# AN INTEGRATED RISK ASSESSMENT METHODOLOGY FOR WASTEWATER TREATMENT PLANTS

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## Abstract

A new methodology for safety, public health, socio-economic and environmental risk assessment for wastewater treatment plants (WWTP) is presented. The main goal of this methodology is to provide the sewage systems managers with a tool for the characterization and evaluation of the risks associated with the WWTP functioning. This methodology was validated with its application on three different WWTP, located on Iberian Peninsula. By the application of the proposed methodology it was possible to calculate the "Global Risk Level" (GRL) for each treatment plant. With GRL values between 49% and 60%, all treatment plants were classified as moderate risk plants. Additionally, it was possible to identify the risk factors and the works sites with greatest risk levels. The major risk factors in the three WWTP are the infrastructures damage, the noise, the hazardous atmospheres with air contamination, low oxygen concentrations and high air humidity and temperature; the liberation of odoriferous gases and the skin contact with chemical agents. The major hazardous works sites are the pre-treatment works and activated sludge treatment. With this tool, it will be possible to detect the potential risk operations and sites with major urgency to eliminate or minimize them for a better performance on a WWTP management.

## Keywords

WWTP, integrated risk assessment, safety, environmental risk, risk level, public health assessment.

## Introduction

The good functioning of the urban wastewater treatment plants is today an environmental, social and legal exigency. However, these infrastructures of environmental cleaning involve several risks with internal and external consequences that the management entities must considerer to eliminate or minimize the accident occurrences. Consequently, system managers need to have methodologies that permit to understand in an objective way and at any moment the risks that are associated with the WWTP functioning and evaluate the vulnerabilities of their targets. Several international organizations proposed methodologies to assess the environmental and public health risks (AENOR, 2000; DGPCE, 2005; USEPA, 1998; WHO, 2007). To minimize the risk of WWTP functioning and other socio-economic activities over the safety, public health and environmental context, there are a set of tools given by national and EU legal framework and by voluntary standards (namely, ISO 14001:2004, OSHAS 18001:2007, ISO 24511:2007, ISO CD 31000:2009 and UNE 150008EX). However there isn't a framework or methodology for an integrated risk analysis that consider simultaneously safety, human health, socio-economic and environmental consequences of an harmful occurrence in WWTP installations.

In this work it was develop a methodology that gives the WWTP managers an easy to use and flexible tool to identify the global risk level (GRL) associated with the WWTP functioning, as well as the main risk factors and WWTP works site that contribute to this GRL. This GRL includes the risk scenarios with implications to safety, human health, socio-economic and environmental targets. This methodology was tested with three WWTP situated in the Iberian Peninsula.

## Methods

The proposed methodology involves the development of six stages: process analysis; hazard factors identification; risk factors systematization; risk scenarios development; calculation of the individual risk levels; and global risk level determination. For the consideration of both internal and external risks, the hazard factors and the works sites were categorized, accordingly their nature and the wastewater treatment line, respectively, for the construction of internal and external scenarios. The first ones refer to safety consequences and the external to the public health, socio-economic and environmental consequences. For each scenario, the risk level ($NR_i$) is determined through the equation (Nunes, 2006):

$$NR_i= [(f_P*\log(P)+f_S*\log(S)+f_E*\log(E)+f_C*\log(C))/(f_P+f_S+f_E+f_C)*\log(5)]*99 + 1 \qquad [1]$$

where P, S, E and C are the indexes of probability, severity, exposition and safety conditions, respectively, and $f_P$, $f_S$, $f_E$ and $f_c$ are the correspondent weighting factors whose, in this works, were all assumed to be equal to unity. Relatively to the indexes meanings, the probability index (P) refers to a likelihood that a harmful happening occurs or the frequency of this happening, the severity index (S) to the damages and their magnitude, the exposition index (E) to the likelihood of the hazard/target contact and the safety conditions index (C) to the implementation of mechanisms and devices of primary (preventive) and secondary (corrective) safety. All these indexes are classified between 1 to 5, through valorisation scales that are determined by expert evaluation. The information necessary to the determination of each index value can be obtained through installations auditing and inquests, databases consultation, material safety datasheets consultation, environmental monitoring reports, technical reports on European, national and regional plans context, inventories of natural and human patrimony values, between others information sources. The values of $NR_i$ are converted to an integer numbers scale (1-5) that can be represented by colours.

For a better judgment of the risk elimination/minimization priorities by the managers, the risk scenarios can be visualized by a Risk Assessment Map were the values of the indexes and the risk level of each risk factor/works site pair are systematized. This map permits to calculate the Mean Risk Level (MRL) for each risk factor or woks site and the Global Risk Level (GRL) of entire plant that corresponds to the mean of all $NR_i$ of the WWTP installations. They can also be summarized by a Risk Assessment Matrix whose permits to easily and immediately recognise the MRL and GRL values. In this matrix, the cells with these values are coloured accordingly the following classification: blue, very low risk (0-22%); green, low risk (23-44%); yellow, moderate risk (45-69%); orange, high risk (70-86%); red, very high risk (87-100%).

This methodology was applied to the risk assessment of three WWTP situated in Iberian Peninsula, two in Portugal and one in North Spain. These WWTP are conventional treatment systems with activated sludge processes. Particularly, the Spanish treatment plant doesn't have the primary settling and have low retention times. So, this process is an advanced high load physical-chemical treatment. One of the Portuguese WWTP and the Spanish WWTP have sludge digesters, the last one with odour treatment and biogas exploitation. In an environmental point of view, the Portuguese WWTP have their discharges over stream courses near Atlantic beaches and the Spanish by a submarine outfall into Cantabrian Sea. To collect information about these WWTP, needed for the attribution of the index values, were performed technical visits and enquiries to the system managers. Some information about the WWTP safety and the information about environmental, socio-economic and public health targets were obtained from some data sources above cited. The entire information collect by this way were compiled on individual files prepared for that.

## Results and discussion

The Risk Assessment Matrix obtained for one of the WWTP studied is presented in figure 1, as an example. Such as it can be seen in this matrix, this WWTP has a moderate risk, with a GRL of 60%. It can be seen also that the risk factor with major meaning is the infrastructures damage (PE3), with very high risk, due to the waste residues and sludge transport trucks. Also, it must be in consideration the high risk factors (the orange cells), namely, the incompliance of the discharges and environmental quality thresholds (PA13 and PA14), the population exposition to infectious agents (PS1), the noise (PF6), the atmospheric contamination with odoriferous agents and toxic gases (PA10 and PA11) and the skin contact with chemical agents (PQ2). The works site with major risk is the gases treatment (LG1), classified as the high risk site. This Risk Assessment Matrix also shows that the factor risk/works site pair PE3/LS10, which corresponds to structures damage by sludge transport, corresponds to a very high risk scenario and needs special attention.

| Risk Factor Code | LL1 | LL2 | LL4 | LL5 | LL9 | LL16 | LS1 | LS2 | LS5 | LS9 | LS10 | LG1 | LG4 | LG5 | LC1 | LC2 | LC3 | LC4 | LC5 | LC6 | LC7 | LC8 | LC9 | LC10 | LC12 | MRL by Risk Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PF1 | 67 | 67 | 62 | 62 | 67 | | | | 62 | | | | | | 12 | 12 | 18 | 18 | 12 | 18 | 18 | 1 | 12 | 45 | 61 | 36 |
| PF2 | | 67 | | | 61 | | | | 61 | | | | | | | | | | | | | | | | 61 | 62 |
| PF3 | | 67 | | | 61 | | | | 61 | | | | | | | | | | | | | | | | 65 | 63 |
| PF4 | 43 | | 43 | 43 | 53 | | | | | | | | | | | | | | | | | | | | | 45 |
| PF5 | 43 | 43 | | | | | | | 43 | | | | | | 12 | | | | 29 | | | | | | 65 | 39 |
| PF6 | 75 | 75 | | | | | | | 75 | | | | | | | | | | | | | | | | 76 | 75 |
| PQ1 | | | | | 56 | | | | 76 | 76 | 67 | 73 | | | | | | | 50 | | | | | 77 | 67 | 68 |
| PQ2 | | | | | | | | | 76 | 76 | 67 | 73 | | | | | | | 50 | | | | | 77 | 67 | 70 |
| PQ3 | 75 | 75 | 50 | 50 | 29 | | 64 | 64 | 64 | 64 | | | | | | | | | 50 | | | | | | | 58 |
| PQ4 | 75 | 75 | | | | | 64 | 64 | 64 | 64 | | | | | | | | | | | | | | | | 68 |
| PQ5 | 71 | 71 | | | | | 64 | 64 | 64 | 64 | | | | | | | | | | | | | | | | 66 |
| PQ6 | 70 | 70 | 56 | 61 | 56 | | 64 | 64 | 64 | 64 | 70 | | | | | | | | 50 | | | | | 67 | 56 | 62 |
| PQ7 | 67 | 67 | 56 | 56 | 62 | | 60 | 61 | 67 | 45 | | | | 73 | | | | | | | | | | 62 | 62 | 62 |
| PQ8 | 50 | | | | | | | 39 | | | | | 43 | 50 | | | | | 36 | | | | | 53 | 53 | 46 |
| PQ9 | 50 | 45 | | | | | | 39 | | | | | 43 | | | | | | 36 | | | | | 53 | 53 | 46 |
| PM1 | 61 | 61 | 56 | 56 | 56 | | 56 | 45 | 62 | 62 | 62 | | | | | | | | 50 | | | | | | | 57 |
| PA1 | | | | | 64 | 64 | | | | | | | | | | | | | | | | | | | | 64 |
| PA2 | | | | | 60 | 60 | | | | | | | | | | | | | | | | | | | | 60 |
| PA3 | | | | | 60 | 60 | | | | | | | | | | | | | | | | | | | | 60 |
| PA4 | | | | | 60 | 60 | | | | | | | | | | | | | 64 | | | | | | | 61 |
| PA5 | | | | | | | | | | | 58 | | | | | | | | | | | | | | | 58 |
| PA6 | | | | | | | | | | | 58 | | | | | | | | | | | | | | | 58 |
| PA7 | | | | | 36 | 36 | | | | | | | | | | | | | | | | | | | | 36 |
| PA8 | | | | | | 44 | | | | | 33 | | | | | | | | | | | | | | | 38 |
| PA9 | | | | | 36 | 36 | | | | | | | | | | | | | | | | | | | | 36 |
| PA10 | 81 | 81 | 70 | 75 | 81 | | 64 | 64 | 81 | 81 | 78 | | 58 | | | | | | | | | | | 70 | 76 | 74 |
| PA11 | 81 | | | | | | 64 | 64 | 81 | 81 | | | 58 | | | | | | 64 | | | | | 70 | 76 | 71 |
| PA12 | 75 | 75 | 70 | 70 | 75 | 36 | 58 | 64 | 81 | 81 | 68 | | 53 | 67 | | | | | 58 | | | | | | | 66 |
| PA13 | | | | | 84 | 84 | | | | | | | | | | | | | | | | | | | | 84 |
| PA14 | | | | | 76 | 76 | | | | | 64 | | | | | | | | | | | | | | | 72 |
| PS1 | | | | | 75 | 75 | | | | | 75 | | | | | | | | | | | | | | | 75 |
| PS2 | | | | | 64 | 64 | | | | | | | | | | | | | | | | | | 53 | | 60 |
| PS3 | | | | | | | | 53 | | | | | 53 | | | | | | | | | | | 53 | | 53 |
| PE1 | | | | | 53 | 53 | | | | | 43 | | | | | | | | | | | | | | | 50 |
| PE2 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PE3 | | | | | | | | | | | 89 | | | | | | | | | | | | | | | 89 |
| PE4 | 76 | 76 | 64 | 64 | 70 | 70 | 47 | 47 | 70 | | 76 | | 53 | 58 | | | | | | | | | | | | 64 |
| MRL by Worksite | 66 | 68 | 59 | 60 | 61 | 58 | 60 | 56 | 68 | 69 | 65 | 73 | 52 | 62 | 12 | 12 | 18 | 18 | 46 | 18 | 18 | 1 | 12 | 62 | 64 | 60 GRL |

*Figure 1. Risk assessment matrix of one of the WWTP studied.*

The other WWTP have also a moderate global risk level, with GRL values of 49% and 57%. The risk factors and the works sites with major values of risk level are summarized in table 1. All this risk factors are classified as high risk, except the noise in one WWTP that was classified as very high risk. Relatively to works site, the pre-treatment works in one WWTP was classified as high risk site and the other ones as moderate risk sites.

*Table 1. Factor risk and works sites with major meaning for the GLR of two the WWTP studied.*

| | WWTP 1 | WWTP 2 |
|---|---|---|
| Major factor risks | Noise and hazardous atmospheres with air contamination, low oxygen concentrations and high air humidity and temperature. | Noise, skin contact with chemical agents, and hazardous atmospheres with air contamination, low oxygen concentrations and high air humidity and temperature values, the odorous gases liberation and the infrastructures damage. |
| Works sites with higher risks | Pre-treatment works. | Pre-treatment works and activated sludge treatment. |

## Conclusions

Through the presented methodology it was possible to calculate the Global Risk Levels of the studied WWTP. Additionally, it was easily to identify what risk factors contributes to these GRL and what works sites needs special attention. With this tool, the system managers can easily make decisions to minimise the risks and to improve their safety, human health, socio-economic and environmental performance. Many issues related with this methodology are being developed at moment, namely the development of objective evaluation scales for each factor and work site.

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