Study of the ecological footprint of the construction activity

Prevention of occupational risks by means of public procurement in central america
Occupational safety
By SYLVIA AGUILAR CAMACHO et al

Biodegradation of organic pollutants in farming soil amended with compost from urban wastewater treatment plants
Environment
By A. ZAFRA GÓMEZ, et al

Programme for preventing falls by older people at home
Safety
By D. S. RISSON RANNA, et al

Full issue
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Construction is not only a thing of buildings and cities. It also takes in many agents, actions and transformations that determine whether the construction process as a whole observes or breaches the principles and criteria of sustainable development throughout its whole life cycle: urban development of rural land, construction of buildings, use and maintenance and demolition or refit. Within this cycle there is at first a strong transformation when the rural or previously non-development land is turned into development land. This study therefore looks at its ecological footprint (EF), bearing in mind the following impacts: machinery, labour, construction material and built-up area.

This study takes a new approach to the assessment of the environmental impact of construction, i.e., the ecological budget, phasing an environmental component into the Andalusia Construction Costs Database (Base de Costes de la Construcción de Andalucía: BCCA). Finally, the proposed method allows us to determine the EF produced by building projects, together with their budget.

In 1993 the World Wildlife Fund (WWF) defined the term “sustainable construction” not only as the buildings per se but also their environment and the way in which “they behave” to form cities. Construction and other agents that intervene directly or indirectly have notable environmental impacts in terms of consumption of natural resources and energy, emission of greenhouse gases and generation of waste; hence the need for taking the environmental aspect into account as a key factor in any sustainable construction approach. Construction is responsible for over 40 percent of the consumption of natural resources, 30 percent of the consumption of energy and 30 percent of greenhouse gas emissions. It also accounts for a significant percentage of the worldwide consumption of wood and water [1].

Faced with the climate-change problem and the constant needs of bringing in environmental improvements, two professors of the University of British Columbia, Wackernagel and Rees, coined the concept of ecological footprint (EF). These researchers created an indicator for comparing the footprint by continents, countries, regions, etc., defined as «the area or ecologically productive land (crops, pastures, forests and aquatic ecosystems) required to produce the resources consumed and to absorb the waste produced by a given population with a specific standard of living on an indefinite basis» [2]. This is shown schematically in Figure 1.

The EF indicator could be applied to the whole edification project, calculating the footprint generated by the various...
sources of impact (energy production, water supply, food consumption, mobility construction material, waste and direct land occupancy).

In our case a methodology is developed to determine the ecological footprint of land use changes, based on a measurement of the project, its budget and location.

**Methodology**

**Land-use change**

Figure 2 shows the various components making up the footprint produced by land-use change, broken down into various levels. The components are defined in terms of project quantities (orange box) and BCCA unit prices (blue box). Other components such as water consumed or direct land occupancy are taken from the general project report or empirical data from other projects. Each direct or indirect cost calls for an input of resources: labour, machinery and materials, all of which in turn produce different types of footprints.
Figure 2. EF calculation flowchart from the project budget

Machinery
Under this heading a study is made of the footprint produced by the use of machinery, in particular its consumption of energy (both fuel and electricity), tying this in with engine power. A distinction has been made between the footprint produced by the use of the machinery itself and by the machine operator. Figure 3 shows the flowchart for turning machine working hours into an energy-based EF.
Figure 3. Flowchart for calculating the ecological footprint produced by energy consumption of machinery

Fuel consumption figures are taken from SEOPAN's machinery cost manual [4]. Once the fuel consumption figure has been
The environmental aspect can be incorporated in a standardised way into the construction work budget by reference to the Regional Council of Andalusia’s Construction Cost Database.

Electricity consumption is calculated in a similar way to the fuel. Electrical machinery, as recorded in the BCCA is analysed, then obtaining kWh from the engine power and hours worked. On the basis that the electricity-producing systems’ yield is 33 percent [5], a calculation is then made of the primary energy consumed. In this case a determination is made of the emissions per source: coal, oil, natural gas or nuclear energy, in proportion to Spain’s energy mix [6].

Labour
An analysis is then made of the worker-generated impact in terms of food consumption, generation of municipal solid waste (MSW) and their mobility (commuting back and forth to work), as shown in Figure 4 and defined in the following sections.
Food generated EF
The footprint produced by workers’ food consumption is taken from the total labour hours necessary in the urban development project and the coefficient EF_m, which represents the footprint for each meal taken during the working day.
It is therefore necessary to obtain the EFm of the various types of food making up the daily food intake of each worker. This food intake accounts for four types of consumed land: pasture, cropland, productive sea, and absorption forest. Each food item will produce two types of footprint: the footprint produced by the consumption of the food itself and the footprint produced by its handling and transformation throughout the whole process.

The footprints produced per type of food (meat generates an EF of pastureland; fish will generate an EF of productive sea; cereals produce an EF of cropland …) are shown in Figure 5 in terms of the global hectares used per ton of food in one year.

Each coefficient will be aggregated in terms of its productive area, thereby obtaining the footprint produced by each food item. The four categories are in turn added together to obtain a general coefficient telling us the total footprint per food item consumed. Applying these figures to the menus served, which in turn depend on the worker’s hours, gives us the food intake EF.

Figure 5. EF of each food type.

**Mobility EF**
Analysis of worker mobility (commuting) is based on the following hypotheses: the construction site lies 30 km from the workers’ homes and each four workers share a car for commuting. The performance figures of the commuting vehicle: used, according to the distance travelled, gives us the litres of fuel consumed and its footprint is obtained in the same way as in the previous case with machinery.

**Municipal solid waste EF**
Waste generation is based on the mean MSW generation index of the
assigned within the project budget to one single activity but rather the across-the-board effect of several construction-site activities.

Environment Report in Andalusia (Informe de medio ambiente en Andalucía) [8]; applying this indicator to the number of workers on the site then tells us the amount of MSW generated. This amount is then broken down into organic, paper, plastic and glass waste and others (including metals), as shown in Figure 6; to these will be applied the conversion rates based on the studies of Wackernagel [9], which takes into account the necessary energy processing intensity, the amount recycled, the energy productivity and the forest equivalence factor, as the amount of wooded land needed to absorb the CO$_2$ produced by all processes. This then gives us a coefficient indicating the EF produced per ton of MSW.

![Figure 6. MSW Percentages](image)

**Materials**

The methodology for calculating the materials’ footprint takes into account the energy incorporated during their life cycle on a cradle-to-site basis, as shown in Figure 7. This energy will then be transformed into hectares bearing in mind the energy productivity of the fuel used in transformation work, applying the forest equivalence factor to this result.
In any urban development site some items will not be proportional to plot size, thereby producing a bigger relative footprint on small sites than large sites. Figura 7. Material lifecycle [3].

Calculation of the MJ of each construction material involves a previous processing for determining corresponding weights since many materials are bought by volume or number-off. Different standards are used to obtain volumes and densities. Finally, the MJ incorporated by each kilogram of material is obtained from lifecycle analysis databases.

Indirect Costs

A groundbreaking element of this study is incorporation of indirect costs in the EF indicator. Indirect costs are those elements that cannot be assigned within the project budget to one single activity but rather the across-the-board effect of several construction-site activities. The site foreman, for example participates in all work and in the use of the tower cranes used in structure execution right up to the installation of fittings. Taking as reference the BCCA, a study is then made of indirect costs attributable to a construction project.

Each indirect-cost item is transformed into useful figures for calculating the EF (effective annual working hours, machinery fuel consumption, water and electricity consumption by site portacabins, etc.), which will then be fed into the footprint scheme according to the process described above, with the idiosyncratic items in this case of water and electricity consumption by site portacabins, worksite illumination and facility start-up tests.

The energy consumption of worksite portacabins takes into account the figures cited in Supplementary Technical Instruction ITC-BT-10, which lays down a consumption of 0.10 kW/m² for use of commercial buildings and offices [10]. In the particular case of electricity consumption for site-illumination, the minimum lighting level of 100 lux (lumen/m²) has been applied to the plot area [11].

Lastly, facility start-up testing consumption is also factored into the picture, involving an analysis of 30 Endesa projects to generate a coefficient relating kWh to the plot area in square metres. This gives a mean consumption of 1.11 kWh/m².

As regards water consumption in washrooms and dressing rooms, an average figure of hot-water consumption per person and day is established according to CTE (Technical Building Code)[12], topped up by 25 percent to allow for toilet use; finally, the number of workers and days worked then give us the total litres consumed.

The total water employed in urban development work is rounded out by direct project costs, where water is just one more construction material. This value is then added to the former to determine the water EF.

Land Occupancy

This section will take into account the land area directly consumed by the project, since it will be biologically unproductive from the moment of occupancy. This footprint will therefore be given by the total construction-activity area, applying the
Impacts on the zone’s trees lead to alterations in the land’s biocapacity.

Affected trees and plantlife

Analysis of the vegetation’s CO₂ absorption capacity (Figure 8) is based on Professor Figueroa Clemente’s studies, establishing the kilograms of CO₂ absorbed yearly by the various tree species in terms of leaf type and size.

The number of trees found in the development area is obtained by defining three plantation intensity levels per square metre. Absorption coefficients are then applied to these trees. This same process will then be repeated with the new vegetation to be planted in the plot during the construction work, duly reflecting cases where the plantlife to be introduced is more beneficial than the withdrawn species, thereby boosting the zone’s absorption capacity.

Figure 8. Tree absorption of CO₂[3].

Figure 9 shows the different absorption capacity of various tree types with a high plantation density. Trees of the Meliţ genus have the highest absorption rate, followed by the Jacaranda genus.
Figure 9. CO₂ absorption broken down by tree type

Practical cases

To validate the proposed method and test the EF indicator’s sensitivity in urban development work, two urban development projects of different types were analysed. The first is a residential plot in La Palma del Condado, with a material execution budget of 187,613.37 euros and an affected land area of 7123.78 m² [14]. The second corresponds to an urban development project of an industrial zone in Écija, with a material execution budget of 13,427,115.05 euros and a 620,256 m² plot [15].

The resulting EF of the residential development project, shown in Table 1, is 260 gha and 36.5 gha per 1000 m² of plot. In the case of the industrial development, shown in Table 2, the EF is 12,834.46 gha and 20.69 gha per 1000 m² of plot.

Table 1. Residential development  
Total footprint: 36,50 hag/1,000m²

<table>
<thead>
<tr>
<th>Impact</th>
<th>Fossil Fuel</th>
<th>Woodland</th>
<th>Pasture</th>
<th>Sea</th>
<th>Cropland</th>
<th>Built-up area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery</td>
<td>1,20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>0,87</td>
<td>2,15</td>
<td>1,46</td>
<td>0,78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>25,40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect Costs</td>
<td>1,13</td>
<td>0,01</td>
<td>1,65</td>
<td>1,13</td>
<td>0,60</td>
<td></td>
</tr>
<tr>
<td>Direct occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,13</td>
</tr>
<tr>
<td>Total</td>
<td>28,60</td>
<td>0,01</td>
<td>3,80</td>
<td>2,59</td>
<td>1,38</td>
<td>0,13</td>
</tr>
</tbody>
</table>

Table 2. Industrial Development  
Total footprint: 20,69 hag/1,000m²

<table>
<thead>
<tr>
<th>Impact</th>
<th>Fossil Fuel</th>
<th>Woodland</th>
<th>Pasture</th>
<th>Sea</th>
<th>Cropland</th>
<th>Built-up area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery</td>
<td>1,56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>0,69</td>
<td>1,41</td>
<td>0,96</td>
<td>0,51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figures 10 and 11 compare the two cases analysed, broken down by type of footprint produced and type of impact respectively. The highest footprint percentage is recorded by fossil fuels (78-80 percent); and the most important impact producing items are materials (69-68 percent) and labour (14-17 percent).

In both cases the energy footprint is the highest, significantly so in the residential project due mainly to the construction material. It is particularly noteworthy that indirect costs are as significant as labour in both cases, whereas they are usually left out of footprint analyses.

The overall results in gha/1000 m$^2$ show that the residential development records a figure almost twice as high as the industrial development, due to the characteristics of future constructions (lower construction density in industrial building than in blocks of flats).

Materials represent the biggest percentage generation of footprint. This is because there are some items that are not proportional to plot size, such as valves, substations, electrical and wiring systems, etc, resulting in a bigger relative footprint in small plots than in large plots.

<table>
<thead>
<tr>
<th></th>
<th>Residential</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuel</td>
<td>28.5</td>
<td>14.2</td>
</tr>
<tr>
<td>Pasture</td>
<td>10.5</td>
<td></td>
</tr>
<tr>
<td>Sea</td>
<td>5.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Cropland</td>
<td>4.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Built-up area</td>
<td>3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Woodland</td>
<td>1.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Figure 10. Ecological footprint per plot area by type of footprint
Conclusions

The proposed methodology, applied to the abovementioned cases, shows the following:

- Results depend directly on the particular characteristics of the project. This brings out the importance of a correct wording thereof. Equipment, machinery, material and facilities all have to be described in the greatest detail in the interests of inputting the maximum possible amount of information and ensuring correct calculation of the footprint.
- Materials represent the biggest percentage of the total footprint (69-68 percent). Any change in material, recycling or reuse, could therefore have a huge effect on overall results.
- Labour weighs in with 14-17 percent of the total footprint, showing how vital it is to factor in this aspect when planning project work, adding value to the human part. The indicator pinpoints where and how intensely human capital is used in the various activities.
- The fossil fuel footprint represents the biggest percentage (78-80 percent), showing the importance of encouraging clean energy production systems (solar, photovoltaic, wind power...).
- The footprint produced by direct land occupancy is not significant (0.35-1.21 percent), but the change in CO₂ absorption capacity is important (e.g., 0.065 tons of CO₂/m² per plot per year in the case of felling holm oaks).
- As a general conclusion, a methodology has been developed for calculating the footprint produced by the construction activity, understood as the whole process of changing rural land into urban development land. All this has been referenced with the BCCA, showing that the environmental aspect can be incorporated into construction work budgets in a standardised way.

Referencias


10. Real Decreto 842/2002, de 2 de agosto, por el que se aprueba el Reglamento electrotécnico para baja tensión.

11. Real Decreto 486/1997, de 14 de abril, por el que se establecen las disposiciones mínimas de seguridad y salud en los lugares de trabajo.

12. Real Decreto 314/2006, de 17 de marzo, por el que se aprueba el Código Técnico de la Edificación.


Prevention of occupational risks by means of public procurement in central america

In Central America, where there is a growing trend of workers' rights breaches, including their right to health and safety at work, the state's public procurement policy is duty bound to set an example in terms of complying with labour legislation, thus falling into line with the international sustainable public procurement movement. This article looks at the role played by five countries in this region in terms of encouraging and enforcing occupational-risk-prevention in the companies they do business with, focusing on three types of commonly procured services in the region (construction, cleansing and security/surveillance). It examines the health-and-safety requirements laid down in public procurement contracts and comes up with some closing conclusions in light of this analysis.

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The countries under study here (Guatemala, El Salvador, Nicaragua, Honduras and Costa Rica) have a population between them of about 39 million, about 42 percent of whom belong to the economically active population (1). (Table 1)

<table>
<thead>
<tr>
<th>Country (year)</th>
<th>Agriculture</th>
<th>Industry</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costa Rica (2010)</td>
<td>15,0</td>
<td>19,5</td>
<td>65,6</td>
</tr>
<tr>
<td>El Salvador (2010)</td>
<td>21,2</td>
<td>21,2</td>
<td>57,5</td>
</tr>
<tr>
<td>Guatemala (2006)</td>
<td>30,6</td>
<td>23,8</td>
<td>45,6</td>
</tr>
<tr>
<td>Honduras (2010)</td>
<td>36,2</td>
<td>19,0</td>
<td>44,8</td>
</tr>
<tr>
<td>Nicaragua (2005)</td>
<td>33,6</td>
<td>19,0</td>
<td>46,6</td>
</tr>
</tbody>
</table>

Source: CEPAL (2011). The 2010 employment rate varied from 4.8 percent in Guatemala to 9.7 percent in Nicaragua (1). Farming is still one of the main economic sectors, although the workforce it employs has fallen by about 2 percent in comparison with estimated figures for the past decade, mainly due to the transition to commerce, manufacturing and construction (2).
Increasing countries’ resources in this area of the world would help to fortify the factory inspectorate system while also ensuring enforcement of labour legislation to the benefit of employers and employees.

All these countries have unfinished business in terms of strengthening factory inspectorate services: the various employment ministers have few resources to hand for this task and the budget earmarked for labour affairs is also limited in each country. Increasing these resources, together with other technical measures, would help to reinforce the factory inspectorate system while also ensuring enforcement of labour legislation to the benefit of employers and employees.

Table 2. Percentages of social security coverage

<table>
<thead>
<tr>
<th>Country</th>
<th>Total population</th>
<th>Economically active population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costa Rica</td>
<td>87,6</td>
<td>87,5</td>
</tr>
<tr>
<td>El Salvador</td>
<td>21,5</td>
<td>22,8</td>
</tr>
<tr>
<td>Guatemala</td>
<td>18,1</td>
<td>17,9</td>
</tr>
<tr>
<td>Honduras</td>
<td>16,9</td>
<td>16,9</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>16,4</td>
<td>18,2</td>
</tr>
</tbody>
</table>


One of these technical measures would be to use consumer power for rewarding those companies that do implement responsible practices. The main consumer in any country is precisely the public sector, accounting for purchases adding up to 15 percent of the Gross Domestic Product\(^3\). It is therefore duty bound to lead the way, and this movement, at worldwide level, has become known as sustainable public procurement.

The main aim of this project is to analyse the Central American states’ role in terms of encouraging and enforcing the prevention of occupational risks in the companies they do business with.

The first step was to carry out a bibliographical review of the legal requisites on the occupational-risk-prevention clauses to be included in the public procurement legislation of each country. To check actual implementation of these requisites an analysis was made of public procurement specifications in three types of common labour-intensive public procurement services, namely construction, cleansing and security/surveillance, to see how occupational risks and state legislation were observed in the procured activities. Interviews were also held with public-sector purchasers to find out how the contracts of these services are monitored, including the type of fines levied for any breaches.

Results

Occupational health-and-safety legislation in Central America ranges from the overarching constitutional rules of each country right down to the specific laws and regulations on prevention of occupational risks. This legislation, however, is not tied in directly with public procurement processes. The legislation governing public procurement in the countries under study calls for bidders to prove they are up to date with their social security obligations and also requires inclusion of a contract clause indicating that no labour relationship exists between the procurement institution and the employees of the contracted firm (which, upon signing the contract, undertakes to comply with labour legislation). Only in the case of Costa Rica did we find any legislation explicitly laying down the requisite of monitoring labour and social-security obligations during contract performance, Directriz Nº 34 del Poder Ejecutivo (Executive Guideline 34), published in La Gaceta (Official State Journal) 39 of 25 February 2002):

- Every public bid invitation and contract regulated by the Ley de Contratación Administrativa (Public Procurement Law) or the Ley de Concesión de Obra Pública (Public Work Concession Law) is bound to include a clause laying down the contracting firms’ inescapable duty to comply strictly with labour and social security obligations, any breach thereof...
serving as contract discharge grounds.

- It is the remit of each administrative level involved in the whole procurement process to check periodically or compliance with the above obligation, on pain of the corresponding disciplinary penalty imposed on the government official who is remiss in this matter, varying according to the severity of the oversight fault.

To identify the types of requisites made by institutions in their procurement documents, an analysis was made of 45 public procurement specifications of the three types of services involved, as follows:

- 14 procurement documents for the security and surveillance service.
- 16 procurement documents for the cleansing and sanitation service.
- 15 procurement documents for the construction service.

Choice of the procurement documents to be analysed was based on non-probability sampling by quotas (and by availability), so it should be noted that no statistical type meanings are sought herein.

Graph 1 shows the number of occupational health-and-safety requisites included in procurement specifications per country for the security and surveillance service. Costa Rica and El Salvador come out as the two countries including most criteria, with Guatemala bringing up the rear.

The personal protection equipment to be used by people working in the security and surveillance service is not explicitly described in the procurement specifications. In the case of Costa Rica it was not found in any of the documents analysed, while those of El Salvador, Guatemala, Honduras and Nicaragua refer to the use of uniforms, footwear, flashlights, protective cape, walky-talkies and bullet-proof jackets, the latter requisite only in Guatemala.

In the case of occupational health-and-safety requisites for the cleansing and sanitation service, (Graph 2) it is once more El Salvador and Costa Rica that include most criteria, albeit not in a standardised way (some institutions are stricter than others). Guatemala, Honduras and Nicaragua show a similar trend in terms of the number of requisites, albeit with far fewer than the other two. There was even one procurement specification that included no occupational health-and-safety requisites.
In Central America there are no national policies to encourage inclusion of occupational health-and-safety clauses in public procurement contracts.

Notably, criteria related directly to the prevention of occupational health-and-safety risks run by people who are going to work in these activities are found only in the documents of Nicaragua and Costa Rica. They are worded as follows: «(…) they shall don all protection wear, including masks, gloves and closed shoes», «(…) assuring use and working operation thereof (the personal protection equipment)». Other procurement specifications call for risk insurance policies, registrator in the corresponding social security bodies and observance of established working hours, among others.

Procurement specifications related to construction include in general a higher number of occupational health-and-safety requisites in the various countries, barring Honduras, which is the country laying down fewest criteria, and Nicaragua, which, in one of the documents studied, laid down no criteria at all. (Graph 3).
In the case of the construction service, occupational health-and-safety requisites are described more specifically in the procurement documents. For example, the three procurement documents of El Salvador include a complete chapter to be met by the contractor on «Aspects related to occupational safety and industrial hygiene». Other requisites, for example, call for drinking water, toilet services and changing rooms to be provided and also the due placement of signage to delimit working zones plus working instructions and specifications for machinery and equipment to be used during the construction process.

Although all procurement documents establish the fact that the contracts do not generate any labour relationship whatsoever between the contracting public institution and the service-rendering firm - whereby it is the latter that is bound to comply with all occupational-risk legislation - one-off cases were found of institutions that included contractual clauses intended to promote occupational safety (and not only to exempt itself from liability thereunder). Clauses were included, for example, dealing with the handling of chemicals by workers, their personal protection equipment, training and instruction, duration of the working day and rest periods, among others and also the watchdog institutions during contract performance over decent-work aspects such as payment of wages on time, minimum salaries and insurance coverage, among others. Crucially they also spell out the breaches that would lead to fines, penalties or even contract discharge.

Although there are cases of institutions implementing practices of this type, there are also procurement documents in which the government authority simply eschews any employer liability and then makes no sort of arrangement for monitoring the social or environmental impact of this procurement or any sort of explicit requisite. This failure to make any explicit requisite ties the government hands thereafter, making it powerless to exert any influence on the firm during contract performance.

In a part of the world showing a growing trend of labour-rights infringements, it is paradoxical to find a lack of any national policies to encourage inclusion of requisites of this type in public procurement (for example, national policies of sustainable public procurement). This means that laying down requisites of this type is not common practice in the region and that public funds, through these unmonitored procurement arrangements, are being spent on firms breaching labour rights that the state itself seeks to enforce.
Construction is the sector showing most procurement maturity in terms of occupational health and safety aspects.

As well as the lack of any national policies, the procurement officers of some public institutions are themselves ignorant about the requisites to be included in their procurement contracts and also about what their responsibility might be during contract performance. For example, one government officer said that he could not tell a company to register its workers for social security purposes since it was a refit job that would last only two months and they were therefore temporary workers. In fact current legislation lays it down that social security coverage comes into play from the very first working day that the worker is hired, regardless of whether it is a temporary or open-ended contract. Another case mentioned is that of the levying of fines or penalties, which are usually associated only with work execution delays (in the case of construction) or quality faults. This means that the contract administrator is unable to admonish the contractor in the event of other types of social or environmental breaches.

The sector with most experience in monitoring occupational health-and-safety requisites is construction, but the government officers themselves acknowledge that this has largely been fostered by international infrastructure-funding banks (such as the International Development Bank, the German banking group KfW and the World Bank, among others), whose loans lay down this compliance as an eligibility requisite.

Conclusions

- Labour rights breaches, including occupational health-and-safety aspects, are a growing trend in Central America; there is therefore a need to maximise available resources to encourage compliance. This is all the more evident if we also consider that the employment ministers also have limited resources to hand.
- One of the possible ways of incentivising good practises is consumer power, i.e., encouraging a body of aware consumers who reward companies that follow responsible practices.
- The main consumer, in any country is the public sector, whose purchasing activity could account for over 15 percent of the Gross Domestic Product; as such it is duty bound to set the right example for others to follow.
- In Central America there is some legislation to guide companies towards due responsibility for the occupational health and safety of their employees but this is not tied in with public procurement legislation, and there is no specific mention of the state’s co-liability with service-rendering firms.
- The most common practices are to ask the bidder to prove it is up to date in social security payments and to indicate that the contracts do not generate any sort of labour relationship between the procuring institution and the employee of the bid-winning firm. This often turns out to be perfunctory, for it is no secret that a firm up to date in its social security payments has not necessarily included all its payroll staff in the scheme; neither does it mean that the firm necessarily comply with labour rights (even if they have signed declarations promising to respect them).
- In each country examples are found of institutions that implement stricter procurement rules, even imposing fines or penalties for any breaches. In default of any national sustainable public procurement policies, however, they are usually phased in by international infrastructure-financing banks or left up to the discretion of each particular institution.
- Of the three types of services analysed, the sector showing most procurement maturity in occupational health-and-safety terms is construction, while the procurement requisites sought in cleansing and security services are minimum or non-existent in some of the cases studied.
- In terms of government institutions it is the local councils that are most lax in seeking occupational health-and-safety requisites, possibly due to a lower technical competence in this field.
- The public procurement legislation of the countries under study contains principles and provisions that could drive...
better enforcement of occupational health-and-safety requisites.

- Government procurement officers should have their role reinforced and also need to be made better aware of their remits and powers as responsible purchasers of public goods and services.

References

This article presents an analytical-chemical and microbiological study of the immediate and longer-term environmental impact of emerging contaminants (bisphenol A, parabens and B-blockers). This impact has been studied in three specific contexts: sewage sludge, the compost obtained from the sludge and compost-amended farming soil. An analytical methodology of good characteristics has been vetted and validated to quantify the compounds under study in the three abovementioned frameworks. Sludge composting effect on the final compost quality has also been studied, together with leaching and degradation of the contaminants. An assessment has also been made of soil microbiota - with and without compost - and of the contaminants, in order to isolate and select microorganisms capable of using these compounds as a source of carbon and energy. The results are scientifically important.


Sludge production in Wastewater Treatment Plants (WWTP) is an inevitable consequence of today’s consumer society; such sludge accounts for a high proportion of human-produced urban organic waste. Europe produces 8 million tons of this type of waste a year [1,2]. Treatment of this waste therefore represents a growing problem calling for an urgent solution; it is now essential to find safe and sustainable alternatives that are manageable from the environmental point of view.

Today’s main WWTP sludge-elimination options are post-treatment land application, landfill storage, incineration and sea discharge[1,2]. Recycling and composting for farming use, thus turning a harmful product into a beneficial product, is a promising alternative from an environmental and economic point of view. It is in fact considered to be the best option at worldwide level, contributing as it does to the recycling of soil nutrients and therefore boosting soil fertility[3,4].

Composting involves the biological breakdown of organic matter under controlled aerobic conditions to form a stable final product, excellent for amending farming soil. The process is driven by microorganisms and, in general, involves high temperatures as a result of biological heat production. Figure 1 outlines the process.

The main obstacle to the farming use of this material is its content of heavy metals and organic pollutants (macro-
micro-contaminants). Heavy metal content is now closely regulated and therefore easy to monitor[3-6]. As for organic pollutants, extensive research has been underway in recent years, focusing on the priority lists of «persistent organic pollutants» (POPs), now regulated to such an extent that the permitted and found concentrations in WWTP sludge have plummeted. In recent years, however, there has been growing worldwide concern about a new more extensive group of compounds of a very diverse nature. These have been dubbed «emerging contaminants» or «emerging pollutants». Very little is yet known about such properties as their persistence; evolution in water, farming soil and sediment; breakdown mechanisms; transfer to the food chain, and their effects on ecosystems and human health. Control of these substances has been phased in as more was learnt about them, and international backing has now been given to sludge recycling and use on farming soil. This practice, however, has generated many misgivings, and many countries, like Switzerland, have flatly rejected it.

![The composting process](image_url)

Figure 1. Outline of the composting process and full-scale compost pile

At the time of writing over 50 million chemicals have been identified, of which about 150,000 have been registered in the European Chemicals Agency for industrial use [7]. Given the impossibility of studying such a high number of potential contaminants, this research project has centred on two groups of compounds of great importance: endocrine disrupting chemicals (bisphenol A and parabens) and a family of pharmaceuticals (β-blockers). Within each group a selection was made of those compounds of greatest commercial interest and habitually used by part of the population, and as such detectable in WWTP input wastewater.

The first group of contaminants, of some concern due to their environmental persistence, comprises the endocrine disrupting chemicals (EDCs). These are compounds capable of altering the normal balance of hormonal functions in animals and their progeny; they are responsible for many reproductive defects, even degenerating into diverse types of cancer [8]. These compounds, of demonstrated estrogenic activity[9], are continually being released into the environment; there is evidence that most of them exist in WWTP sludge. There have been very few studies, however, into their evolution throughout the sludge treatment process (for example in the composting) before application to farming soil and the changes thereafter (leaching, biotransformation).

Bisphenol A is one of the most commonly produced compounds worldwide. It is the main raw material used in the manufacture of epoxy resins and polycarbonate plastics. It has countless applications in manufactured products, ranging from paints to food packaging plastic, baby bottles, dental composites and medical prostheses [10]. By now omnipresent throughout the environment, it is possibly the disruptor currently causing most concern to the scientific-medical community [11]. Its main elimination vector has been shown to be biodegradation[12], but the residual concentrations in WWTP water and sludge are enough to cause adverse effects at endocrine level. It is currently under study for inclusion in the Water Framework Directive (WFD) as a priority hazardous substance calling for stricter control[13]. Figure 2 shows the chemical structure of bisphenol A.
By now omnipresent throughout the environment, Bisphenol A is possibly the disruptor currently causing most concern to the scientific-medical community. It is present in the environment in many different matrices and has been detected in practically all environmental compartments. The reason for its research interest resides in its possible relation with breast cancer, since it has been attributed with endocrine disruptor activity. Figure 2 also shows the chemical structure of the five chosen study compounds.

The second group of contaminants of interest selected for this research study is pharmaceuticals. After being taken, drugs are excreted or urinated in their original form, as metabolites, or in conjugated form, ending up in wastewater with little control over concentrations. In Europe the surface water PEC for pharmaceuticals is 0.01 µg L$^{-1}$ for environmental risk assessment purposes; there are no guidelines on WWTP sludge concentrations. Absorption into solid material is one of the main wastewater drug elimination vectors, so the use of this material as fertiliser is a prime gateway into the environment. A study also has to be made of their environmental persistence to forestall the risk of long-term exposure, which might be responsible for chronic toxicity in animals and plants. This study involves a monitoring of the β-blocker family of pharmaceuticals. Widely used for the control of heart disease, this class of drugs is therefore of great importance and they are omnipresent in the environment. They comprise a group of 13 human pharmaceuticals; those selected for this study are shown in figure 2.

**Objective and Scope**

The Analytical Chemistry Department of Granada University has embarked on a new line of research for studying the environmental impact of many emerging microcontaminants. A threefold goal has been set for this research. Firstly, to observe the effect of the sewage-sludge composting process on the quality of the final compost, doing so by studying the chemical evolution of diverse emerging contaminants from their arrival in WWTP sludge until the final application of this compost.
sludge to farming soil. The second goal is to study the behaviour of these contaminants in the soil of the farmland known as Vega de Granada, once amended with said material. The third and last goal is to study the biodegradation of the contaminants under different conditions to isolate and select microorganisms capable of using these compounds as a source of carbon and energy. These then break down into the following specific objectives:

- Develop and validate an analytical methodology of good characteristics for detection and quantification of selected emerging contaminants in farming soil, WWTP sludge and composted WWTP sludge.
- Study the leaching/degradation of the compounds in farming soil, unamended or amended with contaminated compost, in an experimental farming plot in Vega de Granada.
- Conduct a microbiological study of the farming-soil compost-amending process, selecting the microorganisms capable of biodegrading these families of compounds.

Materials and Methodology
Reagents, standards and equipment

Despite have been used for over a century as cosmetic preservatives, the safety of PBs had not been called into question until recently.

The reagents and solvents used were those habitually used in a chemistry and microbiology lab. The standards of bisphenol A (BPA), parabens (PBs) and β-blockers were supplied by different firms with a purity higher than 99 percent in all cases. Chemical analysis was carried out with a Waters Acquity UPLC liquid chromatography system coupled with a Waters H-Class-Xevo TQS triple quadrupole mass spectrometer. Two extraction systems were tested for extracting contaminants from the samples: a Dionex ASE 200 for pressurized liquid extraction (PLE), and a Digital Sonifier S450D (BRANSON) ultrasonic processor for ultrasound assisted extraction (USE).

Compost samples were collected using conventional shovel loaders, and soil samples using a soil probe for surface samples and a soil auger for deeper samples. Soil temperature and humidity were monitored continuously at the different soil depths studied using an AquaCheck probe. Lastly, the normal glass equipment and other equipment (scales, ovens, stirrers, incubators, etc.) of any analytical-chemistry and microbiology laboratory were used.

Sampling
The variables exerting the biggest influence on the performance of the various extraction techniques were optimised. The optimum value for each variable was determined from the retrieval percentage of the extraction of compost-amended soil (100 µg g⁻¹). In light of the global results a selection was then made of the simplest and cheapest sample-analysis ultrasound technique. Table 1 shows the optimum parameters for each contaminant when using this extraction technique.

Table 1. Optimum analysis parameters using USE-UHPLC-MS/MS (1 g sample).

<table>
<thead>
<tr>
<th>USE</th>
<th>BPA</th>
<th>PBs</th>
<th>β-blockers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction solvent</td>
<td>Methanol</td>
<td>Methanol</td>
<td>Acetonitrile / buffer (1:1, v/v)</td>
</tr>
<tr>
<td>Solvent volume</td>
<td>2 mL</td>
<td>5 mL</td>
<td>5 mL</td>
</tr>
<tr>
<td>Ultrasound time</td>
<td>15 min</td>
<td>25 min</td>
<td>30 min</td>
</tr>
<tr>
<td>Extraction cycles</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasound power</td>
<td>75 %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centrifuge time</td>
<td>30 min (3.700 x g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaporation</td>
<td>Under N₂ current</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redissolution volume</td>
<td>500 µL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lastly, to improve the quality of the final extracts after ultrasound extraction, a scrubbing stage was applied using the QuEChERS technique (Quick, Easy, Cheap, Effective, Rugged and Safe)\[23]; this process was seen to improve analysis quality considerably.

**UHPLC-MS/MS Analysis**

Table 1 shows the optimised parameters for chromatographic separation and detection by means of mass spectrometry. Once these variables had been optimised, the two optimum spectrometry transitions (quantification and identification) were chosen for unequivocal determination of each molecule. Table 2 shows the selected fragments.

**Table 2. Fragmentation of studied contaminants**

<table>
<thead>
<tr>
<th></th>
<th>Transition 1 (Da)</th>
<th>CV / CE (V)</th>
<th>Transition 2 (Da)</th>
<th>CV / CE (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BFA</td>
<td>227.2 -&gt; 210.1</td>
<td>50 / 22</td>
<td>227.2 -&gt; 133.0</td>
<td>50 / 26</td>
</tr>
<tr>
<td>BFA-d$_{16}$</td>
<td>241.3 -&gt; 223.1</td>
<td>46 / 22</td>
<td>241.3 -&gt; 142.0</td>
<td>46 / 32</td>
</tr>
<tr>
<td>MPB</td>
<td>151.1 -&gt; 91.8</td>
<td>38 / 22</td>
<td>151.1 -&gt; 135.9</td>
<td>38 / 14</td>
</tr>
<tr>
<td>EPB</td>
<td>165.1 -&gt; 91.9</td>
<td>38 / 24</td>
<td>165.1 -&gt; 136.6</td>
<td>38 / 16</td>
</tr>
<tr>
<td>Compound</td>
<td>Initial Mass</td>
<td>Initial CE</td>
<td>Final Mass</td>
<td>Final CE</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------</td>
<td>------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>PPB</td>
<td>179.1</td>
<td>42 / 24</td>
<td>179.1</td>
<td>42 / 16</td>
</tr>
<tr>
<td>BPB</td>
<td>193.2</td>
<td>42 / 24</td>
<td>193.2</td>
<td>42 / 16</td>
</tr>
<tr>
<td>Ph-PB</td>
<td>213.1</td>
<td>18 / 10</td>
<td>213.1</td>
<td>18 / 28</td>
</tr>
<tr>
<td>EP-C_{13}</td>
<td>171.2</td>
<td>44 / 14</td>
<td>171.2</td>
<td>44 / 22</td>
</tr>
<tr>
<td>PRO</td>
<td>260.2</td>
<td>20 / 20</td>
<td>260.2</td>
<td>18 / 18</td>
</tr>
<tr>
<td>ATE</td>
<td>267.1</td>
<td>96 / 96</td>
<td>267.1</td>
<td>24 / 28</td>
</tr>
<tr>
<td>MET</td>
<td>268.3</td>
<td>12 / 12</td>
<td>268.3</td>
<td>20 / 20</td>
</tr>
<tr>
<td>SOT</td>
<td>273.2</td>
<td>22 / 22</td>
<td>273.2</td>
<td>28 / 18</td>
</tr>
<tr>
<td>BET</td>
<td>308.2</td>
<td>18 / 18</td>
<td>308.2</td>
<td>20 / 20</td>
</tr>
<tr>
<td>NAD</td>
<td>310.3</td>
<td>20 / 20</td>
<td>310.3</td>
<td>16 / 22</td>
</tr>
<tr>
<td>BIS</td>
<td>326.3</td>
<td>20 / 20</td>
<td>326.3</td>
<td>18 / 26</td>
</tr>
<tr>
<td>Isoproturon-d_{6}</td>
<td>213.2</td>
<td>14 / 14</td>
<td>213.2</td>
<td>26 / 16</td>
</tr>
</tbody>
</table>

CV: cone voltage; CE: collision energy.

Contaminant trend during the composting process

After carrying out the analytical methodology, an experiment was then conducted using samples from a composting process in a pilot plant designed for that purpose. The compost trend was studied for a month. The aim here was to determine the presence/absence of contaminants in the final compost. Samples at different times were taken to carry out these experiments.

Field Study (BPA and PBs)

This was carried out in an experimental plot in the farm of Santa María (Belicena, Vega de Granada). In this plot no type of pesticide, herbicide or insecticide had been used for the previous ten years to avoid alteration of soil microbiota\[24\]. Figure 3 gives a general view of the farm and the subplot.

![Image of the farm of Santa Maria and the experimental plots](image.png)

A series of 1 m² subplots was prepared for each trial, separated by 30 cm thick compartment walls. Existing vegetation was removed to avoid any interference with absorption-desorption mechanisms, degradation of the compounds under study or disruption of any general variable such as the water evaporation rate. Four different conditions were set:

- Plot 1. Soil only. Reference (Control).
- Plot 2. With pure contaminants applied directly to the soil.
- Plot 3. Amended with compost and contaminated with BPA and PBs.
- Plot 4. Amended with compost. Reference (control, blank).
WWTP sludge composting is a promising alternative since it is capable of turning an environmentally harmful product into a beneficial product.

Contamination both of the composted plot and the non-composted plot was effected by adding 1 gram of each compound in a volume of 120 litres of well water. Once doped, two successive operations were then carried out during the whole experimentation period, one sampling operation and one watering operation. Samples were taken at seven different depths (surface and depths of 10, 20, 30, 40, 50 and 60 centimetres). During the first week sample taking was daily, since previous studies had shown concentration to fall exponentially during this space of time, giving vital information on compound behaviour.

Microbiological Study
For this study three samples were taken from each subplot at times of 0, 15 and 30 days and at three different depths surface, 30 and 60 centimetres. Due to time and cost constraints, only the three compounds of the greatest environmental impact were chosen for this study, i.e., BPA, MPB and BPB. The following tests were conducted:

- **Cultivable microbiota count.** Using the plate count method. Results were expressed as a count of colony forming units (CFUs) per gram of soil (CFU/g soil).
- **Microorganism growth kinetics and compound degradation studies.** A battery of microorganisms was selected from the samples of soil treated with the different compounds and composted (coded with the initials of the compound added to this plot and a consecutive number). The selection was made on the basis of the morphological criteria of the colonies formed. Ten of the microorganisms were also used for degradation and kinetic growth tests. The kinetic test involved a base cultivation medium diluted 1/10 with 5 mg L\(^{-1}\) of the compound under study, incubated at 30\(^\circ\) C for five days.
- **Microbiological analyses.** These were conducted at 0, 24, 48, 72 and 96 hours. Results are expressed in terms of the optical density / CFU mL\(^{-1}\) ratio.
- **Chemical analyses.** The amount of degraded compound was determined by the UHPLC-MS/MS technique under the conditions described earlier herein. The samples, once taken, were centrifuged at 13,000 rpm for cell removal. Readings were taken at the start and end of the test (0 hours and 96 hours).
- **Biochemical microorganism characterisation.** Tests of API 50 CH (carbohydrate metabolism study) and API ZYM (enzyme activity study) were conducted. The chosen microorganisms for the carbohydrate test were those capable of breaking down a high percentage of contaminants, specifically those coded as MPB-8, BPB-3 and BPA-4. Likewise, for the enzyme activity test, a selection was made of the most representative of each group of samples, i.e., for methylparaben, MPB-1, MPB-2, MPB-3, MPB-8 and MPB-10; for butylparaben, BPB-3, BPB-7, BPB-12, BPB-13, BPB-15; and for Bisphenol A, BPA-1, BPA-4, BPA-8, BPA-9 and BPA-10.

Results and Discussion

Analytical Method
The first step was to establish the calibration relating the concentration of each compound to the signal generated by the UHPLC-MS/MS equipment. At each calibration level, 1 gram of sample was doped with increasing amounts of the compound to be analysed, with addition of the due internal standards. After treating the standards in accordance with the experimental procedures described above using USE and QuEChERs techniques, they were injected into the chromatograph.

Validation of methods. Quality parameters
In each case a determination was made of the linear dynamic range, the analytical sensitivity, detection limits and quantification and precision and veracity of the method. The excellent results obtained showed the validity of the method developed for the proposed application.

Compost Study
The validated methods were then applied to determination of contaminants in samples of WWTP sludge and compost made therefrom. Most of the B-blockers disappeared in the first days of the experiment. The most persistent were SOT and BET although they had biodegraded completely by the end. It should be noted here that the duration of an industrial-scale pile-composting process of tons of material is about one year. In the case of BPA and the PBs, initial contamination levels fell slightly but high contaminant levels did remain throughout the whole test; they can therefore be classed as persistent under study conditions.
The PBs do not leach into the soil (amended and un-amended). BPA leaches down only to 30 cm. This indicates a good environmental behaviour of the contaminants.

Given the rapid breakdown of β-blockers during the first days of the composting process, as observed in the compound trend study in the pilot plant, our attention focused on the rest of the contaminants apparently showing a slower breakdown rate and therefore higher persistence. The degradation kinetics of BPA and the PBs were studied with presence and absence of compost in the soil. Figure 4 shows an example of the degradation kinetics of a compound under given conditions (BPA).

![Figure 4](image.png)

Figure 4. BPA degradation kinetics in the plot of soil amended with contaminated compost in a surface area (a) and at a depth of 30 cm (b).

The experimental findings for all contaminants fit in with a first-order exponential equation \( C = C_0 \times e^{-k \cdot t} \), where the initial concentration values \( C_0 \), degradation constant \( k \), degradation half-life \( t_{1/2} \) and determination coefficient \( R^2 \) are those shown in table 3.

### Table 3. Degradation kinetic parameters of the contaminants

<table>
<thead>
<tr>
<th></th>
<th>Surface</th>
<th>10 cm</th>
<th>20 cm</th>
<th>30 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BPA in untreated soil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( k ) (h(^{-1}))</td>
<td>6.2 ( \cdot 10^{-3} )</td>
<td>4.4 ( \cdot 10^{-3} )</td>
<td>2.9 ( \cdot 10^{-3} )</td>
<td>2.5 ( \cdot 10^{-3} )</td>
</tr>
<tr>
<td>( C_0 ) (µg Kg(^{-1}))</td>
<td>7.6</td>
<td>8.7</td>
<td>7.4</td>
<td>6.9</td>
</tr>
<tr>
<td>( t_{1/2} ) (h)</td>
<td>112</td>
<td>158</td>
<td>237</td>
<td>279</td>
</tr>
<tr>
<td>( R^2 ) (%)</td>
<td>95.8</td>
<td>98.3</td>
<td>96.2</td>
<td>94.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Surface</th>
<th>10 cm</th>
<th>20 cm</th>
<th>30 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BPA in soil with compost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( k ) (h(^{-1}))</td>
<td>5.4 ( \cdot 10^{-3} )</td>
<td>4.9 ( \cdot 10^{-3} )</td>
<td>4.5 ( \cdot 10^{-3} )</td>
<td>3.6 ( \cdot 10^{-3} )</td>
</tr>
<tr>
<td>( C_0 ) (µg Kg(^{-1}))</td>
<td>14.0</td>
<td>8.9</td>
<td>5.9</td>
<td>4.7</td>
</tr>
<tr>
<td>( t_{1/2} ) (h)</td>
<td>128</td>
<td>143</td>
<td>155</td>
<td>192</td>
</tr>
<tr>
<td>( R^2 ) (%)</td>
<td>95.5</td>
<td>95.7</td>
<td>93.8</td>
<td>97.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>MPB</th>
<th>EPB</th>
<th>PPB</th>
<th>BPB</th>
<th>Ph-PB</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k ) (h(^{-1}))</td>
<td>3.8 ( \cdot 10^{-3} )</td>
<td>3.5 ( \cdot 10^{-3} )</td>
<td>4.1 ( \cdot 10^{-3} )</td>
<td>4.0 ( \cdot 10^{-3} )</td>
<td>2.9 ( \cdot 10^{-3} )</td>
</tr>
<tr>
<td>( C_0 ) (µg Kg(^{-1}))</td>
<td>13.2</td>
<td>15.9</td>
<td>11.91</td>
<td>14.7</td>
<td>11.8</td>
</tr>
<tr>
<td>( t_{1/2} ) (h)</td>
<td>183.8</td>
<td>196.4</td>
<td>167.4</td>
<td>172.9</td>
<td>231.8</td>
</tr>
<tr>
<td>( R^2 ) (%)</td>
<td>98.7</td>
<td>98.9</td>
<td>97.9</td>
<td>97.3</td>
<td>97.2</td>
</tr>
</tbody>
</table>
Compost characteristics can be boosted by isolating the microorganisms of most interest and supplementing the material with them. These microorganisms could be used in the bioremediation of environments contaminated with BPA and PBs.

The conclusion to be drawn from this is that BPA behaviour is similar in the presence and absence of compost, with a significantly higher degradation rate in surface samples (aerobic zone) than lower down (anaerobic zone). The degradation half-life \((t_{1/2})\) in the untreated soil plot is much higher than in the amended plot; this might be because the compost has a higher content of organic matter, thereby favouring the growth of contaminant-degradation-accelerating microorganisms. As for the PBs, under both conditions the five studied compounds showed similar degradation behaviour (all broken down at the surface) and none of them leached into the soil. The latter point is crucial from the environmental point of view; if they do not penetrate into the soil, they do not reach the water table or underground water. Half-lives are also higher than in uncomposted plots in the case of shorter chain PBs (MPB and EPB) and Ph-PB, but in the case of PPB and BPE slower biodegradation was observed in compost-amended plots.

Microbiological Study

An account is now given of the microbiology study results:

*Influence of the presence of the compounds and of the compost on the soil microbiota count*

Figure 5 shows an example (BPA) of the observed trend.

![Figure 5. Example of microorganism count (Log CFU/g soil) in the samples of soil treated and untreated with BPA at different depths, at the test start time (0 days), at 15 and 30 days. (a) Control soil sample without compost (S) and contaminated with the compound (S-BPA). (b) Control soil sample + compost (C) and soil + contaminated compost (C-BPA).](image)

The percentage results of log CFU/g soil obtained in soil without compost treatment (Figure 5a) were different in relation to surface samples (100 percent), with an observed microorganism descent of 9 percent and 25.6 percent for samples taken at 30 and 60 centimetres, respectively. In compost-amended soil (figure 5b) the trend of the number of viable microorganisms in the compost-amended and BPA-contaminated soil was downwards, with a reduction of 0.5 log in the CFL soil count-1 throughout the test time. A comparison of both figures shows how the count falls with increasing soil depth, this behaviour is repeated in all tests conducted over time (0, 15 and 30 days). Neither the control plot samples nor the BPA-treated samples showed any significant variations in the surface count (2 centimetres), indicating that population
levels held steady over time. Likewise, the counts at a depth of both 30 and 60 centimetres showed no significant variation over time in relation to the amount of bacteria present in the control soil samples and treated soil samples, obtaining very similar values in the number of microorganisms in the samples taken at 30 centimetres for each compound and also in those at a depth of 60 centimetres. The PBs showed very similar behaviour in all cases (figures not shown).

A notable finding is the increase in the absolute number of microorganisms in compost-amended soil in comparison to unamended soil; this is due to the microbial input of the composted material, which not only inputs chemical nutrients but also boosts microbial richness. There is therefore a higher microbial development in amended plots. This finding could be very useful in terms of improving compost characteristics, isolating the microorganisms of most interest and supplementing the material with them.

**Biochemical characterisation of selected microorganisms**

The use of the API 50 CH kit for metabolism of carbohydrates and the API ZYM kit for enzyme activity facilitated the characterisation of many microorganisms. The findings of the carbohydrate-fermentation and oxidation processes showed that each microorganism metabolises them differently. This fact, taken together with the results of enzyme activity, which indicates the presence or absence of the activity of a given enzyme, group of enzymes or of a given metabolic vector, enables us to discriminate between the studied microorganisms, selecting those that were different from the metabolic point of view.

**Growth kinetics in the presence of BPA, MBP and BPB as a source of carbon/energy. Degradation of compounds**

Figure 6 shows an example of microorganism growth kinetics for each of the contaminants studied.

The results show that the selected microorganisms were capable of growing in the presence of the contaminant and that this growth was higher than that obtained with the base medium in absence of the compound (control). The difference between both cultures (control and problem) are c. 0.5 log CFU mL⁻¹. The greatest difference between the cultures supplemented with contaminants and the control was observed in the microorganisms coded as BPA-6, MPB-3, and BPB-7 (shown in the figure), this difference being 8.2, 7.6 and 6.3 respectively. In relation to the amount of degraded product, in the case of BPA this was similar in all tests carried out, the microorganisms degrading the compound almost completely (99.9 percent). In the case of MBP there is a great variability depending on the microorganism; the one coded as MPB-3 is the only one capable of completely breaking down the compound, doing so in 96 hours of testing with 99.9 percent degradation. The degradation level observed in other cultures (MPB-1, MPB-2, MPB-8 and MPB-9) was about 20 percent. The microorganisms that degraded the compound least were MPB-4, MPB-5, MPB-6 and MPB-7, with degradation percentages of less than 10 percent. The microorganism defined as MPB-9 was the one found to use this compound least as a source of carbon/energy, with a breakdown percentage of only 5.6 percent. In the case of BPB the amount of degraded compound also varied greatly with the microorganisms concerned. Eight of them achieved a compound degradation rate of over 95 percent; the microorganism coded as BPB-7 was found to degrade the product by over 96 percent.

**Conclusions**

The following conclusions can be drawn from this research work:
Different analytical methodologies have been proposed and validated for detection and quantification of microcontaminants belonging to the family of endocrine disrupting chemicals (PBs and BPA) and one pharmaceutical group (-blockers) in WWTP sludge, compost produced from this sludge and farming soil (amended and un-amended), doing so by means of ultra high performance liquid chromatography coupled with tandem mass spectrometry (UHPLC-MS/MS) after contaminant extraction by means of ultrasound (USE) and QuEChERS. In all cases the quantification and detection limits obtained are low enough to be able to use these methods in the quantification and detection of these contaminants in the environmental samples selected.

The analytical methods carried out offer an important scientific innovation. To date very few methods have been published for the study of these contaminants in the selected contexts, mainly on WWTP compost and soils.

Application of the methodology to the study of compound trends in a pilot-scale composting process showed the rapid degradation of β-blockers and the slow breakdown of the EDCs under the studied working conditions.

The fieldwork carried out in the experimental farming plot of Vega de Granada, on farming soil amended with contaminated urban WWTP compost showed that compounds of the PB family were retained at the surface of the soil (down to 2 centimetres), disappearing completely from this zone if it was kept moist. In the case of BPA, this leached down to a depth of 30 centimetres, disappearing at this layer of the soil. This shows a good environmental behaviour since none of the contaminants penetrate down to the water table and underground water.

All the compounds, moreover, showed a similar behaviour in terms of degradation kinetics, fitting in with a first-order exponential equation, \( C = C_0 \times e^{-kt} \). Working from this equation, a determination can then be made of the half-life for each compound, the initial concentration \( (C_0) \) and the kinetic constant \( (k) \). For most of the contaminants, moreover, the half-lives were higher in the un-amended than in the amended plot. This is due to the fact that the compost amendment of the soil inputs organic material that favours the growth of microorganisms; this could provoke an increase in compound retention and in degradation speed.

The cultivatable heterotrophic microbiota count of the soil treated with the compounds and of the compost-amended soil treated with the compounds showed that, with increasing soil depth, there is a progressive drop in the number of viable microorganisms. The highest microbial development was observed on compost-amended plots.

The morphological and biochemical study of isolated microorganisms allowed different species of microorganisms to be isolated and selected. The microorganisms with the highest enzymatic capacity were those coded as MPB-8 and BPA-4, with 12 and 11 demonstrated enzyme activities, respectively.

The compounds studied were degraded to varying degrees by the selected microorganisms, degradation percentages of over 70 percent being recorded in all cases. The results show the microorganisms ability to grow in the presence of these compounds as a source of carbon / energy. These microorganisms could therefore be used in the bioremediation of environments contaminated with BPA and PBs.

Acknowledgments

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Programme for preventing falls by older people at home

In the global context of a continually ageing population, constantly prone to the dreaded falls and their adverse social, economic and health consequences, this study puts forward a programme for preventing falls by older people at home. The programme, run by a multidisciplinary team of professionals, looks at the risk factors in the older population studied to establish three prevention levels (primary, secondary and tertiary), including measures to limit these falls and their consequences.

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Population ageing has picked up pace in recent years, especially in developing countries. Current forecasts point to a worldwide older population of 1.9 billion by 2050, equalling the childhood population from 0 to 14\[1\]. The UN Economic Commission for Latin America and the Caribbean (ECLAC) [Comisión Económica para América Latina y el Caribe: CEPAL\[2\]] forecasts that older people will outnumber children for the first time ever by 2036. According to the Brazilian Geographic and Statistical Institute (Instituto Brasileño de Geografía y Estadística: IBGE)\[3\], Brazil's population of older people has grown by 80 percent in the last ten years: the 65+ population, accounting for 4.8 percent of the total in 1991, had risen to 5.9 percent by 2000 and 7.4 percent by 2010.

In this demographic scenario it is crucial to understand that, besides the ageing process itself, people also suffer multidimensional physiological alterations that increase the risk of household accidents, falls being the most frequent accident amongst the older population. Falls represent a huge problem for the older person; their high incidence and also their high rate of injuries lead to such grave consequences as disability, institutionalisation and even death.

Older people account for 70 percent of the total number of falls. Falls are associated with high rates of morbidity and...
Falls by older people lead to high rates of morbidity and fatality among this population, creating problems for the community and for the health and social-security system. An older person who suffers a fall is more prone to a reduction of functional and cognitive capacity and also a limitation of his or her daily, social and spiritual life, as well as an increase in isolation and depression, frailty and the risk of mistreatment and violence. Falls can even lead to institutionalisation and early death of the older person involved. Falls represent an increase in costs for the health system, with a greater number of analyses and procedures, hospitalisation, treatment and rehabilitation. Falls by older people are tied in with hearing- and seeing-difficulties, improper use of medicaments, unsteadiness, progressive loss of force in lower limbs, osteoporosis, et al. Several studies show that between 20 and 50 percent of older people fall over at least once a year, with a higher incidence among women. The rate increases directly with age, the sex rate evening out after the age of 75. Of this total, 40 percent of the falls are serious and occur among the 80+, 50 percent are recurrent and between 5 and 10 percent produce severe consequences. Two-and-a-half percent of older people who suffer a fall then require hospitalisation and hardly one half survive for more than one year afterwards.

According to the study conducted by Caberlon, who analysed 6556 older people who received post-fall treatment by health services, the likelihood of fall-related bone fractures increases by 2.2 percent with each year that passes, and women are 15 percent likelier to suffer such fractures than men of the same age. Of the total falls in the community 42 percent occur in the older person’s home or close by, and about 10 percent occur on staircases and downward slopes. Fall frequency increases in the colder months, during the day and in the morning, while daily activities are underway in the kitchen, bedroom and bathroom. The fall rate is higher in women, since they are more active in the home and have less muscular mass than men.

Fall-related injuries have more serious consequences among the older than among the young. For falls of the same severity older people suffer more disability, a longer confinement afterwards, long rehabilitation procedures and a greater risk of post-fall dependency or even death.

The list of fall-related consequences is an alarming one: fractures, severe injuries or even death. For this reason, older people who fall over more than twice every six months should be assessed to find out the reasons for the fall.

Numerous risk factors have to be identified to be able to pinpoint the necessary preventive measures; these factors include the following: impaired vision, hearing and reduction of skeletal muscle, a sedentary lifestyle, cardiovascular and neurological illnesses. Falls represent growing healthcare, social and economic costs. Risk prevention, the proper treatment of injuries, are some of the factors driving the search for strategies to meet this challenge.

The World Health Organisation (WHO) has tackled the healthy-ageing issue in its guide Global Age-friendly Cities, a document in which most of the world’s major cities report a lack of services and programmes for disease prevention and health promotion and put forward their suggestions for improving this situation. Featuring large in the list of important services are preventive screening, physical activity, education on injury prevention, nutritional guidance, and mental health counselling.

Preventive measures, for their part, are defined as actions designed to head off the onset of specific diseases, reducing their incidence and prevalence within the population. They are hence based on epidemiological knowledge of diseases and other specific complaints. Prevention is geared towards detection, control and reduction of illness risk factors, focussing on the illnesses themselves and the mechanisms for dealing with them.

The health debate is tied in with preservation of the individual’s functional capacity, i.e., the capacity of maintaining the necessary mental and physical abilities and skills for leading an independent and autonomous life.

According to Navarro, a preventive programme is a set of activities targeting certain goals, using given resources within a specific period of time. He goes on: proper programme assessment implies several types of activities: the production of information on the development of programmes and their actions and the establishment of a value with respect thereto. Assessment means judging an intervention to help in decision taking; it is considered as such to be a sine qua non for checking the efficacy of the established measures, underscoring the whole planning process.

Once the programme (which must be top quality) has been brought in, it must then be accessible for the target population so that this population can accept and use it. This use will then result in a given coverage of interventions. Once this...
A fall prevention programme has to ensure specific monitoring of its users as well as assessment and monitoring by means of health indicators when coverage has been reached, an impact will then be produced (grossed-up result) on health or specific behaviour.

To ensure all these stages can be duly assessed, it is essential to choose the indicators wisely, depending in each case of the characteristic of the programme itself or the interventions. Donabedian identifies three types of assessment indicators: structure, process and result. Structure indicators deal with the physical area, appropriate technology, human resources, medicaments, access to assessment rules and management of patients, among others; they identify the conditions under which the healthcare will be offered to users.

Process indicators are important in relation to the impact, bearing in mind the importance of being able to determine the programme’s actual effects on the population. In other words, impact assessment in turn depends on obtaining process indicators (supply, use and coverage).

As a result, according to Brazil’s National Supplementary Health Agency (Agência Nacional de Saúde Suplementar: ANS), it is vital to encourage takeup of assessment and monitoring arrangements within health-promotion and risk- and disease-prevention programmes. This initiative aims to ensure viable decision-making procedures and proper definition of intervention strategies and integrated programmed actions to forestall risks, damage and disease, reduce morbidity, cut down the number of years lost to disability and increase individuals’ quality of life.

Any programme should also guarantee specific monitoring of its users as well as assessment and monitoring by means of health indicators. “Health indicators” are here understood to be the parameters, universally accepted, that are used for planning the programmed actions and assessing and monitoring the state of health of the population attended by the programme in a defined timeframe.

According to ANS, the service to implement the prevention programme will have to be run in such a way as to monitor those opting into and out of same, identify the frequency of participation of those included in the programme activities, issue alerts to flag the active search for drop-outs and monitor results obtained by registered programme users. It must be possible to use the service as an information system, catering for all the following: operational software, used for recording healthcare and administrative information of the whole population for accompanying programme users; spreadsheet for digital tabulation of programme results, and specifically developed software, the operational software module for recording and monitoring information on the risk- and disease-prevention programmes.

Some particular data is vital for drawing up risk- and disease-prevention programmes, such as demographic characteristics (age and gender); epidemiological characteristics (risk factors, main causes of illness and fatality); definition of the chosen population for each programme; definition of the necessary resources for programme structuring (human, financial and technical resources, network of providers and incentives to draw in beneficiaries); description of the most appropriate activities for obtaining expected results on the chosen population; result-assessment and -monitoring arrangements and definition of the programme-assessment indicators (of process, structure and result).

Risk- and disease-prevention programmes designed for older people, whose degree of vulnerability is extremely variable, have to bear in mind that ensuring proper health for this age-group is the biggest challenge faced by current healthcare programmes. There is now a stack of evidence to show that a fragmented approach to older-person healthcare, without taking into account their functionality and without factoring in ageing’s knock-on effect on health-illness processes, has a negative effect on health.

Any approach to secondary prevention, therefore, has to work from the particular characteristics of the older person. The reduction of the individual’s functional capacity will make him or her more or less dependent on the most complex healthcare level. Illness-prevention programmes developed specifically for older people have to focus on geriatric syndromes.

An older-person healthcare attention model has to set out to identify individuals running the greatest risk of falling ill or developing a functional incapacity, to be able to break down the various groups for assessment, stratification and monitoring purposes afterwards. Risk-prone individuals can be identified by means of the presence of specific geriatric
The programme, applicable in both public and private health institutions, aims to maintain the functional capacity of older people.

ANS programmes, therefore, make provision for all the following: specific goals, forecasting expected results for the programme population; the result monitoring methodology (definition of indicators of the process, the older person’s health, healthcare quality and costs); the form of integration in the programme activities and the health-service provider network; definition of strategies for encouraging older people to opt into and stay in the programmed activities programme implementation and take-up targets; and the objective-monitoring methodology.

The health service can be made up by a multidisciplinary team to provide the target older-person healthcare: promoting active and healthy ageing; structuring integrated older-person healthcare; encouraging participation by the beneficiary and families in the choice of therapeutic plans and the caring process; monitoring the ageing process: identifying the illness and damage-risk-factors; promoting the continual top-up training of all involved healthcare professionals, concentrating or the specific care needed in each case; identifying and promoting the health recovery and protection factors; promoting functional autonomy and improving older people’s quality of life.

Given the sheer importance of this issue, there is now a pressing need for setting up and running a programme to prevent falls of older people at home, doing so by means of a better understanding of the intrinsic and extrinsic risk factor: associated with the falls of these individuals and the creation of mechanisms to minimise risks and consequences of falls thereby contributing towards active ageing.

This research project describes the roll-out of a programme for preventing falls by older people at home. It involves all the following: identification and minimisation of fall risk by means of prevention actions that factor in the search for intrinsic or individual age-associated risks and the extrinsic risk factors associated with the environment; definition of the criteria of selection, training and instruction and inclusion in the programme; drawing up a multi-risk factor plan, an education and information plan on falls for the older person, relatives and carers; adaptation of the environment to achieve a safe-home; guidance about proper reaction in the event of a fall; and identification of suitable ambulatory and hospital services for dealing with urgent fall-related injuries.

The programme could be applied in both public and private health institutions ensuring well-founded fall-prevention and -management actions, thereby achieving a longer and higher-quality life expectancy, reducing the risks and aftermath of falls and maintaining the functional capacity of older people. This would make a significant contribution to the ongoing drive to reduce healthcare and welfare costs. The programme targets a considerable social benefit, contributing towards the overall goal of active ageing.

**Development**

**General Objective**

This research project aims to develop a fall-prevention programme for older people at home, looking into and minimising risk factors and maintaining these persons’ functional capacity. It has a practical application for public and private healthcare institutions.

**Objetivos específicos**

- Look into the characteristics of public and private risk-prevention and healthcare programmes for older people.
- Develop the programme structure.
- Define scales for identifying intrinsic or individual risks and extrinsic or environmental risks, as well as the criteria for selection, capture and inclusion of programme participants.
- Draw up multi-risk prevention plans.
- Draw up a safe-home manual with guidelines for safe living therein.
- Describe the basic first-aid procedures for bone fractures.

**Methodology**

Delineation of the research: exploratory, cross-sectional and qualitative study.
Thematic area: prevention.
Thematic line: household risks.

Data Collection
Data was collected by means of bibliographical and documental studies and research into falls by older people, pinpointing causal factors and necessary prevention measures. Scales were defined by seeking scientifically valid instruments. Programmes of prevention and maintenance of functional capacity were defined from the literature and practical observation within the field of public and private healthcare.

The functional structure, prevention and manual procedures and healthcare flows were all observed from visits made to healthcare services attending the falls of older people. The researchers made on-the-spot visits to healthcare institutions designed to prevent falls by older people and provide assistance in the case of any falls. The object of these visits was to identify the structure, the services, the processes and operation thereof.

Results and Discussion
Programme for the prevention of falls by older people at home
A sine qua non of healthy ageing, with autonomy and quality of life, is the encouragement of healthy habits and social and intellectual activity to ensure that individuals feel useful. Preventive attitudes can avoid or delay the onset of disability, ensuring that people maintain a good functional performance even at advanced ages. These attitudes are broken down into primary (avoiding the onset of disease), secondary (early diagnosis of disease) and tertiary (avoiding functional worsening after disease onset).

The programme for the prevention of falls by older people is therefore broken down into three types:

- Primary prevention. Promotion of health, encouragement of physical activity, proper nutrition, mitigation of household risks, periodical review of medication to eliminate those that increase fall proneness.
- Secondary prevention. Identification of fall and fracture risk factors with interventions that change the prognosis of those factors that increase the likelihood of falls and fractures.
- Tertiary prevention. Intervention on high risk factors for frail older people who have suffered falls.

After stratification of the risks of the older population included in the fall prevention programme, the individuals are slotted into the respective prevention level: primary, secondary or tertiary. Depending on the older person’s fall proneness, he or she will be invited to take part in functional training within this prevention level, establishing the types of exercise for each degree of risk accordingly.

General Aspects
Aspects considered for structuring the programme for the prevention of falls by older people at home:

Programme Objectives and Coverage. Programme implementation objectives were drawn up from the demographic and epidemiological data of the attended population in relation to the objectives of the healthcare institution, whether public or private. Indicators are established for the purpose of meeting objectives related to the improvement and maintenance of the independence, quality of life and reduction of fatality caused by falls of the attended elders. As regards the economic objectives, the aim is to reduce the associated ambulatory and hospitalisation costs deriving from the complications caused by falls in the older population. Important references for drawing up programme objectives are demographic, healthcare and economic information related to the number of older people opting into the programme, broken down by gender and age living in the geographical area, confinement due to falls at home, fatality and ambulatory and hospital healthcare costs. In any programmes for the prevention of falls by older people at home it is important to indicate all the following for a 12-month period with regard to coverage objectives:

a. Number of older people, broken down by gender and age, initially opting into the programme.
b. Number of household units adhering to the programme.
c. Number of older people opting into the programme.
d. Number of drop-outs (individuals and household units) at the end of 12 months.
e. Objective of reducing A&E attention for fall-related injuries, bruising or fractures.
f. Objective of reducing avoidable falls of older people at home.
g. Objective of reducing the fall-related fracture rate and the fatality rate of older people due to fractures at home.
h. Number of older people reporting an improvement in family bonds.
i. Objective of the coverage rate of bone densitometry in older people as provided for in the programme.
j. Objective of procuring self-help equipment (amount and type).
k. Number of older people carrying out at least 30 minutes of physical activity three times a week.
l. Number of older people reporting an increase in autonomy when carrying out daily activities (with reference to the assessment scale used).
m. Objective of increasing the number of older people who report an improvement in their quality of life.
n. Objective of reducing ambulatory and hospital healthcare costs of dealing with the consequences of the falls of older people.
p. Objective of the programme’s cost effectiveness.

The programme will be implemented in terms of a timetable based on the following: healthcare provision sites, structuring of the multidisciplinary team, assessment and monitoring indicators and the network providing diagnosis and treatment support services.

Objective Monitoring Methodology. The objectives will be monitored through an integrated IT management system working from the information recorded in the programme head office, in healthcare attention sites and in service providers.

Professional qualification and skills of the healthcare team. The healthcare team will have an interdisciplinary format and will act in a coordinated and integrated fashion. It will have a clinical coordinator and will be made up by the following professionals, with an account also of their respective functions:

- Social worker. He or she weighs up the family and social context, identifies the community’s healthcare resources and gives the older person advice on access to healthcare services.
- Doctor. He or she is responsible for clinical management of cases in terms of assessing functional limitations and deficiencies and monitoring the trend of the older person’s illnesses throughout the programme.
- Physiotherapist. He or she evaluates and intervenes in movement dysfunctions that impair mobility, with the aim of ensuring necessary sensory and motor faculties for functional activities such as walking, balance, postural transfers, fine motor skills of upper limbs. He or she indicates and adapts any necessary auxiliary devices.
- Occupational therapist. He or she evaluates and intervenes in learning procedures and adaptation of self-care ability and of the instrumental activities of daily life, interprets the older person’s relation with the activity concerned to ensure that emotional and cognitive aspects are taken into account, adapts the environment, indicates and produces devices and prostheses.
- Nutritionist. He or she assesses and monitors the older person’s nutritional state, re-educates him or her on eating habits and pinpoints the need for any special diets.
- Nurse. He or she builds up a therapeutic environment, educates the family in the prevention programme, creates programme adhesion strategies and gives guidelines to the patient, relatives and carers on healthcare needs.
- Physical educator. He or she encourages the patient to keep up an active lifestyle, seeking to increase his or her functional physical capacity, gives guidelines on activities for the older people participating in primary and secondary fall-prevention programmes.
- Psychologist. He or she intervenes in and monitors the psycho-affective, behavioural and affective aspects, quality of life and family relationships. He or she, where necessary, helps any older person participating in the programme to withdraw from the abusive consumption of alcohol.
- Chemist. He or she gives guidance on the use and posology of medication, instructs the patient and relatives on the risks of medicamental interactions, the use of psychotropic drugs and the risk of falling. Helps out in drug withdrawal.
Team sizing will be directly proportional to the size of the attended population and its epidemiological complexity, to ensure programme objectives are met. Undersizing could overload healthcare professionals with work, impairing healthcare quality and efficiency, while oversizing could impair the programme’s cost-effectiveness.

Programme interaction with the network providing diagnosis and treatment support services. The programme will be structured on the basis of interdisciplinary healthcare professionals, organised as a management system integrated with a network providing diagnosis and treatment support services, acting in a longitudinal form. Health service providers have to be chosen on the basis of convergence with the programme, convenience and ease of access, operating on a referral and counter-referral basis. Treatment and diagnosis support service providers will be chosen on criteria of service quality, convergence and convenience, costs and adaptation to the integrated health model, including the following factors: quality certification recognised by a competent body; localisation and operation close to the programme headquarters and sites, and availability of material therein; convenience of opening hours and access; costs of analysis and services in accordance with cost-effectiveness premises; integration with the IT system.

Production of accessory teaching material. The type, content, information, distribution and production of any accessory teaching material will be directly related to the actions sought by the programme, in accordance with the adopted scaling of the prevention process. Online and printout material will be drawn up in accordance with the programme structure. These include videos, folders, posters, safe-household behaviour manuals, self-caring and fall-prevention manuals, e-mail marketing and cell-phone text messages, among others.

In primary prevention programmes: material geared towards maintenance of the quality of life and health promotion, stressing the aspects of nutrition, physical activity, healthy habits, giving up smoking and cutting down drinking and safety of the environment. In secondary prevention programmes: a preventive approach related to osteoporosis and the risk of falls and fractures. Treatment and mitigation of fall- and fracture- risk factors for tertiary prevention programmes.

Information system. Capable of monitoring programmed activities and registered users and presenting one or more of the following functions: actions of promotion and prevention, interventions and frequency; monitoring of user registration and deregistration; monitoring the frequency of participation of registered programme users, issuing alerts to flag the active search for drop-outs and monitoring ongoing programme results.

Table 1. Osteoporosis risk factors

<table>
<thead>
<tr>
<th>Older people</th>
<th>Younger people</th>
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<tbody>
<tr>
<td>Major previous fracture caused by small trauma</td>
<td>Diseases inducing loss of bone mass</td>
</tr>
<tr>
<td>Female sex</td>
<td>Primary or secondary amenorrhea</td>
</tr>
<tr>
<td>Low bone mass</td>
<td>Late menarche, nulliparity</td>
</tr>
<tr>
<td>Caucasian and Asian</td>
<td>Primary and secondary hypogonadism</td>
</tr>
<tr>
<td>Family history of osteoporosis or fracture of the femur neck</td>
<td>Low weight and height (BMI &lt;19 kg/m2)</td>
</tr>
<tr>
<td>Advanced age in both sexes</td>
<td>Significant weight loss after the age of 25; low calcium intake, high sodium intake; high animal-protein intake; low sun exposure; prolonged immobility; frequent falls; sedentary lifestyle.</td>
</tr>
<tr>
<td>Untreated early menopause (younger than 40)</td>
<td>Smoking and drinking Medicaments (such as heparin, cyclosporine, thyroid hormones, anti-seizure drugs and lithium)</td>
</tr>
<tr>
<td>Use of corticoids</td>
<td>High consumption of xanthine (coffee, cola-based soft drinks, tea).</td>
</tr>
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Source: Brazil, 2006.

Monitoring and assessment variables:

a. Percentage of older people included in the programme in relation to the total population attended, broken down into...
Indicators of fall prevention, quality of life, healthcare quality and cost. Table 2 shows the indicators of demographics, adhesion, dropout, retention, healthcare, costs, falls, fractures, morbidity, fatality, analysis coverage, use of drugs and quality of life, as well as the monitoring instruments used and periodicity.

**Table 2. – Indicators of programmes, monitoring instruments and frequency**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Instrument</th>
<th>Periodicity</th>
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<tbody>
<tr>
<td>Age and gender of users included in the programmes</td>
<td>Management information system</td>
<td>Annual</td>
</tr>
<tr>
<td>Number of dropouts within one year</td>
<td>Management information system</td>
<td>Monthly - monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual - analytical report with earlier period</td>
</tr>
<tr>
<td>Number of family units opting into the programme</td>
<td>Management information system</td>
<td>Annual</td>
</tr>
<tr>
<td>Monitoring of the frequency of A&amp;E treatment for fall-related injuries, bruises or fractures</td>
<td>Management information system in hospitals and clinics</td>
<td>Monthly - monitoring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual - analytical report with earlier period</td>
</tr>
<tr>
<td>Number of falls involving older people before setting up the programme and after finishing the programme</td>
<td>Management information system</td>
<td>Annual - analytical report in comparison with earlier period</td>
</tr>
<tr>
<td>Fall-related fracture rate of older people at home</td>
<td>Management information system</td>
<td>Annual - analytical report in comparison with earlier period</td>
</tr>
<tr>
<td>Number of older people reporting an improvement in family bonds</td>
<td>Family APGAR</td>
<td>During the programme and at 12 months</td>
</tr>
<tr>
<td>Death rate of older people from fractures resulting from falls at home</td>
<td>Management information system</td>
<td>Annual - analytical report in comparison with earlier period</td>
</tr>
</tbody>
</table>
Anti-dropout strategies. These involve participation incentives, motivation and on-the-spot and online monitoring. Incentives might be tied in with discounts in monthly health-plan payments, for users of Brazil’s supplementary health system, supply of fall-related pathology medication, subsidising acquisition of self-help and healthcare equipment; facilities for acquisition of house-improvement material and equipment and also for implementation of these improvements when items have been shown to flout the safe-home list.

Motivation for users to join and then stay on the programme could involve the promotion of healthy living habits, such as collaboration agreements with gyms and dance academies; distribution of cinema and theatre tickets; collaborator agreements with travel and daytrip agencies; setting up centres for social life of older people and intergenerational mingling; healthy-menu promotions in restaurants; hand out of customer-loyalty cards with points for the purchase of products or services related to welfare and quality of life.

On-the-spot monitoring will be by the way of periodic visits to socialising centres, the dwellings of older people and healthcare centres. Online monitoring could be conducted by means of email alerts, a cell-phone messaging system telephone links in search of dropouts and programmed online telephone links for healthcare takeup figures.
Primary prevention programme

Users opting into the programme will participate in organised, service-brokered chats to raise awareness about healthy ageing and quality of life for older people and their relatives. Promotion of functional autonomy workshops. Annual accompaniment with a multidisciplinary team and application of risk search instruments: visual acuity, basic daily activities, instrumental activities of daily life, cognition, functionalities, medicaments and family anamnesis. Yearly consultation with a geriatrician and biannual consultation with a nutritionist. Guidance for relatives and carers on daily care of the older person and prevention of falls: chats and health primer. Guidance for carrying out activities of daily life for the older person, relatives and carers: chats. Occupational therapy and nutrition workshops. Groups of recreations activities and coexistence. Assisted leisure activities. Guided physical activities. Annual home visits by the occupational therapist to check on the risk of falls in the environment and propose a plan of measures to eliminate risk factors. Chats for older people on self-care education. Safe-home guidance: chats, distribution of the Manual de ambientación de la casa segura (Safe-Home and Safety-Guidance Manual) and monitoring by the occupational therapist for modification of risk factors. Increased access to walking and mobility aids such as walking sticks, walking frames and wheel chairs, where necessary. Training in the use of walking aid devices. Increased access to corrective lenses, where necessary. Assessment of administered medication, including medication taken without medical prescription: discussion groups. Group and individual guidance on polypharmacy and risk of falls. Guidance on first aid in case of falls: chats. Control of weight loss for older people with BMI <19 kg/m². Recommendation of sunbathing: exposure to the sun for 15 minutes three times a week between 10 and 12 o’clock for subcutaneous synthesis of vitamin D (this vitamin requires ultraviolet radiation; hence the proposed sunbathing timetable). Recommendation of regular physical activity, with muscle-strengthening exercises. Group guidance for kicking the smoking habit; group guidance for reduction of alcohol intake and reduction of the consumption of sodium and xanthines (coffee, cola-based drinks, tea). Promotion of activities for strengthening of family and social bonds.

Primary osteoporosis prevention programme

a. Annual consultation with geriatrician.
b. Annual check of bone mineral density (BMD) in women > 65 and men > 70.
c. Check of BMD in younger men and women when they show risks of osteoporosis or fractures.
d. Assessment and guidance for suitable calcium diet:
   - **Calcium**: consumption of milk and dairy products. A 250 ml glass of milk (whole milk, semi-skimmed or skimmed) contains 285 mg of calcium. An individual taking 568 ml of milk a day will be receiving about 3/4 of the necessary calcium intake.
   - **Calcium-rich food**: broccoli, cabbage, mustard, spinach, turnip, peas, radish, carrot, cress, orange, apple, fig sardines, tuna, white bread, rice, potato, beans, wheat grain, sunflower seeds and almonds.

e. Control of weight loss for older people with BMI <19 kg/m².
f. Recommendation of sunbathing: exposure to the sun for 15 minutes three times a week between 10 and 12 o’clock for subcutaneous synthesis of vitamin D.
g. Recommendation of regular physical activity, with muscle-strengthening exercises.
h. Guidance for kicking the smoking habit.
i. Guidance for reduction of alcohol intake.
j. Guidance for reducing consumption of sodium and xanthines (coffee, cola-based drinks, tea).
k. Hormone replacement therapy (estrogen and progesterone) boosts bone mass and forestalls fractures, but should be used with caution due to the high risk of breast cancer and cardiovascular diseases.
l. Family guidance (daily caring for the older, prevention of osteoporosis).
m. Multidisciplinary workshops: healthy eating, physical activity and healthy habits.
n. Raising awareness about the subject of healthy ageing among the aged themselves and their relatives by way of chat and other activities organised or brokered by the service.

Secondary Prevention Programme
Older people identified as likely to suffer falls, with a past history of falls in the last year and recorded unsteadiness of postural instability will be assessed in keeping with the fall prevention scheme. Table 6 shows and enumerates the risk factors and apparent causes of the falls as well as the respective interventions in each case, according to evidence presented in the literature.

Table 6. Risk factors and apparent cause of falls, plus subsequent interventions

<table>
<thead>
<tr>
<th>Risk factor and apparent cause of falls</th>
<th>Interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complaints about dizziness</td>
<td>a. Investigation of dizziness episodes</td>
</tr>
<tr>
<td></td>
<td>b. If there is a past history of dizziness (vertigo, «light headedness», hormonal fluctuations, vestibular and others), refer to otoneurologist</td>
</tr>
<tr>
<td></td>
<td>c. If a vestibular syndrome is diagnosed, implement vestibular rehabilitation</td>
</tr>
<tr>
<td>Muscular weakness of lower extremities</td>
<td>d. Programme for muscular strengthening of quadriceps, and ankle flexors</td>
</tr>
<tr>
<td></td>
<td>e. Eccentric exercises</td>
</tr>
<tr>
<td></td>
<td>The exercises are more effective if carried out for groups of older people of high risk and are supervised by physiotherapists</td>
</tr>
<tr>
<td></td>
<td>b. Tai-chi is recommended These can be carried out at home, but should be supervised by a physiotherapist</td>
</tr>
<tr>
<td>Gait problems</td>
<td>a. Prescription or fitting out of walking aids</td>
</tr>
<tr>
<td></td>
<td>b. Training in proper use of the device</td>
</tr>
<tr>
<td></td>
<td>c. Regular visits to chiropodist</td>
</tr>
<tr>
<td>Impaired vision</td>
<td>a. Prescription / fitting of corrective lenses</td>
</tr>
<tr>
<td></td>
<td>b. Annual visits to ophthalmologist</td>
</tr>
<tr>
<td></td>
<td>c. Avoid use of bifocals</td>
</tr>
<tr>
<td></td>
<td>d. Careful feet-finding help in bodily balance after cataract surgery</td>
</tr>
<tr>
<td>Use of psychotropic medication/</td>
<td>a. Check the need for the use of antipsychotics, anti-depressants and benzodiazepines of long and short duration</td>
</tr>
<tr>
<td>polypharmacy</td>
<td>b. Prescribe a reduced number of drugs</td>
</tr>
<tr>
<td></td>
<td>c. Withdrawal drugs not covered by medical prescription</td>
</tr>
<tr>
<td>Specific evacuation needs</td>
<td>a. Use of overnight nappies for frail older people</td>
</tr>
<tr>
<td></td>
<td>b. Carry out functional rehabilitation of pelvic floor</td>
</tr>
<tr>
<td>Arthritis, neuropathies and dementia</td>
<td>a. Specific pharmacological management</td>
</tr>
<tr>
<td></td>
<td>b. Specialist physiotherapy</td>
</tr>
<tr>
<td>Attention deficit: two-tier difficulties - motor and concomitant cognitive deficiencies</td>
<td>a. Timed-up-and-go performance test</td>
</tr>
<tr>
<td></td>
<td>b. Balance training in association with cognitive training</td>
</tr>
<tr>
<td>Excessive alcohol consumption</td>
<td>a. Clinical and laboratory assessment of the presence of alcohol</td>
</tr>
<tr>
<td></td>
<td>b. Medical and psychological feet-finding help in cases of chemical dependence</td>
</tr>
</tbody>
</table>

Source: Adapted from Ramos and Cendoroglo, 2011, P. 239 and 240.

**Tertiary Prevention Programme**

better understanding of the causes and aetiology of falls calls for an analysis of the fall context in each case: the activity being carried out at the moment of the fall, time, type of footwear, site and any pre- and post-fall sign or symptom that might be important for determining the cause and then carrying out the corresponding intervention.

Knee buckling might be related to muscle weakness, knee osteoarthritis and drop attack; a feeling of dizziness related with...
head position and body rotation could be associated with the presence of vestibular disorders. The fall may be a reflector
of an acute illness, such as a respiratory or urinary infection, cardiac arrhythmia, cerebral vascular accident or delirium
among others\textsuperscript{16}. The person concerned might fall at different moments, on several occasions. Falls due to unknown cause:
should be investigated until establishing the aetiology of the event. The systematic search for causal factors ensures proper
management of the situation thereafter, forestalls new events and deals with associated diseases, avoiding comorbiditie:
and overlapping incapacities. In the case of recurrent falls the cause should be assumed to bear a relation with the previous
event. A proper understanding of the sensory and motor strategies comprising bodily balance and the aspects influencing
same, such as cognitive and psychological factors, is crucial for planning equilibrium exercises in fall-prevention and
rehabilitation programmes.

The fall investigation guide (Table 7)\textsuperscript{16} shows the main questions that the older people, their relatives or a responsible adult
should be asked for a proper investigation of the fall.

\textbf{Table 7. Fall investigation guide}

\begin{enumerate}
\item How many times has the person fallen in the last year?
\item Were there any consequences of the fall such as fracture, dislocation, trauma, bruise, abrasion or cut?
\item Did the person have to be taken to a doctor, A&E or hospital?
\item Did it constrain the person’s activities after the fall?
\begin{enumerate}
\item If so, was this due to:
\begin{itemize}
\item fear
\item walking difficulties
\item another reason
\end{itemize}
\end{enumerate}
\item When did the last fall occur?
\item Did the fall happen in the day or at night? At what time?
\item Did the fall occur after eating?
\item Where did the fall occur?
\item Did the faller lose consciousness?
\item Where was the person at the moment of the fall?
\begin{itemize}
\item kitchen
\item living room
\item bedroom
\item bathroom
\item corridor
\item staircase
\item garden
\item garage
\item in the outer courtyard
\item in the street
\end{itemize}
\item What movement was the person performing at the moment of the fall?
\begin{itemize}
\item walking
\item standing up from a chair
\item getting out of bed
\item leaning
\item turning
\item walking to pick something up
\end{itemize}
\item What activity was the person carrying out at the moment of the fall?
\begin{itemize}
\item bathing
\item going to the toilet
\item going back to the bedroom
\item climbing onto a bench
\item putting shoes on
\item house cleaning
\item gardening
\item going up or down stairs
\item getting on or off a bus
\item other
\end{itemize}
\item How did the fall happen?
\begin{itemize}
\item overbalancing
\item knee buckling
\item sudden weakness
\item light-headedness
\end{itemize}
\item Which part of the body first hit the floor or furniture?
\item Was the person wearing glasses or a hearing aid?
\item How did the person feel in the week running up to the fall? Was there any change in his or her health, such as
generalised weakness, fatigue, apathy, breathing difficulties, memory problems, fever, tachycardia, chest pain or
other disorder considered to be important?
\item What medication was the faller taking? Was there any change in normal medication? Was any medication introduced
or withdrawn? Did the person take any medicine on his or her own account?
\item Has the person been hospitalised in the last year?
\end{enumerate}
19. Would the person say that he or she had more difficulty than usual in walking around the house, dressing, bathing, going out of the house, going to the toilet or taking medication?

20. Is the person scared of falling again or has he or she cut down on normal daily activities?

21. Did the person drink any alcohol before the fall? If so, how much?

Source: Adapted from Ramos and Cendroglo, 2011

Clinical decision-taking model in relation to post-fall diagnosis

Table 8 shows the “Post-fall clinical decision-taking model” for exclusion of causal factors in the taking of clinical decisions in relation to the diagnosis of the fall. This model takes into account the presence of extrinsic triggers where the fall event is associated with an environmental factor and has to be investigated exhaustively. Exclusion of other intrinsic factors can even classify the event as typically accidental.
Occurrence of fractures in the population has a multi-factor cause including bone mass, the architecture of their house and their actual age, as well as the fall tendency. Fracture risk factors and the definition of risk groups are important for bringing in fracture prevention programmes for older people (Table 9: Risk factors and apparent causes of fractures in older people and respective interventions).

Functional exercises: primary, secondary and tertiary prevention

Table 9. Risk factors and apparent causes of fractures in older people and respective interventions
Risk factors and apparent causes of fractures

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Interventions</th>
</tr>
</thead>
</table>
| Low mineral bone density | - Clinical assessment: detailed medical history; medication; pathologies associated with osteoporosis; recent weight loss. Physical examination to include: weight; body mass index; presence or absence of dorsal hyperkyphosis; swollen abdomen; reduction of sitting height or other skeletal deformities.  
- Laboratory evaluation: complete haemogram, VHS, TSH, serum calcium, serum phosphorus, 24-hour calciciuria, liver function with alkaline phosphate and kidney function.  
- Bone remodelling markers  
- Bone densitometry  
- Spine radiography  
- Calcaneal ultrasound  
- Treatment with pharmacological measures and food hygiene |
| Previous history of low impact fracture | - Investigation of the bone density rate and other fracture-related factors, as secondary causes of osteoporosis. |
| Chronic use of corticoids (> 3 months) | - Weigh up the possibility of withdrawing or replacing the drug. |
| Profile of «fall-prone older person» | - Identification of risk factors bound up with the past history of falls, give guidance on measures to correct the intrinsic and extrinsic fall risk factors |
| Low BMI / accentuated weight loss | - Investigation of possible nutritional or pathological factors of weight loss.  
- Nutritional guidance |
| Alcoholism | - Recognition and treatment of the drinking problem |
| Smoking | - Guidance on kicking the smoking habit. |

Source: Adapted from Ramos and Cendroglo

Functional exercises are broken down by prevention level, by individual and group exercises, and are described by the intervention scheme shown in Table 10 (Sizing of functional exercises).

**Table 10. Sizing of functional training**

<table>
<thead>
<tr>
<th>Degree of fall risk</th>
<th>Prevention</th>
<th>In groups/Individual</th>
<th>Functional training / Physical exercises</th>
<th>Team</th>
</tr>
</thead>
</table>
| High risk           | Tertiary   | Individualised for people aged 80 or over or high-risk older people. In groups for the rest. | 1. Gait and balance re-education  
2. Strengthening and working of muscle power  
3. Speeding up movements  
4. Functional ADL training  
5. Boosting attention during movements  
6. Training in multi-segmental and multi-directional | Physiotherapists |
Whole-body exercises focusing on balance, strength and gait, such as tai-chi and yoga

Walking
Strengthening exercises Carrying out 30 minutes of moderate physical activity 5 days a week or 20 minutes of vigorous exercise 3 days a week; and 8 to 10 muscle building or strengthening exercises with 10 to 15 repetitions for each exercise, two or three times a week.

Source: Adapted from Ramos and Cendroglo, 2011, P. 241; BRAZIL 2006f.

Exercising Methodology

a. Training, lasting at least 30 minutes, includes specific exercises for bodily balance, mainly in a standing position, with due observation of necessary rest periods.

b. Phased in progressively, they aim to reach the functional levels to ensure, in the end, safe walking, including or uneven surfaces with obstacles, slopes and about-turns around items of furniture.

c. The minimum frequency is twice a week. A third bout could be brought in for home training of specific exercise: geared towards older people with a high fall risk.

d. Group training has to be led safely in relation to the proposed type of exercise and the presence of supports, where necessary.

e. Suitable garments and footwear for the training should be issued to the older people.

f. Physiotherapists are the proper professionals for balance training, especially for the frailest people suffering from several illnesses.

g. Physical education professionals should be included in functional exercises for prevention of low and moderate risk.

h. Strengthening exercises should be brought in, especially for frail older people, but in general should not hinder or override the bodily balance work, which also includes strengthening work in the most dynamic postural control situations.

Population Screening

Fall risk assessment

A screening instrument will be used in the interests of obtaining a better definition of the population of older people posing a fall risk. This is an effective tool for pinpointing older people most prone to fall risk. The screening instrument will be used for classification of the older person’s risk, forming part of the selection criteria for participation of the older person in the scaled fall-prevention programmes. The screening instrument will be applied to all older people who wish to participate in the prevention programme of falls at home.

Fall proneness varies directly with the number of risk factors present. Two important items are considered here: the history of falls in the last year and complaints of gait and balance problems. The history of falls in the last year serves as a strong indicator of the likeliness of future falls (the risk varies from 2.3 to 2.8); in such cases, however, a multifunctional assessment has to be performed for risk stratification purposes. Among people aged 65 and over who had fallen in the last year, the likeliness of future falls varies from 19 to 36 percent. The assessment of walking ability and balance, as the most studied aspect, offers the greatest discrimination between high and low fall risk and is most likely to predict future falls. A positive response by patients to the question of whether they have noted any balance or gait difficulties makes them twice as likely to be considered as a high fall-risk patient.

Fall probability

The screening instrument to be used is based on the algorithm developed by Lamb et al., taken in turn from the guidelines proposed by Ganz et al., and duly adapted for classifying the risk of the older person and giving the most suitable indication.
according to the scaling of the prevention programme.

Fall risk screening instrument I (Table 3) consists of a self-reply flow chart on past fall history, balance problems and difficulties in carrying out daily activities, where PQ = the fall probability. Each branch of the tree represents an estimated fall probability.

Table 4. Fall-risk screening instrument II

The algorithm, containing a performance test, is shown in Table 4, presenting the likelihood of future falls, as a combination between the number of falls in the previous year (none, one, two or more), balance problems when walking, walking speed test over 4 metres, the body mass index and a lower limb muscle strength test, with a sensitivity of 0.78, specificity of 0.46, positive predictive value of 1.44 and probability of 3.02.\textsuperscript{16}
Tabla 9. Instrumento de rastreo del riesgo de caídas II
Fuente: Adaptación Lamb et al; Ganz et al Apud Ramos y Cendoroglo.

Application of instruments for identification of intrinsic and extrinsic risk factors for falls and fractures

Programme participants will be assessed in terms of the presence or absence of intrinsic and extrinsic risk factors. He or she will be included in the respective levels of primary, secondary and tertiary prevention of the programme according to the presence of given indicative risk factors. Working from an identification of the presence of risk factors, the participants will be fitted into the selection criteria, different for each programme level. Risk factors and diagnosis instruments are shown in Table 5.

Table 5. Risk factors and diagnosis instruments

<table>
<thead>
<tr>
<th>Intrinsic/extrinsic risk factor</th>
<th>Instrument</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteoporosis</td>
<td>Bone densitometry</td>
</tr>
<tr>
<td>Impaired vision</td>
<td>Jaeger card</td>
</tr>
</tbody>
</table>
Weakness/balance and gait problems | Tinneti Test
---|---
Environment related | Safe-home and guidance list
Previous falls | Risk fall screening instrument
Polypharmacy | Name, dose, posology and time of use Beer’s criteria analysis of bad drug prescription for older people
Use of sedative, hypnotics and anti-anxiety drugs | Name, dose, posology and time of use Beer’s criteria analysis of bad drug prescription for older people
Alcohol consumption | CAGE questionnaire
Urinary incontinence | Clinical evaluation
Identification of possible BADL incapacitates | Scale of basic activities and scale of instrumental activities of daily life Katz index Scale and Lawton-Brody
Muscular weakness of upper and lower extremities (hand grip) | Muscular force test
Cognitive disorders | Scale of activities of daily life and mini examination of mental state
Social vulnerability | Apgar family test
Quality of life | WHOQOL-OLD

Source: adapted from Moraes (2009) and Ramos, Domingues et al., 2010, Ramos and Cendoroglo (2011)

**Inclusion criteria (identification of eligible individuals)**

**Inclusion criteria for primary prevention:**

a. Aged 60 or over.

b. Living within the service’s sphere of action.

c. Health condition: active and independent older people.

d. Older people classified as posing a low fall-risk after application of fall risk screening instruments.

e. Older people showing one or more of the following risk factors: use of sedatives, hypnotics or anti-anxiety drugs; alcohol drinkers; smokers; impaired vision; showing symptoms of urinary incontinence; arthritis; use of walking aid and with low or moderate family psychosocial risk.

**Inclusion criteria for primary prevention of osteoporosis:**

a. Women over 65.

b. Men over 70.

c. Post-menopausal women (also aged less than 65).

d. Women with BMI <19.

e. Individuals showing loss of stature (>2.5 cm) and thoracic hyperkyphosis

f. Individuals using corticosteroids for three months or more.

**Inclusion criteria for secondary prevention.**

a. a. Aged 60 or over.

b. Living within the service’s sphere of action.

c. Health condition: older people with muscle weakness, with risks of postural instability and gait abnormalities and previous harm.

d. Older people posing a risk of falls with fractures.

e. Older people classified as intermediate risk after application of fall risk screening instruments.
The screening instrument used in the programme is an efficient tool for pinpointing older people most likely to suffer a fall in the future.

**Risk factors:**
- Low physical fitness
- Lower extremity muscle weakness
- Balance problems
- Polypharmacy
- Use of sedatives, hypnotics, or anti-anxiety drugs
- Dizziness
- Visual problems
- Arthritis
- Urinary incontinence
- Use of walking aids
- High family psychosocial risk

**Inclusion criteria for tertiary prevention:**

- Aged 60 or over and identified as frail.
- Living within the service’s sphere of action.
- Older people with eminent functional impairment.
- Frail older people: cognitive incapacity, postural instability, polypathology (≥5 diagnoses), immobility, sphincter incontinence.
- Over eighties.
- People aged 60 or over showing one or more of the following risk factors: polypathology (≥5 diagnoses; polypharmacy (≥5 drugs a day); partial or total immobility; urinary incontinence; postural instability (repeated falls); cognitive incapacity (cognitive decline, dementia syndrome, depression, delirium); older people with a history of frequent post-fall confinement; older people dependent on others for carrying out their basic activities of daily living (BADLs); family insufficiency: older people in a situation of family social vulnerability.

**Forms of encouraging programme takeup**

- Notification of the programme at service attention points; active search (sending out of informative material to the user’s home, phone calls, cell-phone text messages, emails) and spontaneous registration; identification of individuals with frequent traumatology and orthopaedic consultations and identification of individuals with frequent A&E visits due to falls and their complications.

**Safe-Home and Safety-Guidance Manual**

In Emmel and Paganelli, the home-safety aspects comprise ease of access for older people, fitting out the living environment and changing the organisation of human activities to reduce the “barrier effect.” The Manual de ambientación de la casa y orientaciones seguras (Safe-Home and Safety-Guidance Manual) (Table 11) was drawn up to avoid risk factors in the dwellings of older people and make them more accessible.

Table 11 gives suggestions and guidance for creating a safer and more functional household environment and forestalling serious problems for older people (due to architectural barriers). There are some professionals, like occupational therapists, who are capable of guiding, planning and carrying out these adaptations.

**Tabla 11. Manual de ambientación de la casa y orientaciones seguras**

**Outer courtyard**
- Keep open a 1.2 m band of free passage on the pavement, free of any obstacles such as vegetation, posts, clumps of trees and flower beds, etc. Any possible obstacles of a large size, such as identification plaques, awnings, neon signs, vegetation and others, should be located at a height of over 2.1 m.

**Garage**
- Garages should preferably have rough and non-slip flooring without slopes or level changes; it is important for the garage to be under cover since this will keep it dry and safe on rainy days. If possible, awnings should be fitted to avoid any rain being blown into the covered area.

**Getting around the house**
- The flooring should ideally be regular, without slopes or level changes and non-slip; leave no objects in the main passage zone to prevent any tripping.
- Avoid rugs in general, but if they exist they should be low nap, non-skid or fitted with suction cups underneath.
the rugs to the floor with adhesive tape. Put a piece of non-skid rug under the normal rug.

- Do not leave loose visible cables in rooms. Keep them flush to the walls and fix them whenever possible.
- Keep the corridor well lit and, if necessary, fit continuous handrails along the sides. Rooms should be lit, with fluorescent lamps. Light-coloured walls and curtains are an aid to proper illumination.
- Make switches easy to reach at user-friendly height and choose those with illuminated buttons to facilitate use.
- Doors, to be opened with a single movement, should be at least 80 cm wide to facilitate passage. Do not leave any objects behind them to balk their full opening span.
- Window height should be conducive to visual and manual reach, except in rooms where safety and privacy is paramount, such as the bathroom. Each window leaf should be manipulatable with a single movement and a single hand.
- If there are stairs, the bannisters should always be used for going up and down them. Check that the steps are even. Fit non-slip strips on the edge of the stairs and illuminate them. Indicate the end and start of the staircase (using emery paper or coloured bands, etc, of a different texture and colour from the staircase itself).
- Do not leave blankets and eiderdowns on sofas. Leave no tables in the centre of the room, especially when the edges are sharp.

**Kitchen**

- Cupboards should be fixed to the wall and within easy reach.
- Keep the heaviest and most fragile objects at levels that ensure safe handling and avoid any accidental cutting.
- Adjust the height of drawers to the user; where possible fit rotating shelves in wardrobes to make objects easy to reach.
- In the fridge, keep commonly used objects at the levels easiest to reach. When defrosting the fridge, make sure the kitchen floor is kept dry.
- Keep the floor dry near the sink; fit a rubber and non-skid rug in this zone and keep it always dry.

**Bathroom**

- The toilet must have a user-friendly height; this is achieved when sitting users can keep their feet supported on the floor. If it is too low, an adaptation can be fitted at the base or a lift to provide the proper height.
- Support bars should be fitted to make sure the toilet can be used safely. To favour hygiene, keep the toilet paper holder and rubbish bin close by and easily reachable. Lever-type flush mechanisms are preferable or automatic flushes to prevent the need for any strain or force.
- Support bars should be fitted in the shower, whether vertical, horizontal or L-shaped. They should be installed under professional supervision.
- The shower cubicle should be step-free and fitted with wide doors. In the interests of safety, they should be between 0.90 and 0.95 m long. The floor should have a maximum level change of 1.5 cm with respect to the rest of the bathroom; if the level change is any higher, a ramp should be fitted.
- Use non-slip maps made of rubber or fitted with suction cups in the cubicle to forestall any slipping.
- Fit lever type mixer taps in bathroom and shower, preferably with a single lever. If possible, washbasin taps should also be single lever or operated by electronic sensor or equivalent devices.
- Wash basins, toilet bowls and other accessories should be a different colour from the bath to make them easier to see and locate.
- Accessories such as pegs, soap trays and towel racks should be fitted in such a way to make them easily reachable.

**Bedroom**

- The bed should be of such a height to ensure the user can sit on it with the feet resting on the floor and the knees
bent at 90°. If it is very low a wooden platform could be fitted to raise it or a higher mattress should be fitted or the bed should be replaced by a height-adjustable one. If it is too high the legs could be cut down.

- Do not overload the bed with pillows and keep the blanket tucked in below the mattress.
- The mattress should be suitable for the person’s particular state of health; it is important to choose the widest ones.
- A switch should be fitted next to the bed or a lamp with an automatic sensor to light up the bedroom and allow safe movements during the night. A hand lantern is also useful.
- Keep personal objects in the most accessible cupboards, so that the person does not have to stand on a stool or chair or other high object to reach them.
- Avoid slippery rugs beside or at the end of the bed.

Inner courtyard

- The floor should be flat, without any grooves and preferably non-slip.
- If possible, awnings should be fitted in all uncovered areas where most people pass to keep the ground dry and forestall risks.
- Do not leave flowerpots, tables, hoses and other gardening implements in areas where people commonly pass.
- Fit the clothes line at an accessible height so that the older person does not have to stretch and strain to hang up his or her washing, thus avoiding any overbalancing or dizziness episodes. One alternative is to use a standing clothes line.
- Any grids and drains should be fitted outside the main zone through which people commonly pass. When this is not possible they should be fitted flush with the ground.
- If there is a swimming pool the surrounding ground should not be slippery or very rough. Stairs or submerged ramps should be fitted for safe entry, or transfer equipment where necessary. Edges and stair rails should be rounded to avoid injury. The stair or submerged ramp should be fitted with handrails to ensure safe movements when entering and leaving the pool. It is recommended that support bars should be fitted along the internal edges of the pool at water height, when this does not balk access.

Day-to-day safety tips

- Install the phone in an easily reachable place. User-friendly models with large numbers are now available on the market. Set the telephone at top volume for easy hearing. If possible, fit handsets at various points around the house and make sure the older person always has a cell phone in his or her pocket.
- Fit clock and calendar in an easily visible place and with large numbers and colours that stand out from the background.
- Seek help when changing bulbs, filling the water filter, watering plants in high places or arranging cupboards and wardrobes.
- Avoid haste when carrying out activities; hurry could be conducive to distraction and accidents.
- Keep plants pruned to make sure people passing close by are not tripped up.
- Untethered animals around the precincts could cause trips and falls. Keep a list of telephones and addresses in easily reachable sites.
- Keep all communication appliances (landline, cell phone, intercom, etc) easily reachable.
- When sitting down, choose chairs and sofas with armrests, making sitting down and getting up an effort-free action. For the proper sitting posture, chose chairs that allow feet to be kept flat on the floor with knees bent at 90° and back flush against the backrest. If the chair does not in itself guarantee this posture, use a footrest (a wooden support) or back support (a pillow or cushion that supports the lumbar region).
- Use low-heeled, high-grip (e.g. rubber-soled) footwear with good ankle support. Plimsoll type shoes are ideal.
- When sitting down for a long time change posture periodically: cross the legs, stretch, stand up and sit down again every now and then.
- Get out of bed slowly to avoid dizziness and loss of balance. Should any dizziness episodes occur, sit still for a while
to avoid any fall.

- Give preference to chairs that allow change of posture, helping to ward off any cramp.
- Avoid wearing long clothes like dresses or skirts that might drag along the floor.
- Keep the dog kennel away from the house entrance. Tether the dog when necessary. The lead should be of medium length to stop the dog from crossing in front of the walker.
- When walking, avoid using furniture, doorknobs and walls as support. If walking is difficult, seek professional advice for procuring the suitable aid (walking stick, walking frame, etc).

Source: Adapted from Emmel, Paganelli, 2013.

Basic first-aid conduct in case of fractures. Falls might result in several types of fractures: ribs, spine, femur, pelvis, arm and others. Any individual who suffers a fracture suffers pain, which increases with touch and movement; functional incapacity (impossibility of making certain movements) in the affected region; accentuated functional impotence of the extremity and of the joints adjacent to the injury; swelling; changing colour of the affected area; a pulsing sensation in the affected limb; existence of floating bone fragments or abnormal curvature of the affected region [18][19].

The first-aid person has to be prepared to act quickly and know how to react in the event of a fall:

- Observe the general state of the faller, checking for serious injuries or haemorrhage.
- Keep the faller calm and forestall any panic attack.
- Under no circumstances should any attempt be made to reset the bone in its place. Fractured bones should be manipulated only by specialist medical personnel.
- Never move or transport the faller until the affected part has been properly immobilised.
- Exposed fractures call for special care.
- Control the arterial haemorrhage.
- Never touch bare bones.
- Obtain specialist attention as soon as possible.

If the faller is still conscious and is able to stand up and walk, he or she should be taken to an urgency service registered in the Brazilian Health System (Sistema único de Saúde: SUS) or health insurance scheme, as the case may be. If the victim is unconscious or incapable of walking, urgent services should be called in. Mobile urgent services are called in from the medical regulation centre in the case of SAMU (Urgent Medical Attention Service) or by calling the number 192 (regardless of the region and without having to prefix any area code). In the case of private services, it is vital to keep the phone number of the medical regulation centre constantly updated and easily accessible, preferably in easily visible places. Health-insured older people should always keep their identification card in a safe and easily reachable place. Whether the faller is attended by formal or informal carers, the latter should always be aware of the former's insurance coverage. Older people living alone should make arrangements for their neighbours to be able to enter their houses in the event of any fall, duly informing them about their health insurance conditions.

Conclusions

The world population is currently going through an ageing process, picking up pace in recent years, especially in developing countries. In Latin America older adults will outnumber children for the first time by about 2036, building up to a total of 183.7 million people (24.3 percent of the Latin American population) by 2050. In Brazil the population of older people has grown by 80 percent in the last ten years: adults aged 65 or over represented 7.4 percent of the total by 2010.

In this demographic scenario it is important to understand that, together with the ageing process itself, there are also concomitant and multidimensional physiological alterations that increase the risk of household accidents, falls being the most frequent accident among older people. Older people account for 70 percent of the total number of falls.

Death rates are high among fallers in this population. Falls are also often responsible for a reduction in their functional and cognitive capacity, limiting their daily, social and spiritual life, increasing their sense of isolation and depression and also the geriatric syndrome and the risk of mistreatment and violence. Falls can even lead to institutionalisation and early death
Osteoporosis, a progressive disease that leads to skeletal disorders, is one of the main causes of fractures among older people. For the health system falls represent an increase in healthcare costs, with a greater number of analyses and procedures, hospitalisation, treatment and rehabilitation.

Falls by older people are tied in with intrinsic factors deriving from age-related physiological alterations, the presence of pathologies and psychological factors, such as seeing and hearing difficulties, improper use of medication, dizziness/vertigo, balance problems, progressive loss of strength in lower limbs, cognitive decline and alcohol intake. Extrinsic factors are related with the behaviour and activities of the older people and with their environment. Unsafe and poorly lit, badly-planned and -built environments, with architectural barriers, are the main fall risk factors.

Most falls occur inside the home, generally during such daily activities as walking, changing position or going to the bathroom.

Falls by older people could lead to fractures, due to a number of factors such as bone mass, architecture of the dwelling and the physical age of the faller. Recognising the factors associated with fractures and risk profiles is important when drawing up programmes for prevention fractures in older people. One of the main causes of older people’s fractures is osteoporosis, a systemic and progressive illness that leads to skeletal disorders and increases the fracture risk.

Carers, relatives and neighbours have to be instructed for attending the older person who has possibly suffered a fracture until urgency services arrive. Victims needing hospitalisation are taken into referral hospitals of the public or private network for treating older people.

Given the sheer importance of this issue, this research project has tried to set up a programme for preventing falls by older people at home, advocating the importance of understanding the subject and proposing a series of measures to deal with fall-related intrinsic and extrinsic risk factors and mechanisms to minimise risks and their consequences, thereby promoting active and healthy ageing.

The programme aims to be applicable in both public and private health institutions. Its overall goal is to put forward fall-prevention measures to improve the life expectancy and quality of life of older adults, reducing the risks and aftermath of falls and thereby maintaining the older adults’ functional capacity.

The programme is based on the underlying concept of healthy ageing, with autonomy and quality of life, encouraging healthy living habits and the implementation of measures to remove risk factors. The programme is divided into primary secondary and tertiary preventive healthcare, on the basis of a set of actions to promote health and mitigate household risks, pinpointing fall risk factors and necessary intervention on high risk factors for frail, fall-prone adults.

After risk stratification of the population of older people dealt with herein, the individuals are then classified in three prevention levels: primary, secondary and tertiary.

General programme aspects take in the objectives, coverage and methodology, defining selection criteria and participator rules; programme assessment and monitoring indicators; therapeutic projects and clinical protocols to be adopted, activities and their periodicity; development and implementation of programme management information system strategies for information, health education and programme user awareness raising; integration of the programme into the network providing diagnosis and treatment support services; production of accessory teaching material and definition of the strategy to encourage loyalty of programme beneficiaries.

Programme implementation goals are drawn up from the demographic and epidemiological data of the attended population in terms of the objectives of the healthcare institution, whether public or private (health plan insurer/operator). Indicator: are established for meeting the objectives of maintaining or improving, as the case may be, the conditions of independence, quality of life and reduction of fall-related fatality of the older people attended by the service. On the economic side, the objective of the programme is to cut ambulatory and hospital healthcare costs deriving from fall-related complications in older people.

The goals will be monitored through the integrated IT management system, on the basis of information collected at project headquarters and at the points of attention and service provision.

The health team will have an interdisciplinary format, headed by a clinical coordinator, acting in an integrated way...
The programme includes a safe-home manual designed to improve accessibility and safety in the households of older adults. According to a system of rules known to one and all. Team size will be directly proportional to the size of the attended population and its epidemiological complexity, to ensure programme objectives of cost-effectiveness are met. The programme for prevention of falls by older people at home will be structured on the basis of the interdisciplinary action of healthcare professionals organised under a management system integrated with the network of treatment and diagnosis support services, acting in a longitudinal form. Health service providers have to be chosen on the basis of service quality criteria, convergence with the programme, convenience, cost and coincidence with the integrated health model.

The type, content, information, distribution and preparation of any accessory teaching material will be directly related with the actions in view: maintenance of the quality of life and health promotion, together with a preventive approach related to the risk of falls and fractures.

The information technology system will have to be capable of monitoring and assessing both programmed activities and registered users. Indicators of demographics, adhesion, dropout, retention, healthcare, costs, falls, fractures, morbidity, fatality, clinical analysis coverage, use of drugs and quality of life all pose different monitoring periodicities varying according to the programme objective. Retention of programme users will be directly related to participation incentives, motivation and monitoring, both on-the-spot and online.

Risks will be stratified by means of functional scales and fall likelihood. A screening instrument will be used in the interest of obtaining a better definition of the population of older people posing a fall risk. This is an effective tool for pinpointing older people most prone to fall risk. The screening instrument will be used for classifying the older adult’s risk on the basis of selection criteria in the scaled fall-prevention programmes. Risk screening and stratification will be based on adapted older adult health assessment instruments, based in turn on guidelines of the Brazilian Health Ministry and the scale developed in earlier studies, likewise adapted for this study.

Programme participants are assessed in terms of the presence or absence of intrinsic and extrinsic risk factors. They will then be included in the respective levels of primary, secondary and tertiary prevention of the programme according to the presence of given indicative risk factors. Inclusion criteria for programme adhesion are structured in terms of risk stratification and distributed in programmes of primary, secondary and tertiary prevention. The older people selected for primary prevention are active and independent, are classified as low fall risk and present a low or moderate family psychosocial risk. The inclusion criteria for primary prevention of osteoporosis are older people posing risk factors or critical pathologies related to osteoporosis. Those included within secondary prevention are older people with health conditions showing a functional and cognitive decline, classified as having an intermediate risk of falls and fractures and high family psychosocial risk. Frail older people with eminent functional decline, aged 80 or over, suffering a situation of family insufficiency or a situation of family social vulnerability are selected for inclusion in tertiary prevention programmes. Programme takeup is encouraged by notification, active search for users, identification of individuals with frequent traumatology and orthopaedic consultations and identification of individuals with frequent fall-related A&E visits.

The programme for prevention of falls by older people at home has drawn up a Manual de ambientación de la casa segura y orientaciones seguras (Safe-Home and Safety-Guidance Manual), which deals with such issues as ease of access and household safety and safe BADLs. For cases of falls with fractures, the programme describes the basic first-aid procedures stressing the importance of preparing the intervening person for rapid action.

This research project has set out to draw up the programme for preventing falls by older people at home, based on scientific evidence, pertinent legislation and health service routines. Falls by older people imply multifocal factors that have been tackled by means of a practical application, ranging from health promotion, prevention of exposure to risks and harm, right through to treatment and interventions for falls with or without fractures. The programme presents systematic forms of action designed to maintain or re-establish functional capacity, as the case may be, together with healthcare aspects. The cost-effectiveness of the programme for the prevention of falls by older people has not been addressed in depth in this project, thereby leaving the door open for future research into this issue.


