WATER DEPURATION SYSTEMS IN LOW POPULATED AREAS: ANALYSIS AND IMPROVEMENT PROPOSALS

Diaz-Tena, Estibaliz[1]; Elías, Ana[1]; Rojo, Naiara[1]; Medina, Yolanda[2]; Beldarrain, Aitor[2]; Carreras, Joseba[3]

[1] Department of Chemical and Environmental Engineering. University of the Basque Country, [2] Water Discharge Department. Basque Water Agency (URA) [3] Biodiversity Section. Department of Environment. Provincial Council of Alava

The performance of urban wastewater treatment plants located in low populated areas is in most cases poor, which can result in legal discharge requirements unfulfillment. Even though these types of installations are operational plants, they have not been subjected to a rigorous performance evaluation, being as a consequence inefficient processes.The present work describes the actions carried out to determine the operating status of several wastewater treatment plants. Once defined the operating problems, some technical-operational low cost modifications have been proposed in order to optimize the depuration systems. For this end, a number of treatment plants have been selected from different Basque Country localities. The study has been focused on the treatment design analysis and the evaluation of the main physicochemical parameters that characterize the discharge quality, on a year basis. Based on the results, improvement alternatives for the treatment plants have been proposed. In some of the cases, the addition of a complementary treatment has been required. The inversion cost, as well as maintenance and operating costs involved in wastewater treatment plants located in low populated areas is very relevant. Thus, simple and assumable solutions that could improve treatment efficiency and, therefore, fulfil legal discharge limits have been proposed.

Keywords: *Wastewater; Low populated areas; Depuration; Improvements;Low cost systems*

SISTEMAS DE DEPURACIÓN DE LOCALIDADES DE PEQUEÑA POBLACIÓN: ANÁLISIS Y PROPUESTAS DE MEJORA

El tratamiento de aguas residuales en núcleos de pequeña población se presenta hoy en día como un punto débil y deficitario, que en ocasiones conlleva el no cumplimiento de los requisitos de vertido. Muchas de las instalaciones, si bien están operativas, no han sido sometidas a una valoración rigurosa en su funcionamiento, el cual en ocasiones no es muy eficiente.En el presente estudio, se describen las actuaciones llevadas a cabo para conocer el estado de funcionamiento de algunas plantas de depuración de aguas urbanas. Para tal fin, se ha seleccionado un determinado número de plantas en diferentes localidades del País Vasco y se ha procedido a un estudio del diseño de tratamiento así como de los parámetros físico-químicos principales del vertido. En base a ese análisis, se han propuesto alternativas de mejora en las plantas de tratamiento sometidas a estudio, siendo en ocasiones necesario proponer la implantación de tratamientos complementarios. Debido a la importancia que los costes de inversión, mantenimiento y explotación tienen en instalaciones de este calibre, se ha trabajado con soluciones simples y asumibles, que consigan mejorar los rendimientos de depuración y alcanzar así los límites de vertido.

Palabras clave: *Aguas residuales; Núcleos urbanos pequeños; Depuración; Mejoras; Sistemas de bajo coste*

Correspondencia: Estíbaliz Díaz, email: estibaliz_diaz@ehu.es.

1. Introduction

Anthropogenic activities can negatively affect the environmental quality of soils, air and water resources.

In the particular case of water pollution, it can be defined as 'the action and the effect of introducing materials and energy forms or conditions to the water, that in a directly or indirectly form involves a harmful alteration of its quality in relation to subsequent uses or with its ecological function' (Water Spanish Law, 1985). Human activities play a negative role contributing to this pollution.

As human daily activities are linked to water consumption, this kind of pollution is inevitable. The direct urban wastewater discharge into a natural environment (without any previous treatment) can severely affect the receiving environment, as dilution and auto-depuration capacity could be exceeded due to the concentration and nature of the discharge. Therefore, it is important to treat polluted water effluents in order to mitigate their negative effect on the environment and also to avoid diseases from untreated wastewater (Campos, 2008).

2. Environmental actions in Europe

Current environmental and water policies have been based on international directives and decisions for the last forty years both at European and national scale.

Traditionally, human evolution has been based on the concept of unlimited development, with the aim of improving the quality of human life above all. Nevertheless, environmental consequences of global development were not being considered. It was not until the 60s of the last century, when scientists began to alert authorities about the main problems of the planet: poverty, biodiversity loss and environmental deterioration. From that time on, natural environment conservation became an important political issue.

The United Nations Conference on the Human Environment celebrated in Stockholm in June 1972 (United Nations [UN], 1972) marked a turning point in the development of modern international environmental policy.

Twenty years after the first steps set in Stockholm and, thanks to the actions taken so far, the first World Conference of the United Nations on Environment and Development was held in Rio de Janeiro, in 1992. The discussed issues were compiled in three reports (UN, 1992a, 1992b, 1992c), including the concern about the increasing water scarcity in the World.

Regarding water management, a number of basic principles were established in Europe, in 1967, through the adoption of the European Letter of the Water. Approved by the European Council, the letter was structured in twelve principles, aimed at water conservation and protection. Nowadays, the articles are the constitutional basis of the European Water Regulation.

After the aforementioned conference in Rio de Janeiro (1992), the activity of the European Community in relation to the environment became more intense and was materialized trough policies or the so called "*Framework Programs*". The first program was developed in 1972, and in 2007 the 7th Framework Program (FP7) was launched. The main objective of these programs was to find solutions to environmental issues, highlighting climate change, water pollution and waste management. The last program was set on a period of seven years (2007-2013) and, European Framework Programme for Research and Innovation, Horizon 2020, is currently being conducted.

The first action related to water pollution issues taken in Spain was known as "*Plan Nacional de Saneamiento y Depuración 1995-2005*", and was agreed by the Ministers Council in 1995 (Ministers Council [MC], 1995). Three years later (1998) a report called "*Libro Blanco del*

Agua" was published by the Spanish government in order to inform the population about the actual situation of water resources in Spain. In this book, the situation of water and the existing problems in that country were analysed in a homogeneous and unified way. The book proposed that the evolution of water uses could be predicted, and a list of priorities for its use could be established. This document became the basis of the hydrological plans which were being developed in that time.

Ministers Council approved in 2007 the "*Estrategia Española de Desarrollo Sostenible*" (MC, 2007) aimed to cope with the unsustainable water consumption patterns in Spain. It was concluded that environmental degradation due to pollution, biodiversity loss and inadequate use of resources were the most important effects associated with the unsustainable patterns. Appropriate measures were taken by this action in order to curb such unsustainability.

Unfortunately, Spanish water resource management has some limitations, basically due to three factors: marked geographic and climatic differences that lead to an unbalanced water availability, aquifers overexploitation and the lack of new reservoirs construction. In order to deal with this situation and due to the development of water reuse techniques in recent years, the "*Plan Nacional de Reutilización de Agua*" was published in 2010 by the Water General Directorate (Water Directorate, 2010).

In Spain, anthropogenic activities, such as building and agricultural activities exert a strong impact on rivers and mainland water mass. The consequences are water flow alterations, pollution, eutrophication and invasive species proliferation. Therefore, the "*Estrategia Nacional de Restauración de Rios*" came out in 2010 in order to acquire a good status of water masses, equilibrating uses and activities with the conservation of water. The aims pursued with this strategy were to make a national diagnosis of the current status of rivers (mainly defining the degradation causes) and, in turn, to promote society participation to improve the ecological status of the rivers.

3. Wastewater depuration systems in low populated areas

Spain is formed by more than 8.000 municipalities, of which 6.000 have less than 2.000 habitants. According to the 11/95 Royal Decree, January 2006 was the deadline for low populated areas to implement an appropriate wastewater treatment, when the polluted water was discharge in inland waters or estuaries.

Nowadays, the problems posed by these low populated areas are of great concern as several weak points in their wastewater treatment facilities have been detected. In order to accomplish the applicable legislation, 11/95 Royal Decree, wastewater treatment facilities were installed in many regions. Those facilities were, in many cases, designed as big treatment systems, but in a smaller scale. Thus, the characteristics of the discharges generated in low populated areas and their specific needs were not taken into account, leading to an unaffordable maintenance and exploitation cost.

Different characteristics of the wastewater generated in low populated and in more densely populated areas can be expected. These differences are related to the high flow fluctuation and polluting load, as well as to its high contaminants concentration because of its lower water supply. It is interesting to point out that a significant increase in the population of low populated areas in summer is very common. As a consequence, the generated wastewater flow increases during this period and, thus, the amount of wastewater to be treated. Coincidentally, it is common that the quality of the treated effluent gets worse in the same period, which evidences the inappropriate design of wastewater treatment facilities.

Therefore, wastewater treatment facilities installed in low populated areas must be designed under special premises, with the main objectives of ensuring a minimum energy consumption, as well as maintenance and operation simplicity. Several additional factors should also be taken into account, such as operation efficiency or sludge management, in order to guarantee the minimum cost, and the lack of visual and/or noise impact.

The need to find alternatives to the conventional wastewater treatment led to the development of the ‘Non-Conventional Technologies’ (NCTs), also known as low cost systems.

The operation mode of NCTs and conventional technologies is essentially the same, although it differs in some aspects. On the one hand, the conventional wastewater treatment technologies work under energy requirements. On the other hand, the NCTs use natural treatment methods, but the required surface for their implementation is larger than that required by the conventional technologies.

The variety of treatment operations applicable to the wastewater generated in small urban areas is extensive and, in many cases, the best solution can be a combination of some of them. Huertas et al. (2013) concluded that the basic criteria for the selection of the best NCT must be focused on technical, environmental and economic aspects. In addition, a possible classification of NCT was performed by these authors, according to the degree of tolerance of each technology to various criteria and the range of population (Table 1).

Table 1. Use of NCT for treatment according to population equivalent (Huertas et al, 2013)

Recommended treatment	Population range (population equivalent)			
	50-200	200-500	500-1.000	1.000-2.000
Septic Tank	✗			
Imhoff Tank		✗	✗	
Primary Decantation				
Lake Treatment	✗	✗	✗	✗
Wetland	✗	✗	✗	✗
Sand Filter	✗	✗	✗	✗
Infiltration-percolation	✗	✗	✗	
Bacterial-bed	✗	✗	✗	✗
Sequential Reactor	✗	✗	✗	✗
Prolonged Aeration	✗	✗	✗	✗
Biological Rotating Contactor	✗	✗	✗	✗

4. Case study

The main objective of this research work was to study the coupling of low cost systems and existing wastewater treatment facilities located in low populated areas, in order to improve operational efficiency and accomplish discharge legal requirements. Thus, the actual situation of several inefficient wastewater treatment facilities located in some low populated localities of the Historical Territory of Álava (Basque Country, Spain) was studied.

Álava has more than 300 localities and nearly 98% of them have less than 2.000 inhabitants (figure 1). Almost all the generated discharges have similar characteristics, as they are constituted by an urban discharge, without industrial wastewater inputs, and with unitary load system.

Information related to the treatment steps constituting the wastewater treatment facilities in Alava was collected (figure 2). It was concluded that most of the plants are composed of either a single primary treatment (47.18%) or the combination of a primary and a secondary system (39.44%). On the one hand, the septic tank is most commonly used as primary treatment (76.53% of cases). On the other hand, treatment filters (74.32%), in most cases trickling filters, are the most commonly used among the reported secondary treatments.

Figure 1. Population distribution in Álava

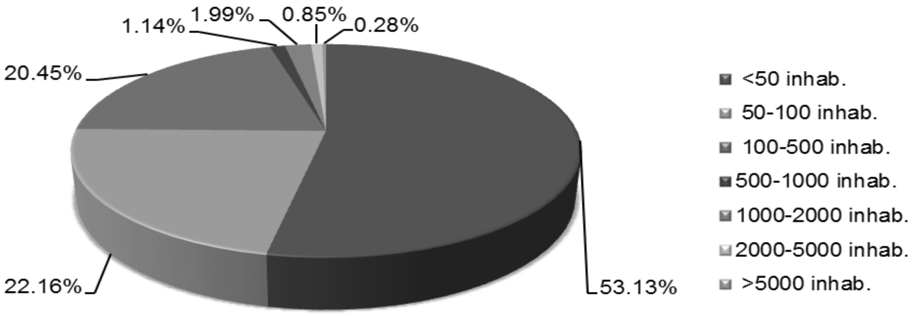
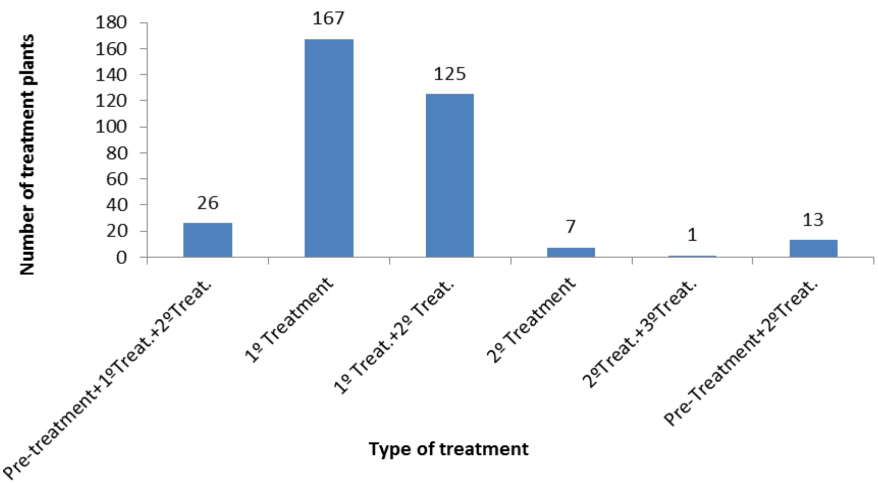


Figure 2. Treatment plant classification of Álava localities according to treatment steps (prepared from URA-Basque Water Agency data)



Four facilities were selected in order to study their actual operational situation. This treatment plants were selected as they were considered to be in a poorer state than the rest and to need an urgent improvement. Relevant data related to the selected facilities are shown in Table 2.

Based on the previous analysis of the discharges generated in each facility (each one corresponding to one of the selected low populated locations), it was concluded that all the effluents often exceed the limits of suspended solids (SS), 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), detergents and oils and fats. Especially during summer periods, when the number of population significantly increased, a decrease in the water quality was observed. Therefore, the discharge limits were not always fulfilled. The same trend was observed when rainfall became more abundant, as in winter. The historical output concentrations throughout time for each selected location are shown in figures 3-6. The discharge limits are indicated as a horizontal line.

Table 2. Details of the locations under study

Facility	Regular inhabitants	Summer inhabitants	Treatment system
Facility 1	210	290	Septic tank + tricking filter
Facility 2	153	190	Primary decantation+clarifying tank+tricking filter
Facility 3	46	80	Septic tank + tricking filter
Facility 4	57	90	Primary decantation+clarifying tank

Figure 3. Historical values of SS, BOD_5 and COD in facility 1

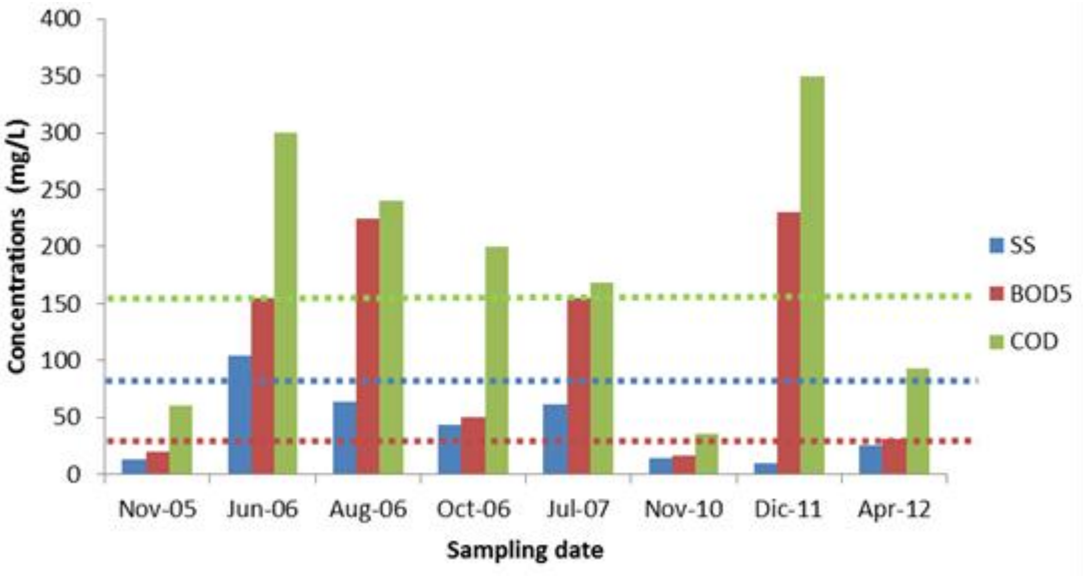


Figure 4. Historical values of SS, BOD_5 and COD in facility 2

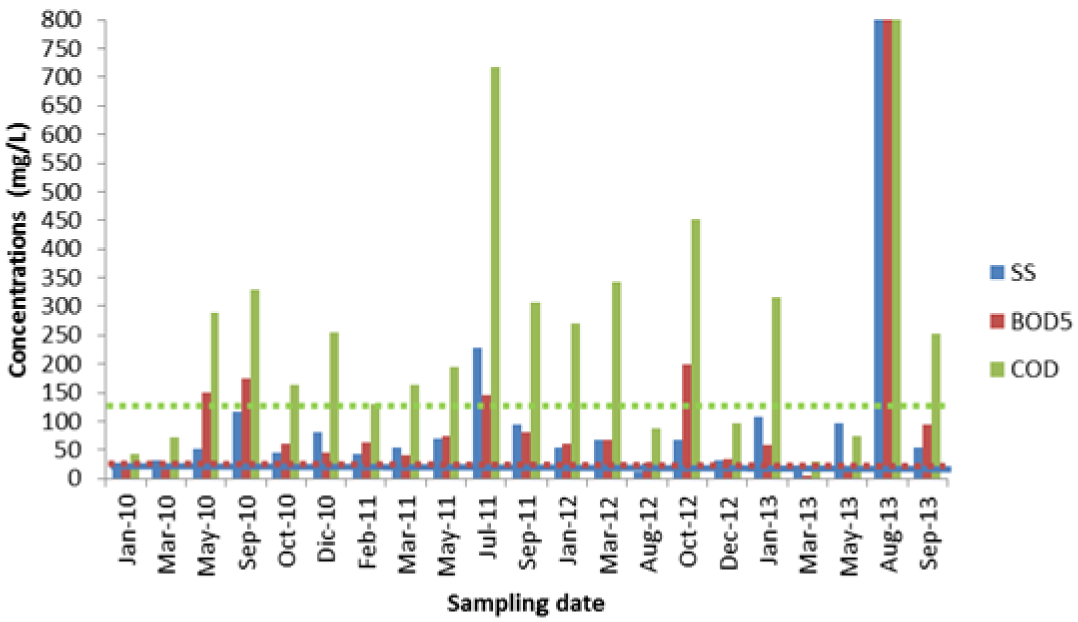


Figure 5. Historical values of SS, BOD_5 and COD in facility 3

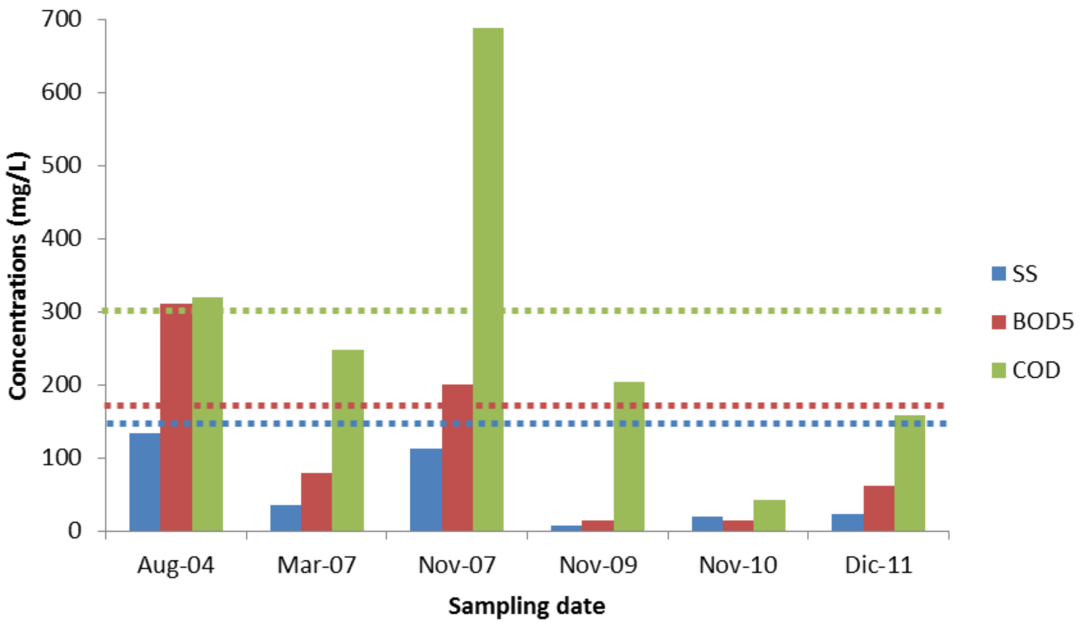
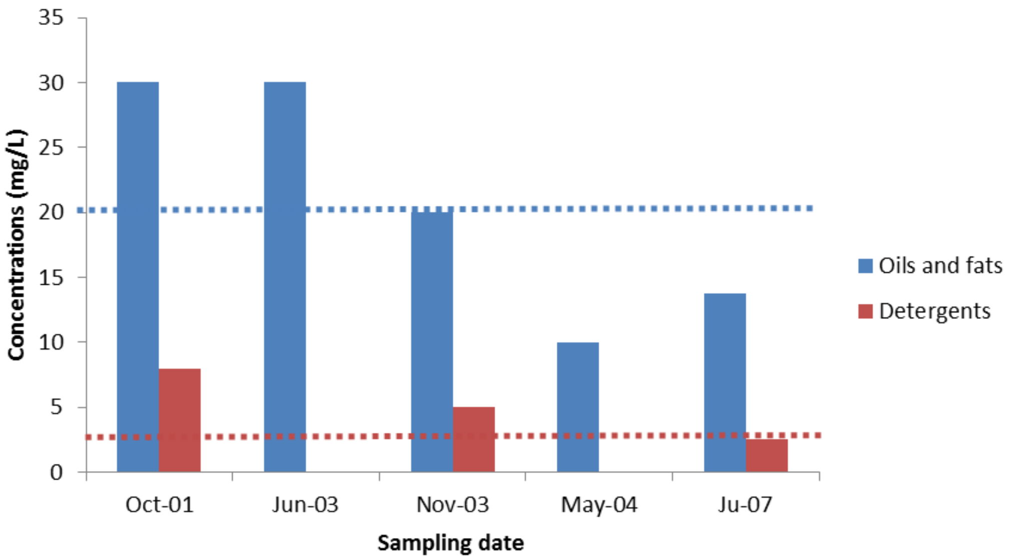


Figure 6. Historical values of detergents, oils and fats in facility 4



It has been concluded from this historical analysis that the discharge composition was highly dependent on the month in which the sample was taken. Thus, the analysis of the current situation was considered crucial, in order to evaluate the actual efficiency of each depuration system and to study the implementation of possible process improvements. A continuous sampling during a year, including both the summer season and periods of heavy rain, would allow the detection of operational variations in the systems, parameters that are over discharge limits, as well as most problematic months. Therefore, a sampling schedule was established: October 2013, December 2013, February 2014, April 2014, June 2014 and August 2014. Samples were taken twice a month.

A deeper study focused on the characteristics of each system was conducted using the preliminary analysis of the analytical results and plant inspections. It was concluded that two solutions could be applied.

The compact nature of the selected facilities made considerably difficult to establish control and monitoring strategies. Their design was very rigid and they did not consider changes in inhabitants, a fact that generated fluctuating efficiencies, and affected the accomplishment of the legal discharge limits. When equipment renewal was not an alternative, slight design changes on the ongoing equipment would lead to significant improvements in the treated effluent quality.

Alternatively, it would be possible to integrate a complementary treatment in the operating system. In both cases, the selection should be based on simple and assumable solutions which could improve treatment efficiency and, therefore, ensure the fulfilment of legal discharge limits.

5. Conclusions

The deep analysis of wastewater treatment facilities in low populated areas is a key factor for their effective performance. The systems efficiency monitoring allows the detection of operational problems. Frequently, these kinds of problems are related to design deficiencies, which sometimes could be overcome by the implementation of viable and economically feasible solutions.

In the locations considered in this study, treatment systems did not accomplish discharge limits, generally due to parameters such as suspended solids, biochemical oxygen demand and chemical oxygen demand.

The alternative proposed covered the implementation of improvements in the design, with modifications in various stages of the treatment. Furthermore, it can be considered the implementation of additional treatment systems based on the latest non-conventional treatment technologies, which would help to achieve a discharge quality according to current law.

Acknowledgments

Thanks are addressed for URA-Agencia Vasca del Agua and Diputación Foral de Álava for their collaboration and technical support. The authors wish to acknowledge the financial support received from the Basque Government (BFI-2011-119) and UPV-EHU under program UFI 11/29.

6. References

Campos, C. (2008). New perspectives on microbiological water control for wastewater reuse. *Desalination, 218,* 34-42.

Huertas, R., Marcos, C., Ibarguren, N., & Ordás, S. (2013). Guía práctica para la depuración de aguas residuales en pequeñas poblaciones. *Duero River Basin*. Legal Deposit: VA3-2013.

Ministers Council (1995). Plan Nacional de Saneamiento y Depuración de Aguas Residuales (1995-2005). Approved by the Resolution of 28 April 1995 in Spain.

Ministers Council (2007). Estrategia Española de Desarrollo Sostenible. Ministry of the Presidency. National Printing Office of the Spain Official State Gazette. Legal Deposit: M-9352-2008.

United Nations (1972). Report of the United Nations Conference on the human environment. United Nations Publication. Sales No. S.73.II.A.14.

United Nations (1992a). Report of the United Nations Conference on Environment and Development: Volume I Resolutions Adopted by the conference. United Nations Publication, Sales No. E.93.I.8. ISBN 92-1-100498-5.

United Nations (1992b). Report of the United Nations Conference on Environment and Development: Volume II Proceedings of the Conference. United Nations Publication, Sales No. E.93.I.8. ISBN 92-1-100498-5.

United Nations (1992c). Report of the United Nations Conference on Environment and Development: Volume III Statements Made by Heads of State or Government at the Summit Segment of the Conference. United Nations Publication. Sales No. E.93.I.8. ISBN 92-1-100498-5.

Water Directorate (2010). Plan Nacional de Reutilización de Aguas. Versión Preliminar del Plan. Water Directorate, Ministry of Environmental, Rural and Marine. Accessible from http://www.magrama.gob.es/ (last access April 2014).