Screenings and grit production from Portuguese WWTP

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Abstract

Urban wastewater treatment (WWT) has become a most relevant issue once it is necessary to ensure the environmental impact minimization of wastewater discharge, compliant with the legal standards. However, in wastewater treatment plant (WWTP) by-products are generated, such as screenings, grit and sludge's, which must be properly treated/recycled and sent to final destination to avoid environmental impacts. The most commonly used methods to disposal screenings and grit in Europe are landfilling which is the least recommend option on waste management hierarchy. The aim of this study was to analyse and quantify the screenings and grit productions in urban WWT in Portugal in order to explore the waste reuse to minimize environmental impacts. The work was based both on data collected using specific surveys to treatment management entities (ME), on financial statements and other legal reports of ME between 2009 and 2013. The collected data correspond to 60% of the population served by WWTP in Portugal. The grit production increased significantly in the first two years and the screenings production increased from 2009 until 2011, after then both decreased slightly. The initial variation may be explained by population growth. The results revealed a significant variation from ME to ME in the wastes productions per capita. The collected data also disclose that the screenings and grit were usually sent to landfill disposal.

Keywords: Wastewater treatment, screenings, grit, wastes, waste reuse

Introduction

A wastewater treatment plant (WWTP), which is considered, *a priori,* as an environmental technology, contributes to several environmental impacts due to its energy consumption, use of chemical compounds, emissions to the atmosphere and by-products production such as screenings, grit and sludge, the post-treatment of which will also have diverse environmental effects.

The implementation of the Urban Wastewater Directive (91/271/EEC) is leading to a significant increase of WWT with the consequent increased production of by-products.

The screenings, grit and sludge are classified as wastes under the European List of Waste (Commission Decision nº 2000/532/EC) and National legislation the Ordinance nº 209/2004 with the code 19 08 01, 19 08 02 and 19 08 05 respectively.

Usually, special attention is given to sludge treatment and final disposal, but screenings and grit are neglected due to the relatively small amounts that are produced (Cadavid-Rodríguez & Horan 2012 and 2013, Le Hyaric et al. 2009), but also because there is no specific legislation for this type of wastes.

There is already legislation to regulate the use of sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and man, thereby encouraging the correct use of sludge (Directive 86/278 / EEC).

The removal of screenings and grit in WWTP preliminary treatment facility is crucial to protect and prolong the life of downstream equipment's, such as pumps,

valves, mixers and air diffusers, and help to improve the efficiency of downstream treatment processes.

The screen equipment element consists of a parallel bars usually ranging from large to middle size openings or a perforated plate with different geometry and size opening. The materials removed by these devices are known as screenings. The nomenclature of screen element is typically based on their purpose and the size of the openings. The size range of the openings as a means of differentiation is not well defined (Davis 2010). Table 1 provides a screens and sieves classification according to size opening defined according to the guideline DIN 19569, part 2 (2002) referenced by Fechen et al. (2006).

Table 1

The screenings consist of a mixture of coarse solids such as: paper, rags, sanitary products, organic and faecal matter, plastics, wood and others (Le Hyaric 2009, Metcalf & Eddy 2014). This waste are often coated with faecal matter, as such they are putrescible and unpleasant odours (Davis 2010). In last years, the size opening of screens decreases from a few cm to a few mm or less, mainly in WWTP with membrane bioreactor (MBR) (Table 1) (Fechen et al. 2006). As a result of reductions in size openings, the volume of screenings produced has increased.

The quantity and quality of screenings depend on the type of equipment, operating conditions, the sewer system (separate or combined), geographic location and consumer habits.

Le Hyaric et al. (2009 and 2010) determine the solid composition of screenings and obtained a high content volatile solids (>85%) which underlines high organic matter content.

Materials in wastewater, like sand, gravel, broken glass, egg shells, and other material that having a settling velocity substantially greater than the organic, are called grit (Davis 2010). There are several possible ways to remove grit from the wastewater like a vortex-type chamber, a gravity flow chamber, and an aerated chamber. As the screenings, the quality and quantity of grit depend on the type of the equipment, the operating conditions, the sewer system (separate or combined), the geographic location and the consumer habits.

Grit removed will contain large quantities of moisture and some organics in an inefficient grit removal system, the organic content of unwashed grit can be up to 50%. Typical values of organic content in grit are: unwashed grit, 50-60%; dewatered grit, 30-40%; and washed and dewatered, 15-25% (EPA 1995).

The best way to predict the amount of waste (screenings and grit) is taking into account the historical WWPT data collected. When no historical data exists, then the better way is consulting the available data published in scientific literature. There are various sources and types of data available for estimating the amount of collected

screenings and grit such as Mara (2003), Metcalf & Eddy (2014), EPA (1995 and 2004), Davis (2010).

It is important to characterize the quantity and quality of theses wastes in order to implement an adequate treatment and disposal strategies. The scientific studies related with this subject show that the most commonly used methods to disposal screenings and grit are: landfilling or incineration (Le Hyaric et al. 2010). However, landfilling is the last option on waste management recommended by European and National legislation (Directive nº 2008/98/CE and Decree-Law nº 73/2011, respectively), and should only be applied when there is no other viable alternative.

The waste management legislation obliges to respect the following priority order to prevent and reduce waste production: prevent, reuse, recycle, recovery enhancements such as energy and climate friendly solutions, and finally landfilling.

There is a reinforcement of National and European environmental regulations concerning limitations and taxation of landfill. The costs for landfilling screenings and grit of WWPT are similar to landfilling municipal solid wastes and show a wide range of tariffs (ERSAR 2009). The prices or tariffs for landfills are influenced by a number of factors such as the standard of the landfill, the competition between different disposal routes, the type and nature of waste being accepted.

The energetic valorisation by incineration might be a good alternative if those kinds of wastes had not such a high moisture.

Some screenings reuses solutions go through biological treatment by composting or anaerobic digestion to obtain organic and energy recovery (Cadavid-Rodríguez &

Horan 2012 and 2013, Le Hyaric et al. 2010). However, before the biological treatment, it is necessary previously to remove the inorganic material component that usually appears in the screenings (sanitary textiles, plastics, glass and metals), but that separation are complicated. Therefore, it is necessary to invest in training and environmental campaigns of awareness concerning non-introduction of inappropriate objects during domestic wastewater production or in sewer systems (visits chambers).

The grit can be valorised through their use in construction for example in landfill (daily casing material and final sealing); settlement pads; road construction (earthworks and pavements) and manufacture of concrete and mortar (Pereira 2008, Borges et al. 2015). However, it is noteworthy that the valorisation and reuse of screenings and grit is only possible if those are in good technical conditions, and if handling and application does not result in any risk to public health.

During the last years, in Portugal it has been found a significant growth in municipal WWT; from 2002 to 2012 the population served increased from 58% to 79%, respectively. In mainland Portugal, according to Water and Waste Services Regulation Authority, there are 1,732 collective septic tanks, 2,536 WWPT and wastewater production is 235 $L.day^{-1}.inhab^{-1}$. In the Portuguese urban wastewater service there are 283 management entities (ME), state or locally owned public utilities and private utilities. These ME collect wastewater from 81% of households and treated wastewater from 79% of households (ERSAR 2015).

Available data of screenings and grit production is sparse in Portuguese WWT and spread over many sources.

The aim of this study was analysed the production and management of these wastes: screenings and grit and contributing to finding the real amount in order to propose mitigating measures in production and suitable disposal.

Methodology

The work was based on financial statements and other legal reports of Portuguese ME, available on internet official sites, and on specific surveys made to ME in order to collect data of at least 80% of population served by WWT. The purpose of the surveys was to complete information, the served population, the wastewater flow treated and the screenings and grit productions. With the data collected several calculations were carried out such as, the per capita screenings and grit productions.

In order to correlate the amount of wastes produced to the type of treatment and the served population, three representative WWTP (Alcântara, Beirolas and Chelas) from SIMTEJO were studied. SIMTEJO is one of the largest management companies in Portugal which serves the municipalities of Amadora, Lisboa, Loures, Mafra, Odivelas and Vila Franca de Xira (hydrographical basin of the Tejo, Trancão, small streams from the right bank of the Tejo river between Vila Franca de Xira and Algés, the small rivers of the Mafra West Municipality and Atlantic front), presently serving a total population of about 1.5 million inhabitant, in a geographic area 1,000 km^2 and with around 30 WWTP. The WWPT have different dimensions from average daily flow of design of 80 to 140,000 m^3 (SIMTEJO 2015). Figure 1 shows the SIMTEJO covered area.

Figure 1

Results and discussion

Screenings and grit production in Portugal

The number of WWPT in Portugal has improved considerably over the last decade as a consequence of implementation of the Urban Wastewater Directive (91/271/EEC), the population served by WWT increased from 58% (2002) to 79% (2012) (ERSAR 2015) as shown in Figure 2.

Figure 2

As a consequence of the WWT capacity increase, it would be expected a growth on screenings and grit productions.

In order to collect data of at least 80% of population served by WWT, as referred in methodology, a specifically surveys was sent to 20 ME (representing about 86% of the population served by WWTP). These surveys resulted in 13 answers, but only 8 of ME sent some data. However, considering both the available public data and the survey responses, it was possible to cover approximately 62% of the population served by WWT. Therefore, the entities considered in present study are: Águas de Santo André, Águas de Trás-os-Montes e Alto Douro, Águas de Zêzere e Côa, Águas do

Algarve, Águas do Noroeste, Águas do Oeste, Águas do Sado, SANEST, SIMARSUL, SIMDOURO, SIMRIA, SIMTEJO, SMAS Caldas da Rainha.

However even with these entities it was not possible found the screenings and grit amount for every year; in those cases, it was considered the value of the previous year. These happened for the following entities: Águas do Noroeste in the years 2012 and 2013; Águas de Santo André, Águas de Trás-os-Montes e Alto Douro, SIMRIA in the year 2013.

Due to the high number of bibliographical sources consulted in the present study, the Table 2 resume for each ME the different data sources.

Table 2

The screenings and grit amounts variation between 2009 and 2013 are show in Figure 3 a). As can be seen from Figure 3 a) the grit production vary significantly between 2009 and 2010, essentially because population served increased and consequential the wastewater flow treated as demonstrated in Figure 3.b). The screenings production increased until 2011, in accordance with flow evolution. After 2011, the annual screenings and grit amount decreased slightly.

Figure 3

Screenings and grit productions in 2013 were 5,659 ton and 7,869 ton, respectively, for a served population of 5,832,830 inhabitants and an annual flow of 439,555,000 m^3.

The wastes and wastewater average per capita values over the years were found to be relatively constant; the great differences were observed from the average of grit per capita values, as show in Figure 4. The discrepancies found in different years might due to several factors: WWTP number, treatment technologies, served population, lifestyle, the rainfall and the sewer systems state.

Figure 4:

The screenings and grit productions in Portugal, for the year 2013, may be estimated at 8,495 ton and 12,256 ton, respectively, considering the average per capita values and the population served (8,181,332 inhabitants = 79% of the Portuguese population from (INE 2011)).

As referred before from the 13 ME some values were estimated whereby considering only the available data, the number of ME is reduced to 7. When the grit and the screenings per capita values from these 7 ME were calculated a very discrepant per capita values were obtained, and consequently the amount of wastes produced by each ME. Figure 5 shows the wastes per capita variation for the 7 ME. The discrepancies between ME are due mainly to two factors: lifestyle and different treatment technologies.

Figure 5:

Taking into account the maximum and minimum values per capita for 2013 (Figure 5) the expected wastes production in Portugal ranged from 5,189 and 11,987 ton to screenings and from 7,353 to 26,734 ton to grit. Using per capita values of an average of ME (13) or using per capita values of each ME, for extrapolation the country wastes production, a very significant difference between the results were obtained. Therefore, a reliable prediction depends on real data, considering the specific areas and technology used.

The three WWTP (Alcântara, Beirolas and Chelas) from SIMTEJO main characteristics are presented in Table 2, in order to correlate the amount of wastes produced to the type of treatment and the served population.

Table 2

Analysing the wastes production of these WWTP it was found that (Figure 6 and 7):

- The grit productions vary significant after 2008 essentially because the increased of wastewater flow treated and after 2010 decreased.
- The variation of screenings productions is small and appears not to be influenced by increased flow rate. In fact, there has been a decline in per capita screenings production.

- Despite the wastes removal equipment was identical in the three WWPT, it was found a different per capita wastes productions.

Figure 6

Figure 7

One factor that appears influencing the flow and grit productions is the precipitation because some part of rainfall goes to WWTP. Figure 8 show the evolution of wastewater per capita production and the precipitation (Prodata 2015).

According to the data shown in the Figure 8, 2010 it was the year with higher rainfall. Analysing the evolution of the average precipitation in 2010, there exist a clear relationship between the flow and the grit production with rainfall (Figure 9 a) e b)), but this does not occur for the screenings production. (Figure 9 c))

Figure 8

Figure 9

Screening and grit disposal

Data collected from the surveys demonstrate that most of the wastes are sent to landfill. As mentioned, landfilling is considered the last of the hypotheses in waste

management terms, and should only be applied when there is no other viable alternative.

The according of National and European environmental legislation, the landfilling of any waste is subject to a tariff, which is regulated by ERSAR (2009) and it depends on the type of wastes (urban solid waste, ordinary industrial waste or hazardous industrial waste), the type of landfill and the entity providing the waste management service. Thus the landfilling cost is estimated taking into account an average tariff (ERSAR 2009) plus an eco-charge (2 €.ton^{-1}) (Pereira 2008).

The estimated cost of landfilling screenings and grit in Portugal, for the year 2013 were 271,842.7 € and 392,192 €, respectively.

Considering these facts, one of the advantages to divert waste from landfills is to minimize the cost of treatment. It can mean an immediate saving of about 0.2% in WWT costs by cubic meter.

In order to reduce the amount of waste disposal in landfill it was necessary to study alternatives solutions. The screenings and grit valorisation has many environmental and economic advantages:

- Reducing the amount of waste sent to landfill, complying with legal guidelines;
- Increase the amount of waste recovered, complying with legal guidelines;
- Reducing the amount of extracted aggregates, promotes the sustainable use of resources;
- Reduction the associated costs with screening and grit final disposal;

- The screenings and grit valorisation implies less waste sent to landfill and lower costs for ME.

Conclusion

According to the present study, the estimate values of wastes production from WWPT was difficult to predict because it depends of several factors like WWTP number, treatment technologies, served population, lifestyle, the rainfall and the sewer systems state.

Taking into account the maximum and minimum values per capita for 2013 the expected wastes production in Portugal ranged from 5,189 and 11,987 ton to screenings and 7,353 and 26,734 ton to grit.

The current final disposal of screenings and grit in Portugal does not contributed to the waste management hierarchy, because these wastes are sent mostly to landfills.

There are already some solutions for the valorisation of such wastes. However to choose the appropriate technology it is necessary to have detailed characterization (qualitative and quantitative) of the two types of wastes.

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Table 1 – Classification of screens and sieves according to size opening (Fechen et al. 2006)

Type of screens	Size opening (mm)	WWT process
Coarse screen	60 - 20	Activated sludge
Middle screen	20 - 10	
Fine screen	10 - 2	Biofilter
Coarse sieve	≥ 1	MBR
Fine sieve	< 1	
Micro sieve	≤ 0.05	

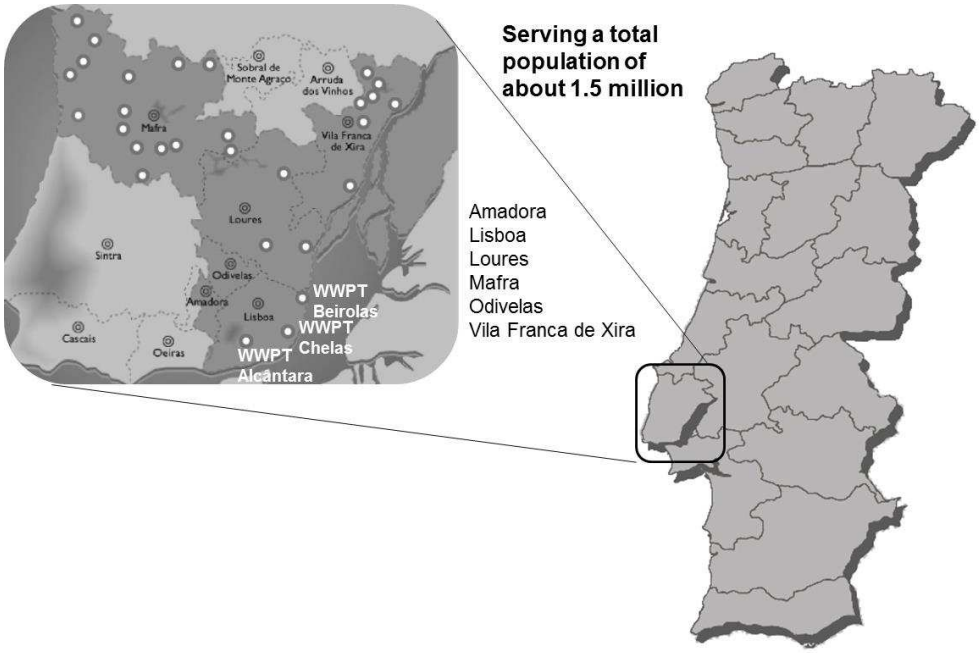

Figure 1: SIMTEJO covered area (SIMTEJO 2015)

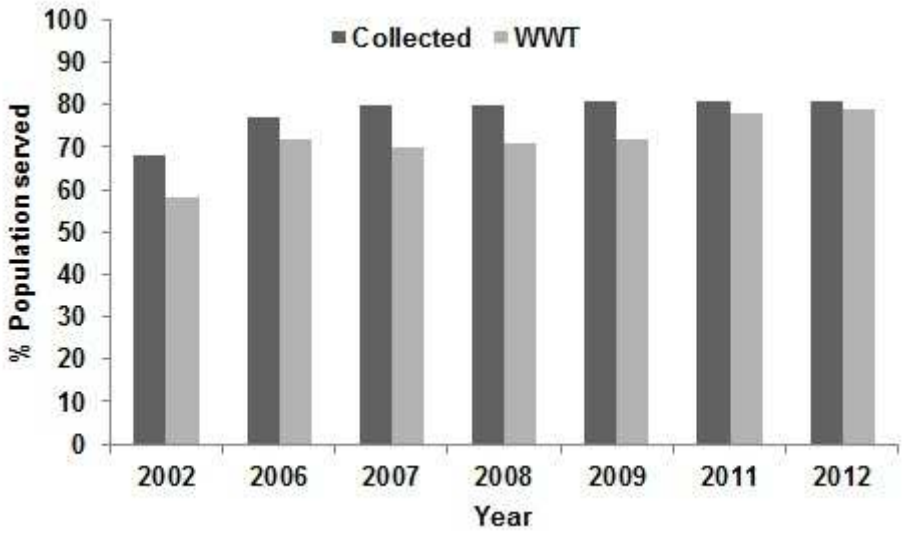

Figure 2: Evolution of wastewater coverage level in Portugal (2002 - 2012)

Table 2: Bibliographical sources consulted for ME

Management entities	Bibliographical sources
Águas de Santo André	ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ Águas de Santo André financial statements (2009 - 2013) available on: http://www.adsa.pt/
Águas de Trás-os-Montes e Alto Douro	ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ Águas de Trás-os-Montes e Alto Douro financial statements and sustainability reports (2009 - 2013) available on: http://www.aguas-tmad.pt/
Águas de Zêzere e Côa	Specifically surveys ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ Águas de Trás-os-Montes e Alto Douro financial statements (2010) and sustainability reports (2010 - 2012) available on: http://www.adzc.pt/
Águas do Algarve	Specifically surveys ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ Águas do Algarve financial statements (2009 - 2012) available on:http://www.aguasdoalgarve.pt/
Águas do Noroeste	ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ Águas do Noroeste financial statements (2010) and sustainability reports (2010 - 2012) available on: http://www.adnoroeste.pt/
Águas do Oeste	ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ Águas do Oeste financial statements (2010-2012)) available on: http://www.aguasdooeste.pt/
Águas do Sado	Águas do Sado financial statements (2009-2012) available on: http://www.aguasdosado.pt/
SANEST	ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ SANEST financial statements (2009 - 2012) available on: http://www.sanest.pt/
SIMARSUL	Specifically surveys ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ SIMARSUL financial statements and sustainability reports (2009 - 2012) available on: http://www.simarsul.pt/

SIMDOURO	Specifically surveys ADP financial statements (2010 – 2013) and sustainability reports (2011 - 2013) available on: http://www.adp.pt/ SIMDOURO financial statements and (2010 - 2013) available on: http://www.simdouro.pt/ Águas de Gaia financial statements (2010 - 2013) available on:http://www.aguasgaia.eu/pt/
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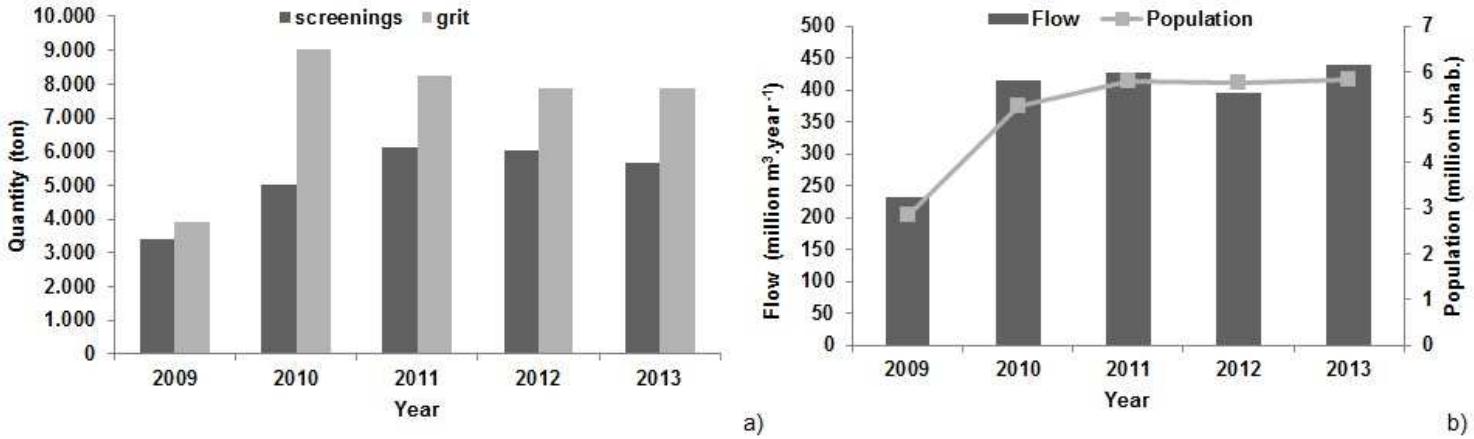


Figure 3: Evolution of a) screenings and grit productions and b) flow and population between 2009 and 2013

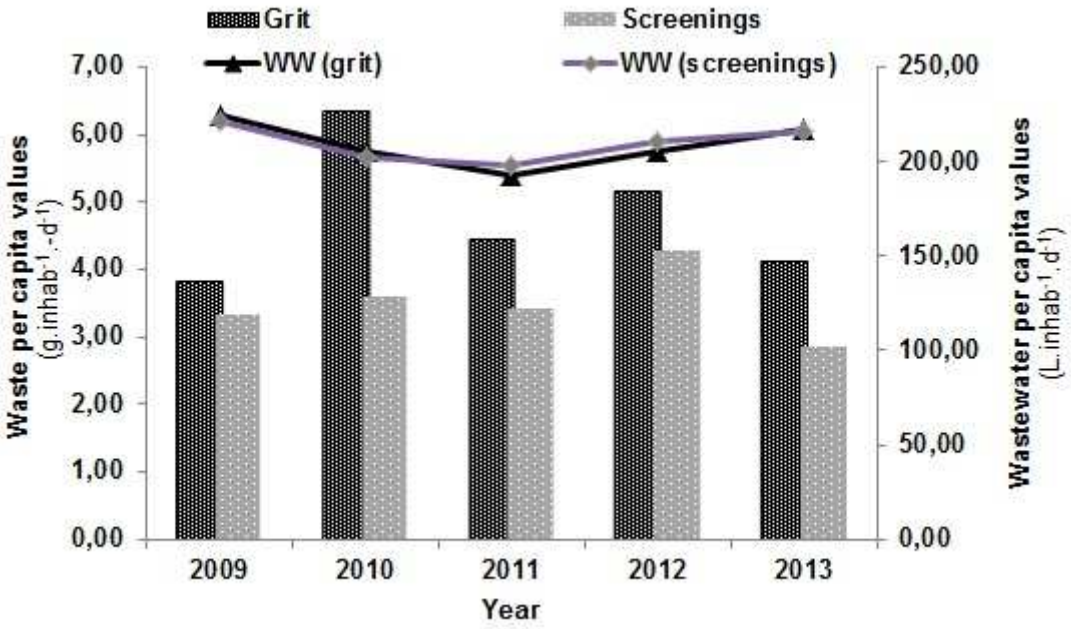
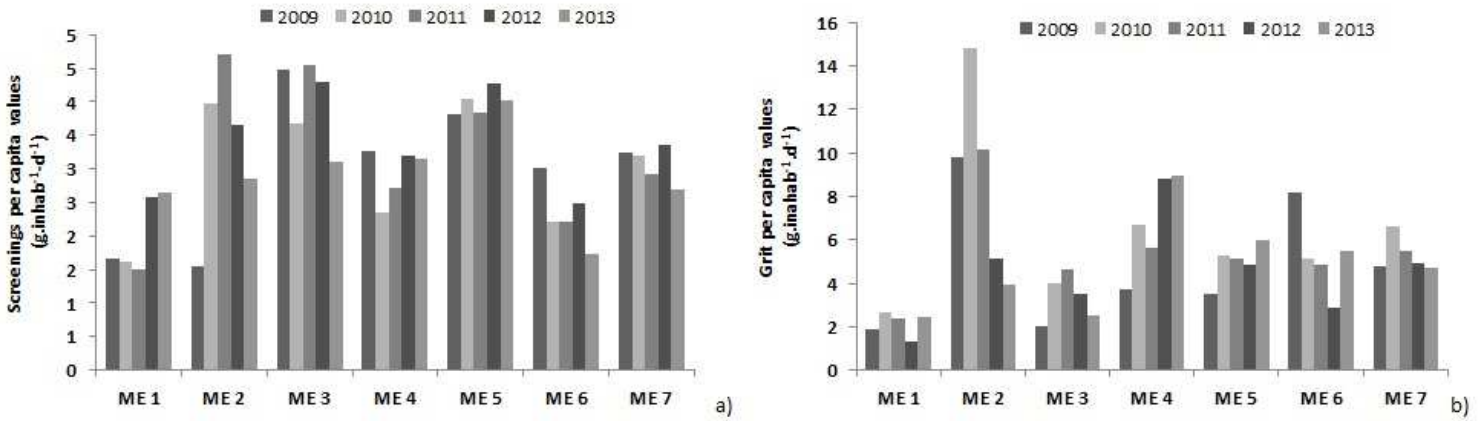


Figure 4: Evolution of wastes and wastewater average per capita in 13 ME



M1 - Águas de Zêzere e Côa, M2- SIMARSUL; M3 - Águas do Algarve; M4 - Águas do Sado; M6 - Águas do Oeste; M7 - SMAS da Caldas da Rainha; SIMTEJO

Figure 5: Evolution of a) screenings and b) grit per capita by ME

Table 3: The main characteristics of SIMTEJO WWTP

	Alcântara	**Beirolas**	**Chelas**
Project Population (ep)	756,000	213,500	211,000
Population (2012) (ep)	531,146	177,207	139,349
Project flow ($m^3.d^{-1}$)	140,000	54,500	52,500
Flow (m^3) (2013)	53,708,041	16,971,070	14,177,553
Screenings removal	Coarse screening systems to remove solids > 6 mm	Coarse screening systems to remove solids > 6 mm	Coarse screening systems to remove solids > 6 mm
Grit removal	Aerated grit and grease removal	Aerated grit and grease removal	Aerated grit and grease removal
Final disposal	Landfilling	Landfilling	Landfilling

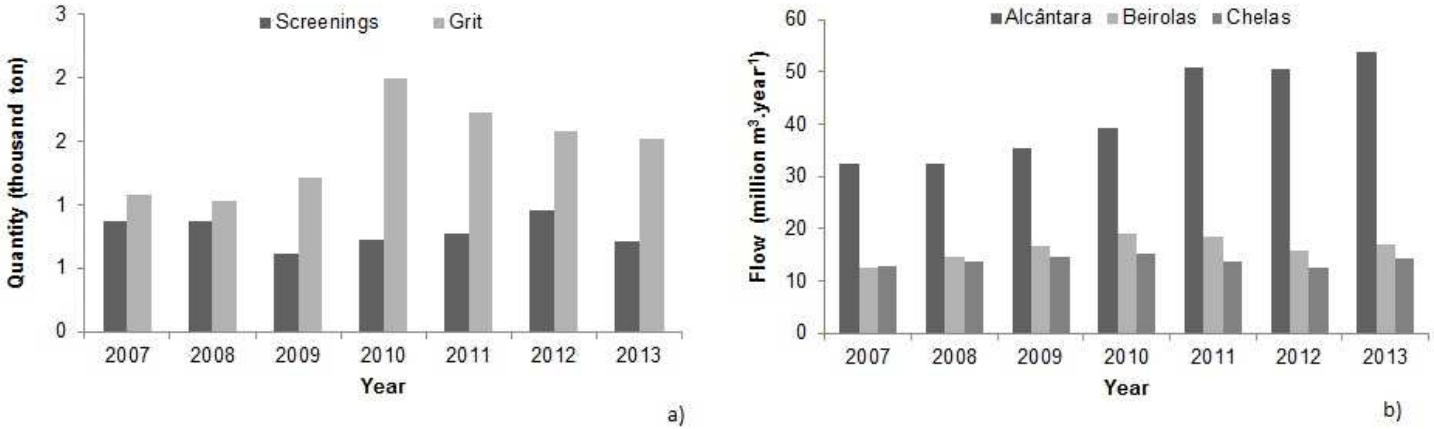


Figure 6: Evolution of a) WWTP Simtejo screenings and grit productions b) and WWTP flow between 2007 and 2013

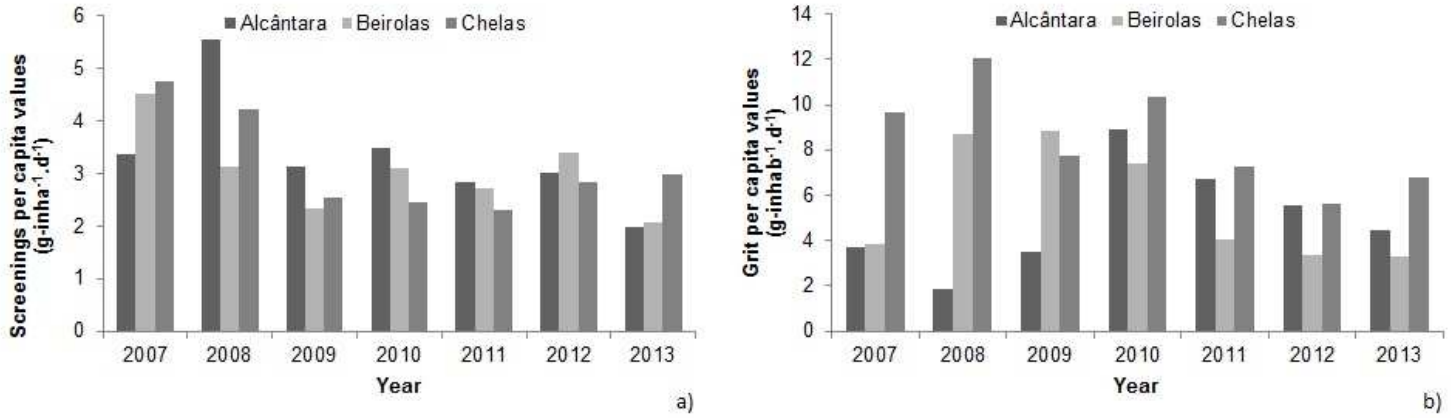


Figure 7: Evolution of a) screenings b) and grit per capita by WWTP

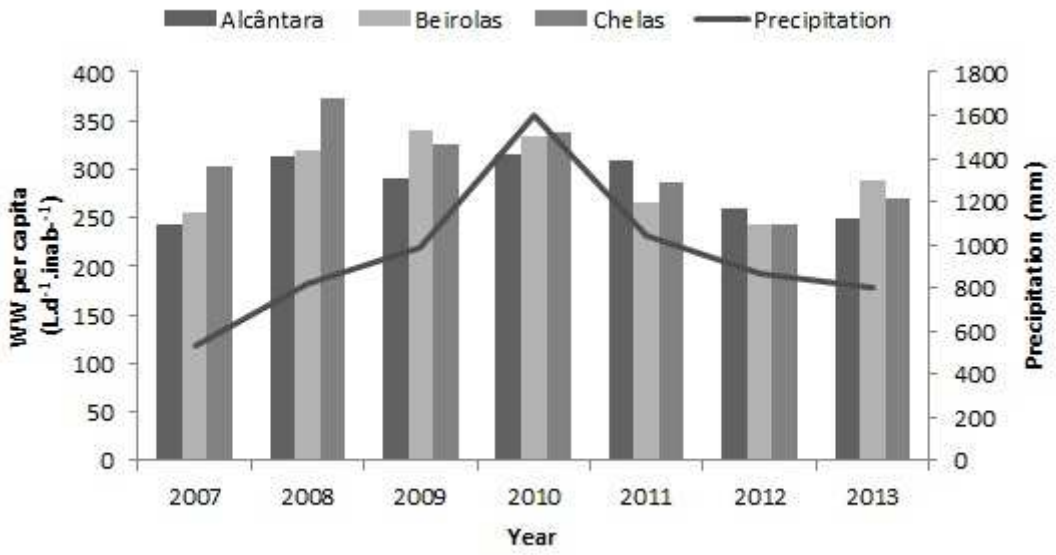


Figure 8: Evolution of wastewater per capita production and the precipitation in Lisbon

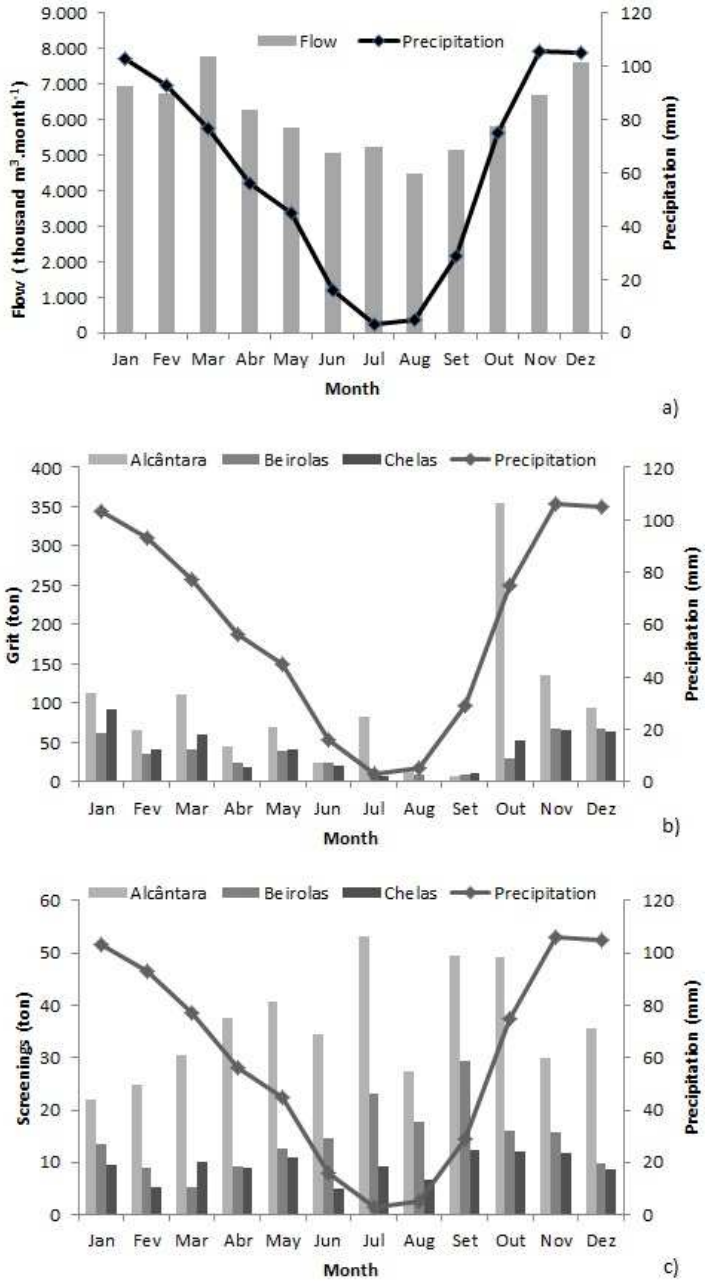


Figure 9: Evolution of precipitation in Lisbon with a) wastewater flow, b) grit and c) screenings production