

Characteristics of exposed cavities of urban trees in a landscape of Southern Jakarta and their filling using polyurethane foam

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Abstract. A study was conducted to determine the characteristics of exposed cavities on the trunk of urban trees in a Central Business District (CBD) landscape, South Jakarta. The position and number of exposed cavities, as well as the dimensions, were recorded. Each exposed cavity was then filled using a polyurethane foam, followed by wound dressing using colored resin. One month after the filling process, the reliability of the filled cavities was measured using a micro-drilling resistance technique. The results showed that most of the exposed cavities were found in the main trunk (48.84%) followed by primary branches (41.86%), stem base (6.98%), and secondary branches (2.32%). Almost 69% of the exposed cavities revealed symptoms of decay, including discoloration. The exposed cavity volumes ranged from 0.04 dm³ to 63.61 dm³ with an average of 9.79 dm³. Most of the exposed cavity were 10 cm to 30 cm deep (41.86%), followed by those 5 cm to 10 cm deep (25.58%), 3 cm to 5 cm deep (18.60%), 30 cm – 50 cm deep (9.30%), and more than 50 cm deep (4.65%). The filling of exposed cavities using polyurethane foam indicated good reliability. There was no checking and/or cracking on the surface of the filled cavity, either on the Trembesi trees, Flamboyan trees, or palm trees.

1. Introduction

In the last two decades, the planting and replanting of trees for shading and the construction of tree-filled parks in large cities in Indonesia have been increasing rapidly. Nearly every city has planted more trees for shading and parks. This is not only due to the rapid development of the areas of the cities and infrastructure, but also thanks to the government and the people's increased awareness of the need for trees in the city's ecosystem. Even, some large-scale property managements have even admitted that the presence of trees on their land is a valuable asset and is an integral part of the entire infrastructure which they manage [1]. On the other hand, the awareness to check regularly the health of urban trees followed by treatment for any problems that might be found in the trees is also very important.

Trees are important part of urban spatial planning and play roles in climatic amelioration, architectural function, and aesthetic support [2]. Moreover, trees often take part in the history of a city [3]. Therefore, efforts to ensure that trees continue to exist in cities is paramount, including



efforts to prevent the toppling of trees. One physical characteristic of a tree that is susceptible for toppling is the presence of an exposed or open cavity in the trunk or branches of that tree [4]. An exposed or open cavity, which is a defect that forms quite large holes in the trunk or branch of a tree, commonly occurs due to a wound on the bark as well as the woody tissue which is followed by a decaying process. In fact, exposed cavities could not only reduce the aesthetic value of the trees, but also trap the humidity or the damp inside the trunk or the branch that simulates the decaying process of the tree's trunk or branch. Moreover, an exposed cavity has a negative impact on the bio-mechanical properties of the tree, even causing tree failure [5]. When this happens, it does not only cause economic loss, but also social loss, threatening human safety, and of course ecological loss since the most important oxygen producer on Earth may be disappeared as the impact. Unfortunately, information available by far about these defects and the treatment techniques are still very rare, thus not giving incentives to those managing urban parks and forests to quickly treat these deformities.

One of the ways of preventing trees with wounds or cavities from toppling is by filling the wounds [6]. Wound filling is also very useful in preventing the entry of pathogens into the inner trunk or branch of the tree, hence reducing the possibility of decay. The use of plastic as filler for oak tree trunks that suffer with cavities due to decay-causing fungus attacks have been attempted in former report [7]. In this study, the use of plastic as filler was combined with the application of two kinds of fungicide with different active ingredients, namely thiadiazole and thioallophanate. The results of the experiment demonstrated that filling the wounds with plastic combined with fungicides was quite effective. Polyurethane as a wound filler in large-leaved lime trees, small-leaved lime trees, horse-chestnuts and silver birches was also quite effective [8]. The use of polyurethane foam as a filler in the treatment of oak trees gave fairly good results [9]. There are two kinds of polyurethane foam, the flexible type and the rigid type [10]. Rigid polyurethane foam could be applied as material to isolate the construction of coolers, while the flexible foam can be used as padding materials in transportation, furniture, and packaging [8]. Polyurethane foam is a friction and a wear-resistant material, resistant to atmosphere, oxygen, and ozone, stable at both hot and cold temperatures and has good isolating properties [3]. Therefore, polyurethane foam is suitable for use as a wound-filler in trees.

A study was conducted with objective to discover the frequency and characteristics of exposed cavities in urban trees in South Jakarta, and the possibility of filling them by using polyurethane foam.

2. Materials and methods

2.1. Study location and target trees

This study was conducted in a Central Business District (CBD), located in South Jakarta which covers an area of more than 40 hectares. The number of trees in this area amounts up to a total of 1038 trees, consisting of 17 species of trees. Observations was conducted on 245 trees (where 23.6% of the entire population of trees are in this area), located in the roadside. However, only 32 trees were investigated with exposed cavities, which then selected as targeted trees for further characterization.

2.2. The characteristics of exposed cavities

Wounds found on the target trees were recorded for the location or position (root, main trunk, main branch, secondary branch, twig, *et cetera*), shape, dimensions, and volume (figure 1). In addition, the presence of any decaying or rotting and other defects around the wound were also noted. The volume of the wounds was classified into four categories: small, medium, large, and very large, based on the criteria in table 1.

Table 1. Classification of wound volumes in the targeted trees.

Wound classification	Wound volume (dm ³)
Small	< 10
Medium	10 – 30
Large	30 – 50
Very large	> 50

2.3. Exposed cavity filling

After the dimensions were measured, the dead tissues on the surface of the wound and in the periphery of the wound were cleaned using a rubber-tapping knife. If the wound was filled with water, soil, trash, or insects, these debris were cleared out first, then the wound was covered using plastic, then rested for 48 hours. Afterwards, the entire surface of the wound was sprayed using a fungicide solution containing the active ingredient chlorothalonil 5% at a dose of 5 ml solution/cm² wound surface area.

On the sterilized wound surface, a “wound filler cast” (constructed from 0.5-1.0 mm thick thin fiber sheets) was attached with a 3-4 cm gap on the uppermost part of the wound to insert the polyurethane foam injector. The “wound filler cast” was attached on the trunk or branch with the help of a duct tape. After the “wound filler cast” was attached properly, the polyurethane foam was injected into the wound cavity through the gap in the upper part of the “wound filler cast” until the whole wound cavity was filled with polyurethane foam.

The polyurethane foam injected into the wound was left in the wound to harden (cure) for approximately 3 days. Then the “wound filler cast” was taken off, the filling was trimmed using a serrated knife and sand paper until the surface was leveled with the trunk or branch around the wound. The surface of the filling was then slathered with colored resin (dosage: 15 ml/cm²) to make it water-resistant.

2.4. Evaluation of filled cavity

Evaluation of the quality of filled cavity was conducted one month after the filling process. In this case, the point observed was the presence of cracking or checking of the surface of the filled cavity. If there were any cracks on the filled cavity, the part that had cracks were measured for the length and width. In addition, one month after the wound was filled, the density the filling was measured by using a Resistograph® microdrilling resistance.

3. Results and discussion

3.1. Characteristics of targeted tree

Out of the 245 trees observed, 32 trees were found with exposed cavities, consisting of 20 Trembesi or Rain tree (*Samanea saman* (Jacq.) Merr.) trees, 9 Flamboyant (*Delonix regia* (Bojer) Raf.) trees, and 3 Royal palm (*Roystonea regia* (Kunth) O.F. Cook) trees. Most of the trembesi trees had trunk diameter of 39.75 – 52.74 cm, with minimum diameter of 26.75 cm and maximum diameter of 91.72 cm (the average diameter was 53.09 cm). Most of the flamboyant trees had trunk diameter of 35.04 – 44.91 cm, with minimum diameter of 25.16 and maximum diameter of 64.65 cm (the average diameter was 41.93 cm). The trunk diameter of the palm trees was almost the same, between 32.17 cm and 37.58 cm, with an average of 34.39 cm (figure 1).

Most of the trembesi trees were 12.7 – 15.2 m tall, with minimum height of 10 m and maximum height of 23 m (the average height was 15.98 m). Most of the flamboyant trees were 12.64 - 14.25 m with minimum height of 11 m and maximum height of 17.50 m (the average height was 14.17 m). All of the palm trees was almost the same height, between 13 m and 14 m, with average of 13.33 m (figure 2).

From figure 1 and 2 it can be said that most of both the trembesi and flamboyant trees with exposed cavities had large trunk diameters; which ranged from 39.75-91.72 cm for trembesi trees and 35.03-64.65 for flamboyant trees, and were categorized as tall; which ranged from 17.8-23 cm for the trembesi trees and 14.26-17.50 for flamboyant trees. This indicated that two of tree species were quite

old (estimated to be approximately 25 years old), whereas the palm trees were estimated to be approximately 20 years old.

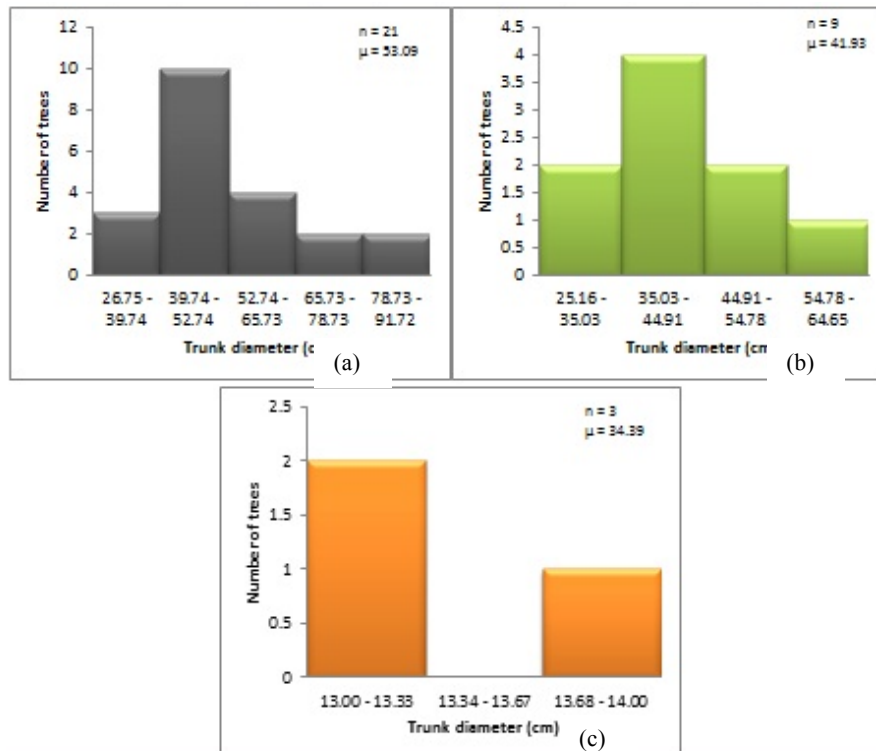


Figure 1. Trembesi tree (a); flamboyan tree (b); and palm tree (c) trunk diameter distribution.

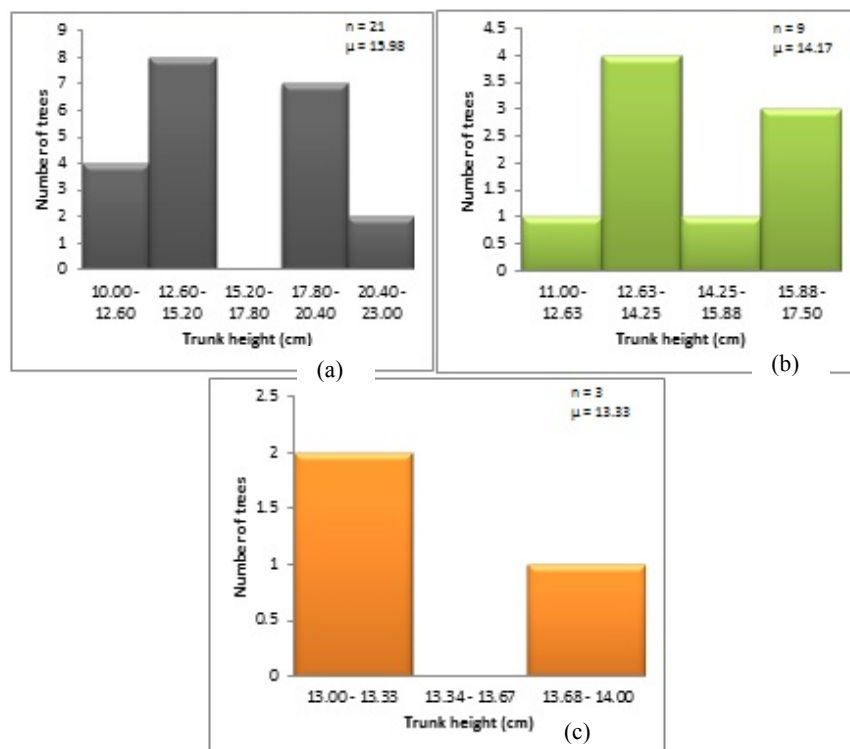


Figure 2. Trembesi tree (a); Flamboyan tree (b); and palm tree (c) height distribution.

3.2. Exposed cavity characteristics

The results of this study enlisted that there were 43 exposed cavities among 32 targeted trees. In other words, there were numerous targeted trees with multiple exposed cavities. Most of the exposed cavities were found on the main trunk (48.84%), followed by main branches (41.86%), stem base (6.98%), and secondary branches (2.33%). No exposed cavities were found on the stem base of either the Trembesi trees or the palm trees (table 2).

Table 2. The percentages of exposed cavity position on the targeted tree parts.

Tree Species	Percentage of exposed cavity occurrence(%)			
	Main trunk	Main branch	Secondary branch	Stem base
Trembesi	30.23	34.88	2.33	0.00
Flamboyan	9.30	6.98	0.00	6.98
Palm	9.30	a	a	0.00
Total	48.84	41.86	2.33	6.98

a) Palm trees do not have branches

Exposed cavity that are very large in volume ($> 50 \text{ dm}^3$) were only found on Trembesi trees (2 trees, 10.34%), while only one Flamboyan tree (10%) had a wound with a volume considered large ($30 - 50 \text{ dm}^3$). On the other hand, there were no large volume exposed cavities found on the palm trees. In general, the exposed cavities volume ranged from 0.04 dm^3 to 63.61 dm^3 with average of 9.79 dm^3 . The largest exposed cavity in volume (63.61 dm^3) was found in a Trembesi tree, while the smallest in volume (0.04 dm^3) was found in a palm tree (table 3).

Table 3. The average exposed cavity volume in each species of targeted tree.

Tree Species	Exposed cavity volume (dm^3)		
	Min.	Max.	Average
Trembesi	0.24	63.61	11.37
Flamboyan	0.39	39.60	8.91
Palm	0.04	1.08	0.53

The distribution of exposed cavity volumes in all the targeted trees is displayed in figure 3, while the number of exposed cavity in each tree species which was classified based on the volume is displayed in figure 4.

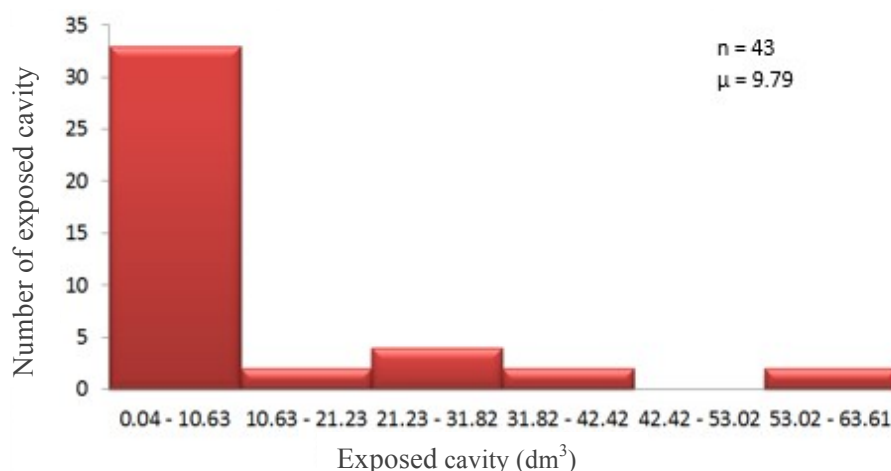


Figure 3. The distribution of wound volumes in all the target trees.

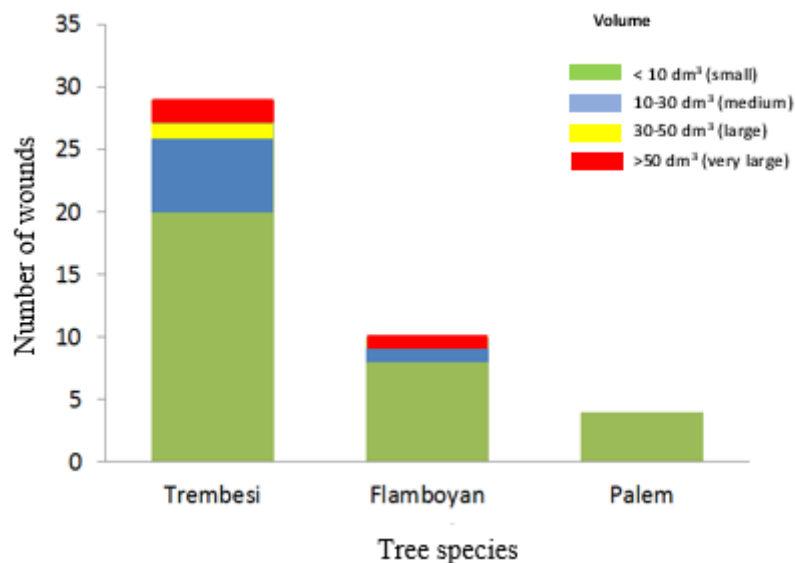


Figure 4. The number of wounds in each tree species based on the volume.

Seen from the depth, most of the exposed cavity on the trees in the CBD, South Jakarta, were 10 cm to 30 cm deep (41.86%), followed by those 5 cm to 10 cm deep (25.58%), 3 cm to 5 cm deep (18.60%), 30 cm – 50 cm deep (9.30%), and more than 50 cm deep (4.65%). The deepest exposed cavity (100 cm) was found in a trembesi tree with a trunk diameter of 50.96 cm and was 14 m tall. On the other hand, the shallowest exposed cavity (2.5 cm) was also found on a Trembesi tree with a trunk diameter of 41.71 cm and was 20 m tall. The distribution of exposed cavity depth in each tree species in detail is displayed in figure 5.

The results of this study also revealed that 51.16% of the exposed cavities found on the targeted trees occurred due to decay on the surface of the pruning areas. It is believed that the pruning which occurred in the past were not according to the standards i.e.: (1) the slope of the pruning was not angled enough towards the base of the trunk, so water or dirt was trapped on the surface of the pruning areas and supporting the growth of pathogens (fungi, bacteria); (2) after the pruning process, the surface of the pruning areas was not treated with fungicide and was not covered with wound dressing, so it was susceptible to infections by pathogens; (3) and the chainsaw used was not sterilized when used for pruning.

Pruning areas that have decayed were also found in other locations such as the Ragunan Zoo, Jakarta [3] and Karawaci, Tangerang [11]. Another decay causing factor that stimulated the occurrence of exposed cavity was nail wounds. It was detected on 34.88% of targeted trees. Decay causing factor on the rest of the exposed cavities was undetected.

3.3. Quality of filled cavity

Results of the observations one month after the filling process revealed there was no checking and/or cracking on the surface of the filled cavity, either on the trembesi, flamboyan, or palm trees. In other words, the quality of filled cavities in the 43 exposed cavities in the trees in the CBD was very good. This data was also supported by the measurement of the mass density of filled cavities using Resistograph® micro-drilling resistance which demonstrated that all of the filled cavities had fairly good mass density. The density of filled cavities in both the trembesi and flamboyan trees was only slightly lower than that of the natural tree trunk wood mass. In other words, the holes caused by the wounds have been covered using polyurethane masses with adequate density.

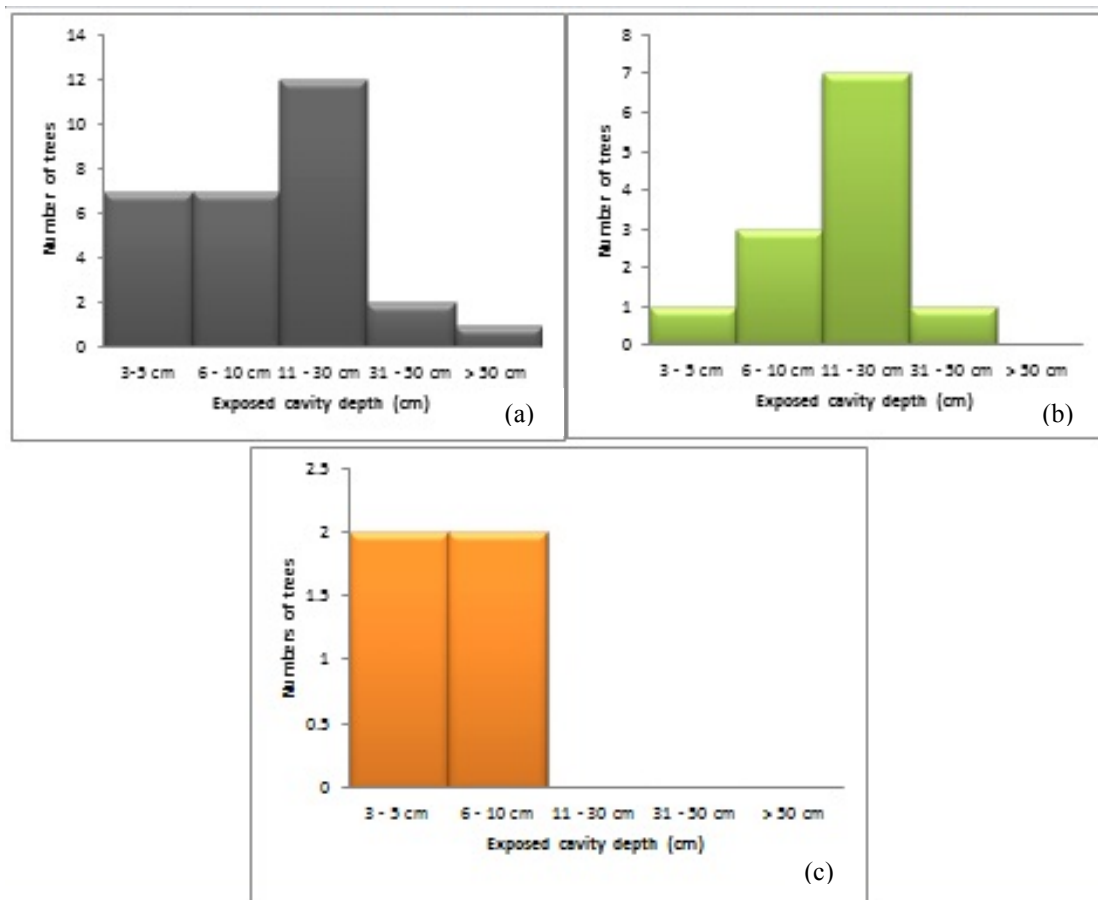


Figure 5. The distribution of the wound depth in the Trembesi trees (a); Flamboyan trees (b); and Palm trees (c).

4. Conclusions and recommendations

4.1. Conclusions

1. Most of the exposed cavities on the trees in the CBD area, South Jakarta, were found on the main trunk (48.84%), followed by those found on the main branches (41.86%), stem bases (6.98%), and secondary branches (2.33%). No exposed cavity was found on the stem bases of Trembesi and palm trees. Exposed cavities with very large volumes ($> 50 \text{ dm}^3$) were only found on Trembesi trees (2 trees, 10.34%). There was only one Flamboyan tree (10%) which had an exposed cavity with a large volume ($30 - 50 \text{ dm}^3$). On the other hand, there were no exposed cavities with a large volume found on the palm trees. The volume of the exposed cavities ranged from 0.04 dm^3 to 63.61 dm^3 with an average of 9.79 dm^3 .
2. Observed from the depth, most of the exposed cavities on the trees in the CBD area, South Jakarta, were 10 cm to 30 cm deep (41.86%), followed by those 5 cm – 10 cm deep (25.59%), 3 cm – 5 cm deep (18.60%), 30 cm - 50 cm deep (4.65%), and $> 50 \text{ cm}$ deep (4.65%).
3. Most of the exposed cavities (51.16%) on the trees in the CBD area, South Jakarta, are believed to be caused by decay on the surface of pruning area. It might be due to pruning process in the past that were not conducted according to the standards.
4. Based on the absence of cracks on the surface of the filled cavity and the mass density of the filled cavity, the quality of the filled cavity in the trees in the CBD area, South Jakarta, was very good.

4.2. Recommendations

1. Tree pruning should follow at least these three guidelines:
 - a. Every time a chainsaw and/or a handsaw is to be used, it must be sterilized using 70% alcohol or other disinfectants to inactivate the pathogens (fungi, bacteria) that might still be found on the blades.
 - b. The surface of the pruning area must be completely smooth and must be angled (at least 30°) towards the base of the tree so that water or dirt would not be trapped on the surface of the pruning area.
 - c. Immediately after the pruning, the surface of the pruning area must be treated with a fungicide and covered with exposed cavity dressing to prevent infections by pathogens.
2. Monitoring for the possibility of tree parts decaying should be done at least once annually.

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