PRESENCE, DISTRIBUTION AND BIOALTERATION PHENOMENA ASSOCIATED TO HIGHER PLANTS IN THE PAMPLONA CATHEDRAL (SPAIN)

GARCIA-MURILLO, S.

MARTIN-PEREZ, S.

SUMMARY
This investigation was carried on the presence and distribution of higher plants in the Pamplona Cathedral and their participation in workstone alterations. The number of species proliferating is limited to a few, which are developing preferring some determined sites versus others. The Temple and the Barbazana Chapel are the dependencies more affected by their presence. This kind of life forms are capable of altering the stonework, either by mechanisms of direct and indirect action, or by chemical and physical processes; their action result in the appearance of alterations such as: mortar loss, disjunction, ashlars displacements, disgregations, breakings, and surface erosion.

1. INTRODUCTION

Understanding bioalteration as any undesired change in the properties of the material due to the activity of life forms, then higher plants are clearly an important bioalteration factor.

Even though several authors [1][2][3] indicate this important bioalteration capacity, either by physic or chemical mechanisms, and even point out the relevance of their presence in the alteration of microclimatic parameters, visual obstruction, etc. [4], the studies on bioalteration in this sense are scarce. [5][6].

Organisms this kind represent a problem specially serious in preserving archeological sites, since these are places favoring their growth [7]; however, their presence on any kind of monument mean a danger for its preservation. Within this group of life forms we can distinguish between seasonal or perennial species of continuous growth, in which their roots progressive spreading provoke and increasing pressure; and between herbaceous, shrubby and arboreal species, in which the degree of mechanical alteration they provoke increase in the same order.

The Pamplona Cathedral, one of the great buildings of the Spanish Artistic Heritage, is affected in some of its positions, by abundant presence of this kind of organisms, thus it was thought convenient to undertake a study of their presence and distribution, as well as of the bioalteration phenomena they represent.

2. DISTRIBUTION OF HIGHER PLANTS IN THE CATHEDRAL

In the field study it was seen that higher plants are organisms that grow, occasionally with big extensions, on walls and structures of the various Cathedral dependencies.

The Temple and Barbazana Chapel are the Cathedral dependencies where this type of life forms found a bigger number of positions, and adequate conditions for their developing. Figures 1 and 2, respectively show main sites of the Temple and Barbazana Chapel affected by their presence.

However, the remaining buildings are not free from colonization, Table 1 shows a list of positions where colonization has been detected.

Bearing in mind the locations indicated, can be deducted that this type of organisms appear mainly on areas where, in on one way or another, particle material is accumulated.

- Places where mortar union between ashlers is altered or lost, what make the surface bigger and rough; the presence was observed to be major in the contact side between three ashlers than in between two.

- Horizontal surfaces of moulding, buttresses... where mortar loss is favored by the action of atmospheric agents.
Table 1
Growing places of higher plants in the Pamplona Cathedral

<table>
<thead>
<tr>
<th>DEPENDENCY</th>
<th>AFFECTED AREAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SACRISTIES AND CHAPTER HOUSE</td>
<td>Area of contact with garden. Surface under the water pipes attached to the walls of the Canonical Sacristy.</td>
</tr>
<tr>
<td>CLOISTER</td>
<td>Gargoyles topping the buttresses. Angle formed by the arcade and the paved walk enclosing the cloister garden.</td>
</tr>
<tr>
<td>BEDROOM AND ADJACENT ROOM</td>
<td>Angle of contact with the paved walk enclosing the yard to which it opens. On the wall, at the right of the yard door, up to 4 meters height approximately.</td>
</tr>
<tr>
<td>REFEETORY</td>
<td>Oblique surface of the South façade buttress, at the upper cornice level. Moulding of the left upper side of the East façade. Upper side of the tower on the East façade. Buttress Southern of the East façade. Angle of contact with the paved walk enclosing the yard to which the East façade opens. Lower part of the buttress nearest the kitchen South façade, in the West façade. Oblique surface of the buttress above the scullery, in the West façade.</td>
</tr>
<tr>
<td>KITCHEN</td>
<td>First ashlars of the North façade. Lowest third southern of the South façade. Lower ashlars of the southern half of the West façade.</td>
</tr>
<tr>
<td>JESUS CHRIST CHAPEL AND CORTES ROOM</td>
<td>Northern side of the façade of the old Cortes Room. Lowest part of the façades adjacent to the garden Small southern exposure in the corridor from the Cortes Room area to the Jesus Christ Chapel.</td>
</tr>
<tr>
<td>LIBRARY</td>
<td>Area of contact of the North façade with the yard paved walk. Lower third of the dependency South façade.</td>
</tr>
</tbody>
</table>

- Contact angles between surfaces, specially if forming corners or other kind of obstacle, against which the wind carries, deposit and accumulate materials. Because of probably the last two prime circumstances, bigger abundance of these organisms is found in the lower and higher levels of the façades.
3. NATURE OF PROLIFERATING SPECIES

It was possible to establish that the plants developing in the Cathedral, which can constitute a bialteration factor, belong to a small number of species:

Centranthus ruber (L.) DC
Parietaria diffusa Mert. et Koch
Umbilicus rupestris (Salisb.) Dandy
Sedum album L.
Cheiranthus cheiri L.
Hedera helix L.

Besides these species, other as Sonchus sp. Fragaria vesca L., several poaceae... appear sporadically. Occasionally high dried stems, of considerable appearance, could be seen, but were not identified with any specific specie. They are shrubby type stems, and therefore of bigger consistency.

It was noticed that the different species present some preference for one or other locations. Centranthus ruber, appears more abundant on horizontal surfaces of higher places, although it is also present on vertical surfaces where mortar is lost. Parietaria diffusa, is more extended in low places, in contact angles and places between ashlars. Umbilicus rupestris and Sedum album develop on roofs and water pipes. Cheiranthus cheiri, as well as Centranthus ruber prefer high places. Hedera helix, for its climbing plant condition, climb on the walls taking advantage of the surfaces given by electricity conductions, water pipes or the proper stone surface roughness.

Table 2 reflex proliferation of more abundant species on the different Cathedral dependencies. Species grown in the ground contact side have not been considered because they present more diversity derived from direct contribution of seeds and materials from the gardens.

### Table 2
Species proliferation on the Cathedral Dependencies

<table>
<thead>
<tr>
<th>Dependency</th>
<th>Centranthus ruber</th>
<th>Parietaria diffusa</th>
<th>Umbilicus rupestris</th>
<th>Sedum album</th>
<th>Cheiranthus cheiri</th>
<th>Hedera helix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temple</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
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<tr>
<td>Sacristies and</td>
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<td>-</td>
<td>-</td>
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<td>+++</td>
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<td>Chapter House</td>
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<tr>
<td>Cloister</td>
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<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Barbazana</td>
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<td>-</td>
<td>-</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Bedroom</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Refectory</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Kitchen</td>
<td>-</td>
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<td>Tithe barn</td>
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<tr>
<td>Defensive tower,</td>
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<td>-</td>
<td>+</td>
<td>+++</td>
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<tr>
<td>cortes room,</td>
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<tr>
<td>Jesus</td>
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<tr>
<td>Chapel</td>
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</tr>
<tr>
<td>Library</td>
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<td>++</td>
</tr>
</tbody>
</table>

(- absence; + sporadic appearance; ++ moderate presence; +++ abundant)
4. BIOALTERATION MECHANISMS

Higher plants are acting on the Pamplona Cathedral substratum both mechanic and chemically, not forgetting the fact that their presence constitute an aesthetic factor which denotes carelessness and abandon.

The direct action of plants on the several dependencies of the Cathedral is visible by a series of bioalteration indicators: mortar loss, disgregations, surface erosion, breakings, disjuncture and ashlars displacement.

Mortar loss and breakings observed, have their origin, apart from physicochemical factors derived from the environment, mainly in the pressures induced by the growing of the roots. Plants identified as more abundant in the Cathedral are durable plants, of continuous growth. In their growing, roots are taking advantage of areas presenting less mechanic resistance, what explains why the mortar between ashlars is the most common location of appearance in all the Cathedral dependencies, although some times the workstone is invaded there where cohesion is diminished, fractured, or other circumstance that makes the resistance lower. This mechanical action result in material (stone or mortar) fractures which reach, more frequently if is mortar, a fissuring or fragmentation state with the consequent lost of material.

Also, the growth of roots has displaced some ashlars in relation with others, when the forces required for this are minor; as happens in the flying buttress of the Temple sanctuary and the inclined surface at the left of the Barbazana Chapel North façade, at the trefoil gallery height.

Disjunctions appear linked to the presence of climbing plants, specifically ivies. The aerial roots of ivies strongly adhere themselves to the substratum. The adherence strengths result in, or at least accelerate, the disjunction process by forming parallel discontinuities to the stone exposed surface, what implies frequent detachments of small plaques which remain adhered to the roots and, either while growing or when are dried or eliminated, get taken off the wall. This phenomena is quite generalized in the Cathedral façades open to the Ronda Obispo Barbazana, northern side of the old Cortes Room, the Jesus Christ Chapel façade and the transition area between the Chapter House and the Canonical Sacristy.

Disgregation of substratum, both mortar or stone, by plants is shown as slightly cohesioned material, and more or less pulverulent, and is mainly a consequence of the chemical action, basically of base exchange produced in the roots and its secretion, by compounds of acid action and chelae. This chemical action is increased by the circumstance that, wherever higher plans appear, water stagnation and particles retention are favored.

In some places of the Cathedral, mainly surfaces crowning flying buttresses and buttresses of the Temple and drums and cupolas located above the bell towers, plants grow with great intensity, reaching considerable size. In this cases, the stems thickness and their continuous rubbing the substratum moved by the wind, turns in a mechanic erosion rounding the ashlar edges to which their presence is linked. This erosion is favored for the mentioned decohesion, generally associated to its presence.

Besides, higher plants are indirectly performing important bioalteration phenomena in the Cathedral. Their presence are inducing important climatic alterations in adjacent substratums. Insolation and wind are reduced, and water stagnation and particles retention are increasing. In this situation, apart from the obvious negative effect that the increase of water retention or stagnation implies, for its chemical dissolution effect on the substratum, and mechanic for the freeze-thaw cycles, other important consequence is that other organism growing is being favored. The circumstances detailed bellow are clear examples:

- In numerous occasions (flying buttresses and buttresses of the Temples, battlement cylinders at the transept south, under East and South windows of the Barbazana Chapel, northern side of the old Cortes Room, buttress at the left of the refectory West façade, and the moulding area at the Southern side of the refectory west façade), higher plants are responsible for rain water running on the substratum just bellow them, carrying part of the particles present, creating in this way the adequate habitat for the development of other organisms, what generally turns in chromatic alterations and/or coverings, whose extension affect areas showing run offs silhouettes.

- There are some plants in the Cathedral that do not grow directly on the substratum, but their presence can result, short term, in bioalteration phenomena. They are higher plants that have developed taking as
support the water pipes of the several dependencies, specially at the Temple naves, the tithe barn and the scullery. Their presence in the water pipes makes difficult for the water to flow, thus it overflows and spili on the stonework underneath, at the same time, as previously explained, the water retained is channeled through the under face with the consequent negative effect indicated.

- The presence of vegetable stratum in the gardens surrounding the Cathedral dependencies (Ronda del Obispo Barbazán, Plaza de San José, patio del Arcedianato) and enclosed by them (Library and cloister garden), result in a higher degree of humidity and material at the lowest part of the buildings. Variations of the environmental parameters facilitate the development of abundant life forms at the lowest ashlars, whose action derives in presence of biological film, spotting, deposits, coverings.. To remark the abandon and carelessness of the Library internal yard, where weeds proliferate and stripping rests of some former structure are piled up, and the garden adjacent to the kitchen west façade where storage of stone structures (pinnacles, ashlars..) has allowed ill weeds to develop close to the wall.

The existence of trees, horse chestnuts, developing on the ground close to the Temple northern façade, whose size is big, reaching the same height as the side nave, provide great shadow to the walls. Besides, their branches reach some of the buttresses, originating mechanic erosion on the walls as a consequence of the leaves and branches rubbing the stone on windy days. Also, their roots might be harming the foundations structure. On the other hand, these trees, and those growing at the Ronda Barbazán, are attractive to birds, such as sparrows and magpies, who actively participate in bioalteration phenomena.

5. PREVENTIVE MEASURES

Undertaking preventive measures to diminish the effect of higher plants on the Cathedral is not an easy task, however, some kind of action is necessary since, as described, their presence are in some cases producing important damages. Maintenance of the gardens surrounding the buildings is necessary, and it would be convenient to isolate the walls from the garden by a kind of walk side. Other important aspect is the maintenance and good conditions of water pipes and roofs; this would imply a cleaning to eliminate cumulated material and plants growing on them whose development is creating problems to drain the water in some places. Also needed is a general review of the water pipes and repair those parts which are not in good conditions and are provoking high dampness in the stone.

Other determining parameter for this kind of biodeteriogen is the accumulation of particle material. Wind is the factor facilitating this contribution, by carrying particles which are deposited against any obstacle found. There are positions in the Cathedral that should be modified such as the places where there are mortar losses and structures damaged by breakings; examples of this are the horizontal surfaces topping the flying buttresses and the crownings of the Temple buttresses. Cleaning, jointing and repairing works of these structures are advisable.

Within the preventing measures, pruning of the horse chestnuts trees present at the Temple northern façade position should also be done.

Regarding the elimination of the plants growing on the Cathedral, and since the traditional weeding is not effective because it cannot entirely eliminate the plant, it would be necessary to use a herbicide which could get the target. However, an evaluation study of the compounds, dosage, period and the more adequate application techniques has to be done first.

6. CONCLUSIONS

The study proves the existence of bioalteration of the stones at the Pamplona Cathedral originated by higher plants, being the Temple and the Barbazana Chapel the dependencies showing more problems in regard with these organisms development.

Their performing mechanisms, including both direct and indirect actions, result in bioalteration indicators appearance such as mortar losses, disgregations, surface erosion, breakings, disjunctions, and ashlar
displacement. Also their presence contribute to changes in the climatic conditions of the adjacent substratum, thus favoring the implantation of other kind of organisms. Since the species identified as biodeteriogens are durable plants of continuous growth, it is believed necessary to undertake a series of preventive measures to stop bioalteration advance and prevent new damages.

REFERENCES