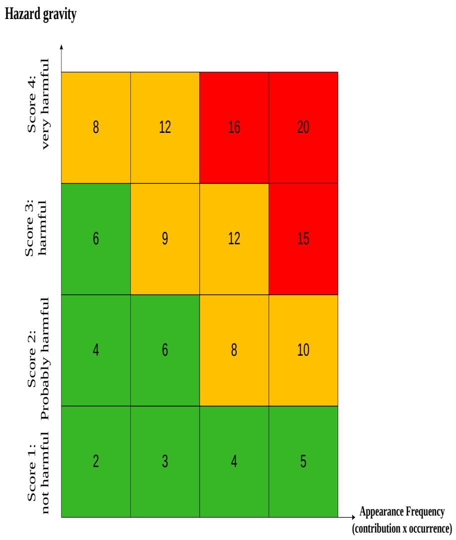

Figure 2. Risk matrix

6 RESULTS AND DISCUSSIONS

After getting risks classification, main dangers have been attributed a score raging from of 1 to 4.The methodology allowed drawing up a statistical model in order to highlight the samples number to be taken automatically.

"Fig. 3" below presents the validation example of the developed monitoring plan; Escherichia Coli risk.As it seen on "Fig. 3",the model calculates a number of 118 samples required to be analyzed with a confidence level and a prevalence level equal to 95% and 2,5% respectively. These outputsdepends on the input parameters; the hazard score (adverse effects, occurrence, contribution), type of risk and population.

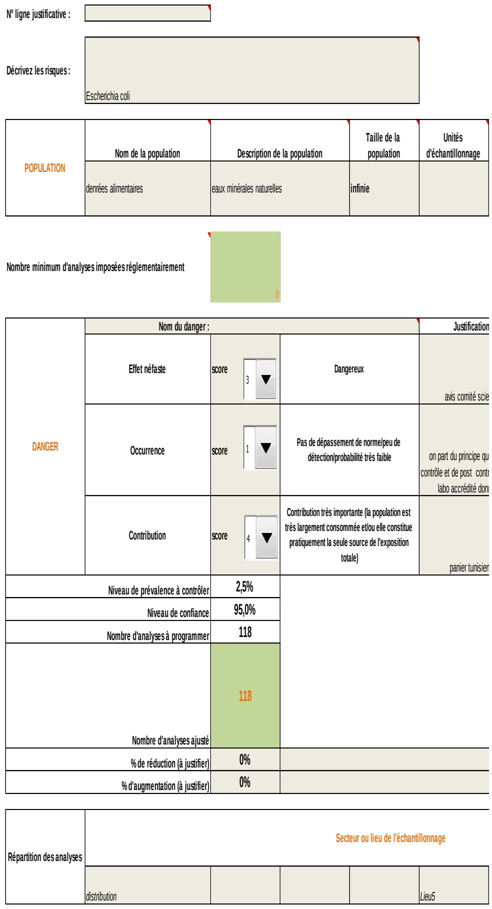

Figure 3. Statistical model parameters

For drinking water, the monitoring plan is as follows in "Table 3". Assuming that the above requirements are met and that the official services verify their correct application by each producer from the source to the bottling or the distribution network, the overall program of analyzes which can be established as indicated in table 3 below.

Table 3. the proposed monitoring plan for drinking water

Contami	Anal
Enterococ	45
E.coli	118
Total	45
Sulphito-	4
Nitrates	58
Arsenic*	118
Mercury*	118
Lead*	118

Tin	15
Pesticides	118
HAP	118

*: to be replaced by other elements in subsequent years depending on the results

This monitoring plan is being evaluated and the above-mentioned model will be used as a working tool for the Tunisian services competent for the establishment of future control plans. Depending on the evolution of scientific information available, a danger score can evolve other contaminants which may also be added on the basis of risk manager/assessor requirements, data availability and the characteristics of the method. Recommendations for future use and application are provided.

7 CONCLUSIONS

The methodology adopted in this work and the proposed model make possible to define the samples number to be analyzed for some probability of contamination in supply or distribution system of wateron the basis of their anticipated human health impacts. Once this monitoring plan has become operational, it can be used as a tool for the determination of the prevalence that may be present in water; creating control plans based on risk assessment, strengthen the application of regulatory requirements to prevent health risks associated with the consumption of water and deciding on early warnings to intervene in a timely manner.A reapplication of this methodology can be applied for the regeneration of monitoring plans for all food chains.

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ABBREVIATIONS

PL prevalence level
CL confidence level
HAP polycyclic aromatic hydrocarbons
ANCSEP Agency of sanitary and environmental control products

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