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Active Materiality as The Basis of Architectural Design in Dealing with Pollution

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Abstract: *This paper describes the architectural design process based on an understanding of living materials' properties and their growth process in response to pollution. The development of the design method was based on the existence of living materials and their potential to be the active unit of architecture. Living materials could actively grow and adapt through their reactions to external factors, in this case, pollution, allowing the material to be in a passive phase temporarily due to the forces. This paper focuses on the development of design methods based on the understanding of algae, fungi, and lichen as the living materials that will detect and detoxify air and soil pollution around Daan Mogot, West Jakarta. By conducting research through design, this paper then proposes architectural design by injecting the active-passive growth process of living materials (algae, fungi, and lichen) into the context using split and absorb mechanisms. In response to pollution, the active and passive schemes of living materials become the foundation of architectural design. This paper then proposes the term "active materiality," considering the existence and capability of the living materials as the active unit. The development of an architectural design method in this study demonstrates the possibility of design ideas to enhance dialogue between humans, other living things, and the environment and to develop programming to respond to environmental issues.*
Keywords: materiality, living material, material growth, active-passive, pollution

Abstrak Tulisan ini menjelaskan proses perancangan arsitektur berdasarkan pemahaman mengenai proses pertumbuhan material hidup dalam merespons polusi. Pengembangan metode desain dilakukan berdasarkan kehadiran material hidup dan potensinya sebagai unit aktif dalam arsitektur. Material hidup secara aktif mampu bertumbuh dan beradaptasi dengan faktor eksternal, dalam hal ini, polusi sehingga memungkinkan material tersebut berada dalam fase pasif sementara. Tulisan ini kemudian berfokus pada pengembangan metode perancangan berdasarkan pemahaman terhadap alga, jamur, dan lumut kerak sebagai material hidup yang mampu mendeteksi dan mengurangi polusi udara serta tanah di Kawasan Daan Mogot, Jakarta Barat. Melalui penelitian perancangan, tulisan ini kemudian menggagas rancangan arsitektur dengan menginjeksi proses aktif-pasif pertumbuhan material hidup (alga, jamur, dan lumut kerak) dalam konteks melalui mekanisme "split" (memisahkan) dan "absorb" (menyerap). Skema aktif dan pasif dari material hidup tersebut dijadikan sebagai basis perancangan arsitektur dalam merespons polusi. Istilah "active materiality" diajukan dalam tulisan ini dengan mempertimbangkan kehadiran dan kemampuan material hidup sebagai unit aktif. Pengembangan metode perancangan arsitektur dalam studi ini mendemonstrasikan kemungkinan ide perancangan

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yang dapat meningkatkan dialog antara manusia, makhluk hidup lainnya, dan juga lingkungan dalam mengembangkan pemrograman yang merespons isu lingkungan.
Kata Kunci: materialitas, material hidup, pertumbuhan material, aktif-pasif, polusi

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Introduction

Architecture needs to respond to environmental issues, specifically pollution. This study does not focus on the high-performance technology needed to respond to this issue; instead, it highlights the capabilities of living materials. It is critical to change our perception of the presence of living materials because they have exceptional yet hidden properties and qualities that could perform in response to external forces, in this case, pollution.This study focuses on algae, fungi, and lichen as they are seen as the active units in architecture in response to pollution. By investigating their properties, growing medium, and growth process, we could see how they actively survive (Ballantyne, 2016) and perform. Unfolding material properties could reveal what is beneath the surface of the material (Ingold, 2007). It is the objective aspect of the material and might be a measurable aspect in which they could tell the stories behind them since they are not considered to be fixed attributes, but rather processual and relational (Ingold, 2007).

It becomes important to see the medium, substance, and surface of the material as parts of exploring living materials' life cycles and growth processes. Medium is seen as something that could detect the occurrence of substances, for instance, the medium of air and water (Gibson, 1986). It could allow movement and perception from the medium itself (Ingold, 2007).The events that happened within the medium entail different kinds of adaptation and behavioural adjustment of the material (Gibson, 1986). If there is any change in the process of material growth, it will not affect the substance since it is stored within the growth process and is resistant to both medium and surface (Gibson, 1986; Ingold, 2007). Substance is heterogeneous in that it has an unlimited set of mixtures of elements, and when we talk about the substance, we tend to ask about its composition and what elements it is made of (Gibson, 1986). Surface is seen as something where the action of the material takes place and as something that is transitory between substance and medium (Gibson, 1986; Ingold, 2007). Since it is transitory, the surface is considered the most active element (Gibson, 1986). As a result, substance and surface are things that happened internally during the material growth process.Within the complex processes of material growth, the true simplicity, essence, and character of materials can be revealed (Poerschke, 2013).

Time plays a role in the material growth process that could be seen as permanent as well as temporary or changing (Gibson, 1986). As time goes by, it could "reconfigure" the surface (Ingold, 2007). These permanent and temporary states are important in understanding how material growth responds to external forces.Permanence, I argue, is a type of primary growth that occurs continuously, whereas the temporary is a transitory process of becoming in material growth (Dewsbury, 2012; Ludwig et al., 2012; TorresCampos, 2020).Material must adapt to external forces and maximise its full potential during the becoming process (Ludwig et al., 2012).The adaptation process may include behavioural adjustments and the capabilities of materials to create residue (Dewsbury, 2012). In this study, the architectural scenario created by the growth process of algae, fungi, and lichen is seen as the new element, whereas the polluted context is considered the existing aspect. The relationships between them have the possibility of creating a new active-contextual system, as stated by Abudayyeh (2021), through their active processes.

It is also important to investigate the material properties and the growing medium. It could learn about the requirements for living materials to function and reveal the layers beneath the physicality of materials.Exploring the process of growth could reveal the living materials' life cycle, which may consist of their generation and regeneration processes (Pasquero & Poletto, 2019), as well as their behavioural response to any forces that may occur during the process. The understanding of living materials' properties, the growing medium, and the growth process could help to generate mechanisms for the design scenario, along with investigating pollution behaviour in context, specifically in Daan Mogot, West Jakarta, as one of the most highly polluted areas in Jakarta according to AirVisual. In this study, the mechanisms of split and absorb are used within the design process.

This study describes the architectural design process for how pollution behaves within the context and how the living materials could actively respond to and adapt to the pollution as external forces. This study then generates design ideas that focus on the growth processes of algae, fungi, and lichen that play roles in detecting and detoxifying air and soil pollution in context. Therefore, the relations among algae, fungi, and lichen are important, and we should not see them as separate units.

Methods

This study proposes a design scenario that explores how the growth process of the living materials could respond to air and soil pollution. It is done by research through design, and designing is part of the research methodology itself (Till, 2012). This study began with a literature review to investigate how the chosen living materials could respond to pollution by exploring their properties, growing medium, and process of growth, which are necessary as the basis of the design scenario. The chosen living materials are limited to algae, fungi, and lichen to respond to pollution. Algae and fungi could help detoxify the pollution. Algae are the most effective at reducing air pollution; fungi may be able to resolve soil pollution; and lichen may be able to detect pollution in the environment.Therefore, relations between these three living materials are important to detect and detoxify pollution.

According to AirVisual, the area around Daan Mogot is categorised as unhealthy, showing a value of the Air Quality Index (AQI) within the range of 101–200, especially during peak hours (at 06.00–08.00, 15.00, 18.00–20.00, and 23.00–05.00) (PT. Transportasi Jakarta, n.d.) when the activities and mobilities are high. An observation is conducted to investigate how the pollutants behave in

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the context. The context is then divided into five areas with varying pollution behaviours by identifying pollution sources and physical and/or spatial properties of the area. The study of pollution behaviour in each spot is important to reveal the possibilities of how the pollution occurred onsite since the sources of pollution are varied. It is found that there are three major pollution behaviours in context, which are trapped, attached, and centralized. A design mechanism is then generated as a response to pollution in the context based on the variations of pollution behaviors. This study uses a "split" and "absorb" mechanism in which it allows the pollution to be split or separated from existing physical structures or properties and then filtered through absorption. The mechanism will serve as the foundation for polluting the living materials in the context and will be used to generate design scenarios.

Result an Disussions

Investigating active-passive scheme of the living materials within the growth process

In this study, living material is seen as active unit that can be seen through their properties and growth process. The growth process of living material begins with (1) active process, (2) passive process, and then (3) going back to active process (re-active).(see figure 1) The first active process is seen within the primary growth (Ludwig et al., 2012) of the material that there lie some relations between the medium, substance, and surface (Gibson, 1986). Since it is a primary process, it becomes important to see how substance and surface react with the appropriate medium, specifically the medium from natural resources. In particular, the first active process can be seen through the metabolism process of materials. After going through the active process, the material should undergo (2) the passive process or slowing down. This process can be categorized into two terms: a) passive process due to the reflection of the external forces in which I called it as self-optimization phase 1 and b) passive process because the materials are about to decay in which it is called as self-optimization phase 2 in relation with the material's response (Loschke & Ludwig, 2016). The two terms of the passive process can be seen as some possibilities of material growth, so it does not need to have all of these two passive schemes within the growth process.

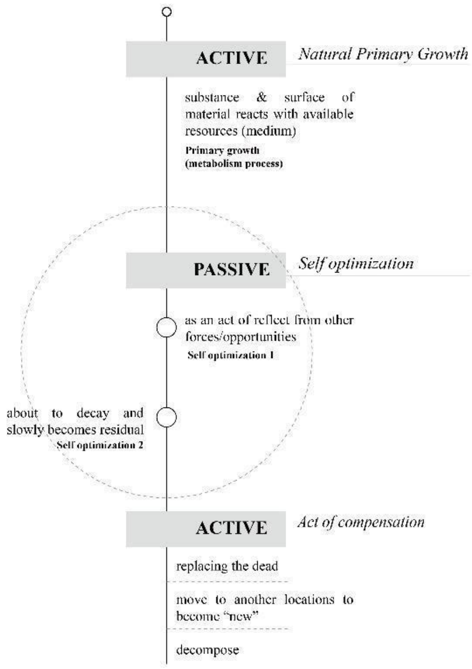

Figure 1. Active materiality scheme (source: Author, 2022)

Then, after going through the passive process, the materials will slowly return (3) to be active as a way to overcome the previous passive process. In this term, I called it an act of compensation. In this stage, materials will try to decompose as a response to self-optimization phase 2 or replace the dead units due to the external forces as a response to self-optimization phase 1. In

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particular, I called the whole scheme "active materiality". As an active unit, living materials need to pass the passive process as a way to reactivate the material. It can be seen through its interactions within the process of growth. The term "active materiality" becomes the basis in developing architectural design based on the material properties and the growth process of living materials in response to pollution.

Investigating the growth process of the living materials

The chosen living materials have different growth process and behaviors towards pollution. Algae cleans pollution through photosynthetic process. It begins with algae cells move and gather with other cells creating algae turbulence in water. Then, algae splits water and absorbs the nutrients from the water. When the air pollution comes, algae will exchange pollutants with their chemicals from the nutrients, releasing (what chemicals) to the air. To make algae grows faster, it has to be exposed to lights (whether it comes from sunlight or LED light)(see figure 2) (Srivastava & Gupta, 2020). Algae also has to be conditioned in the temperature ranging from 21C-28 C and it needs to be kept in a closed and transparent surface so that the light could pass through the surface, allowing the algae to grow (Singh & Singh, 2015).

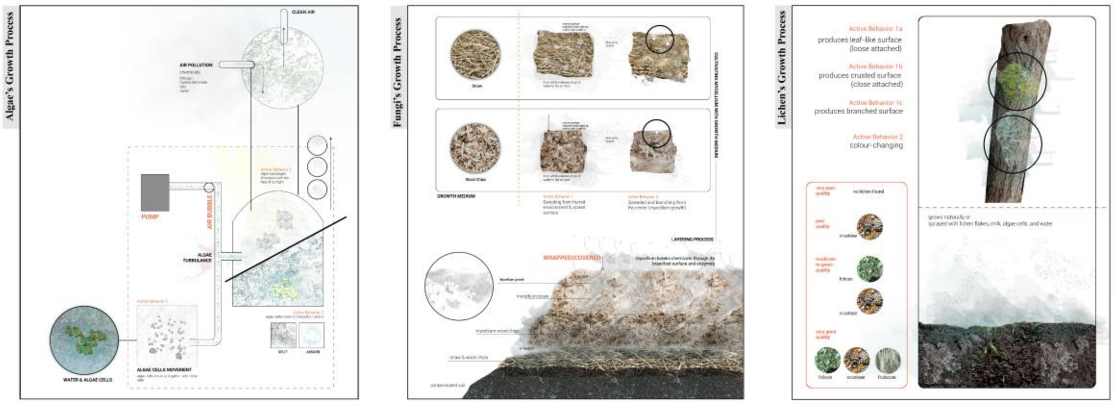

Figure 2. Growth process of algae, fungi, and lichen (source: Srivastava & Gupta, 2020)

Fungi has a different growth process in response to pollution. Through mycoremediation or decomposition process, fungi, specifically mycelium will remove soil pollution in context (Akhtar & Mannan, 2020). It requires appropriate growing media to make the mycelium in fungi grow faster. It is found that wood chips and straw are suitable for growing mycelium faster. The growing mediums have to be pasteurized first to remove the contaminants that are attached within them. After being pasteurized, they have to be packed in a semi-closed yet transparent surface to make the mycelium grow from the growing medium. The mycelium shows their active behaviors by sweating due to the humid condition and enclosed surface while being packed. When the mycelium has grown, the mycoremediation or decomposition process could begin by layering the contaminated soil with the growing mediums (wood chips and straw) and water. Then adding another layer that consist of mycelium wood chips, mycelium straw, and water. After that, the layers need to be closed by putting any surface to wrap them. Through these layers, it allows the mycelium in fungi to spread, branch, and break chemicals for decomposing the contaminated soil.

While algae and mycelium in fungi could detox the pollution, lichen helps to indicate pollution through its growth form

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and colors (Gabrys, 2018). Lichen has three variations of growth form, they are crustose (crusted form), foliose (leaf-like form), and fruticose (branched form) (OPAL (Open Air Laboratories), 2015.). When there is only lichen with the crustose form in the area, it indicates the poor quality of the environment whereas the growth of lichen with foliose and crustose form indicates the moderate to good quality of the environment and when there are foliose, crustose, and fruticose form of lichen, they indicate the very good quality of the environment. Lichen has the ability to change its colors depending on the environmental condition (OPAL (Open Air Laboratories), 2015). They also could grow naturally or manually by human spraying the growing medium with lichen flakes, milk, algae cells, and water. To make lichen grows, it has to be kept shaded.

Pollution as the external force could affect the process of material growth, specifically algae, fungi, and lichen as the living materials. In this term, air and soil pollution are parts of the passive process or in the self-optimization phase within the living materials' growth process. They need to compensate for the forces (pollution) through photosynthetic process (algae) and decomposition process (fungi). They also need to actively indicate the pollution through the growth of lichen. Through these investigations of the living materials' growth process, it could help develop the design scenario in which they will be injected into the context (see figure 3)

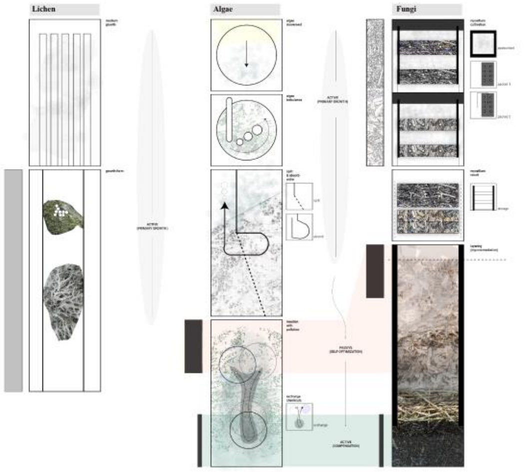

Figure 3. Living materials physical requirements (source: Author, 2022)

Developing design scenario based on the pollution behavior in context and the living materials

The development of the design scenario begins with understanding the context (see figure 4) and the pollution behavior. The context is divided into five spots indicating the variations of air and soil pollution behavior. Spot 1A and 1B are located in a small residential area where the street is narrow. The air pollution mainly comes from the vehicles that pass by the street, mainly motorbikes. The pollution are trapped on the street due to the presence of a roof that shades the street and a high wall that bounds the residential area. The area is mainly used to park the resident's motorbike, gather, and sometimes hang the clothes in the afternoon. Spot 2 is located nearby the market and river. The street is wide enough for the vehicles to pass by and park.

The source of pollution mainly comes from the vehicles and stacked of waste that are thrown away in the street. Spot 3 is located under the flyover of Daan Mogot. Mainly, the air pollution comes from the traffic fumes that are attached to the existing structure of the flyover itself. The pollution are also trapped and

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concentrated in the lower area of the flyover. Spot 4 is located on the depo of TransJakarta. The air pollution mainly comes from the vehicles (buses) that pass and park in the depo. The pollution are attached and centralized within the area due to the mobility of the buses. In response to the existing condition of context, the air pollution in spot 1A and 1B need to be released from the trapped due to the roof and narrow street. The pollution in spot 2 also needs to be released and should respond to the stacked waste that are found in the context whereas in spot 3 and 4, the pollution that mainly comes due to the attachment to the existing structure and centralized in certain areas needs to be cleared and reduced.

Figure 4. Context of study (source: Author, 2022)

From the investigations of pollution behavior in context and the previous understandings of the living materials' growth process, it is found that the mechanism of "split" and "absorb" could respond to the issue (see figure 5).

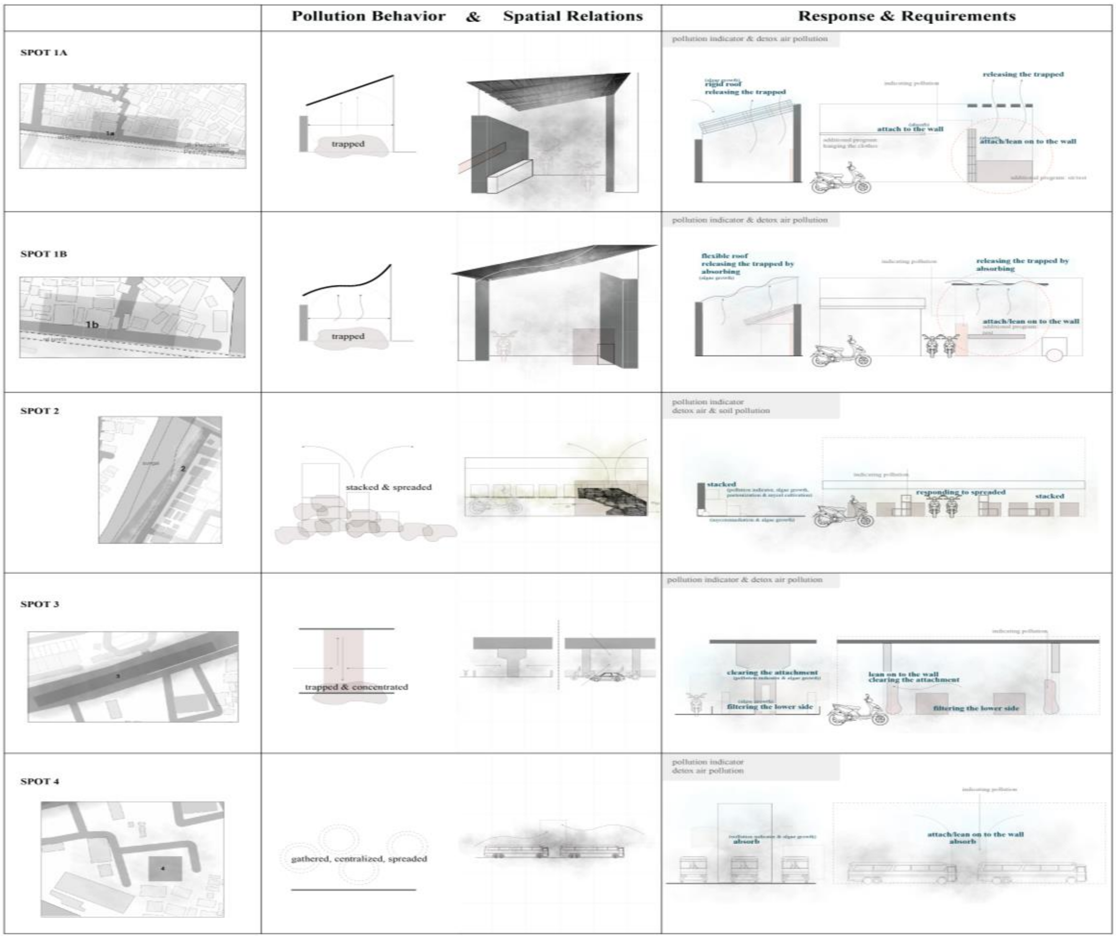

Figure 5. Catalog of pollution behavior and response (source: Author, 2022)

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The "split" mechanism works to indicate, separate program, and detoxify the soil pollution whereas the "absorb" mechanism helps to absorb the air pollution since the pollution needs to be released from the trapped, cleared from the attachment, and reduced from centralization. The "split" and "absorb" mechanisms are not seen as separated operations but they also could relate to each other to respond to pollution in context.

Implementing the scenario into the context

From the scenario, the mechanism of "split" and "absorb" are used to respond to pollution. These mechanisms are applied differently in each spot based on the pollution behavior found in the context. In spot 1A and spot 1B, there are two main mechanisms. a) The mechanism of split is used to indicate the air pollution through the growth process of lichen. b) To detox the pollution, the relations between split and absorb should be applied. The program is splitted according to the existing context, for instance hanging the clothes and sitting whereas the air pollution is absorbed and released from the trapped through the growth process of algae using photobioreactors that are attached to the high walls (side) and roof (upper level).(see figure 6)

Spot 2 has four main mechanisms of split and absorb to respond to air and soil pollution. a) Mechanism of split is used for stacking the growing media of fungi so that the mycelium will grow and help to detox the soil pollution due to the waste that are thrown away onsite. b) Mechanism of split is also used to separate the program in detoxing air and soil pollution. This scenario separates the activities of pasteurization of the growing medium of fungi (to cultivate mycelium), mycoremediation, and the absorption of the air pollution using algae. c) Mechanism of absorption is extended through seeking the relationships between lichen and algae. Lichen and algae are arranged together so that it could work to indicate the pollution (lichen) and at the same time absorb the pollutants (algae within the photobioreactor). d) Then, if we see the system as a whole, it is found that both the split and absorb mechanism are conjoined with one another to respond to pollution in context.

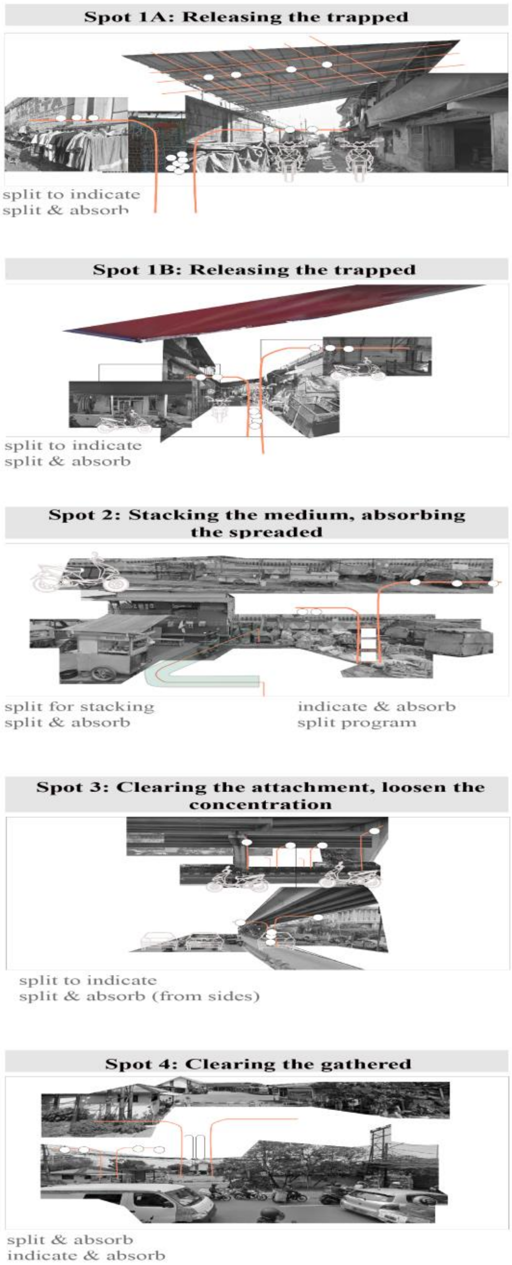

Figure 6. Mechanism applied in the context (source: Author, 2022)

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Spot 3 has two main mechanisms. a) Mechanism of split is used to indicate the air pollution though the growth process of lichen. The air pollution mainly comes from the attachment of the pollutants in the existing structure and the traffic fumes. b) Mechanism of split is also used to separate the scenario then followed by the mechanism of absorption using algae within the photobioreactor (see figure 7). Spot 4 has two main mechanisms. Similar with spot 3, (a) the mechanism of split is followed by the mechanism of absorption to filter the air pollution. b) Also similar with spot 2, lichen helps to indicate the air pollution and at the same time algae helps to absorb the air pollution since the pollution's behavior in this spot are centralized, and spreaded.

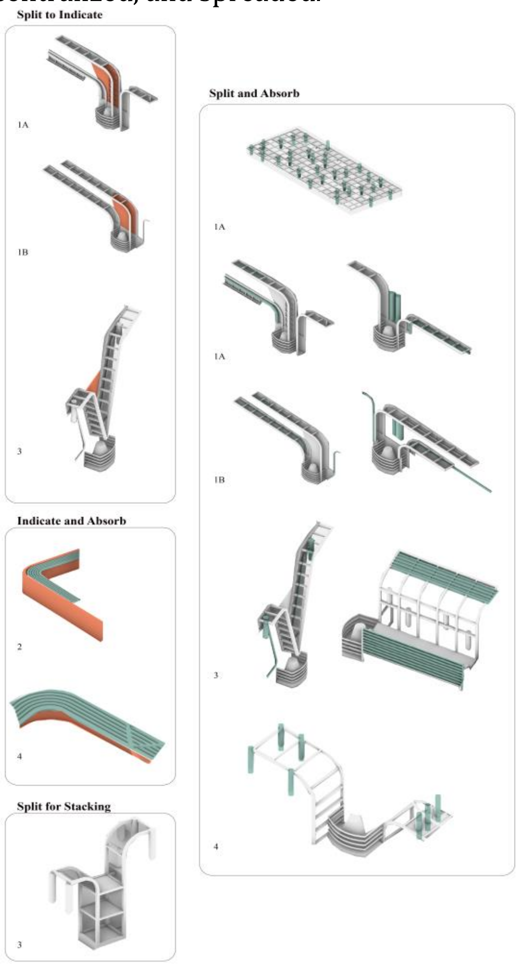

Figure 7. Split and absorb mechanism catalogue (source: Author, 2022)

Thus, if we see the system as a whole, the growth process of lichen could help indicate the air and soil pollution by looking through its growth form (whether it is leaf-like, crusted, or branched) and its color. To make the lichen grows, raw wood is used as the growing surface. Lichen will actively indicate the pollution and at the same time algae will absorb the air pollution using photobioreactor through its photosynthetic process. The algae tank could help distribute algae cells to the photobioreactor. It is a cyclical process that when algae cells die while trying to detoxify pollution, human has to fill the tank with new algae cells to replace the dead cells. Then, the new cells in algae tank will be distributed again to the photobioreactor to continue the photosynthetic process in detoxing the air pollution. In response to soil pollution, the process should include preparing the growing medium. In this case, wood chips and straws are used as the appropriate growing medium since they will grow faster. The preparation of the growing medium involves pasteurization process to sterilize the medium. Then, mycelium of fungi will grow (mycelium cultivation) from the growing medium in a humid environment and enclosed surface. Mycelium and the available growing medium will then be used to reduce soil pollution through mycoremediation or decomposition process (see figures 8).

From this design scenario, it can be seen that the active process occurs when lichen indicates pollution, algae's performance in photosynthetic process, and the process of growing mycelium of fungi (see figure 9 and 10). This active process can be seen as the primary growth of the living materials. It could enhance a new living architectural system since it includes the metabolism process of the materials (Beesley, 2016). The passive

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process occurs when pollution inhabits the environment, allowing the living materials to adjust and force them to be in a passive state or self-optimization phase. It could be seen as a transitional process of the living materials (Torres-Campos, 2020). The reactivation process can be seen when algae exchange chemicals between its nutrients and air pollutants and mycelium of fungi start to decompose the soil pollution and break the chemicals. It is an act of compensation from the previous passive state to become active again. From the proposed design scenario, the hidden behaviors of living materials could be revealed and we could see their macro and micro growth process in response to external forces, in this case, pollution.

Through the existence of external forces (pollution), the living materials could have a second life (Valenti & Pasquero, 2021) that will give a new meaning to the whole active process. Through this design scenario, it could be seen that the material growth process includes human's involvement in exploring the growing medium. This process allows human to have a co-working partnership and to relate with the living materials (Collet, 2021; Pasquero et al., 2020). It also extends our dialogue with the living materials since we see the process as a whole and beyond their properties (Riskiyanto et al., 2021). This study then could shift our view in seeing the connection between human and nature (specifically from the living materials) that the relationship between them is reciprocal.

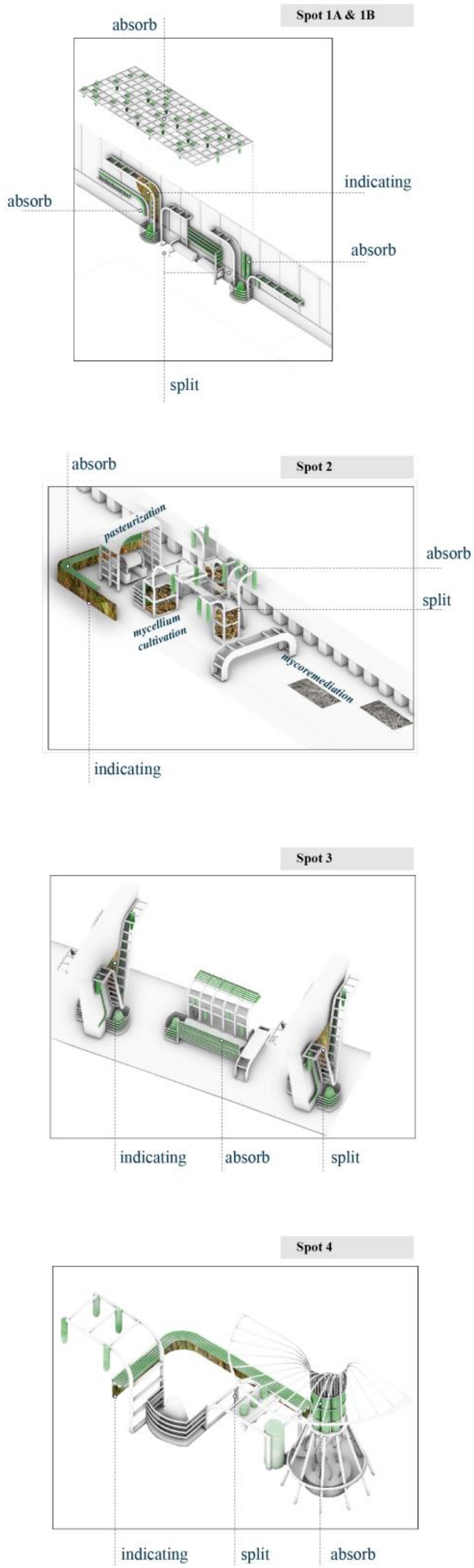

Figure 8. Design scenario in each spot (source: Author, 2022)

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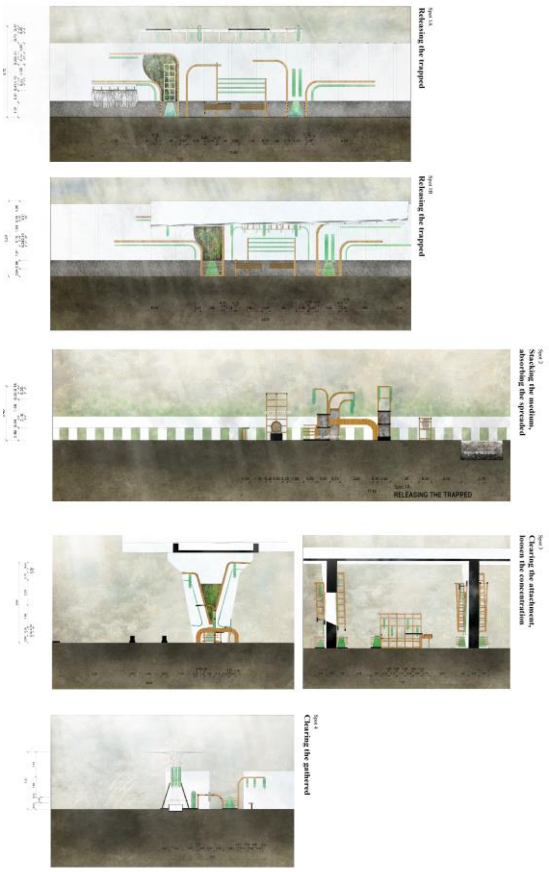

Figure 9. Sections of design scenario in context (source: Author, 2022)

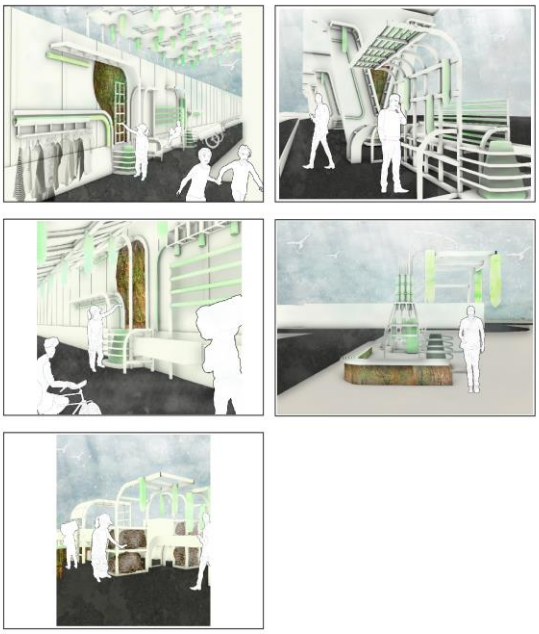

Figure 10. Design scenario in context (source: Author, 2022)

Conclusion

The term "active materiality" refers to the capabilities of the living materials, which are seen as the active units in architecture. They could respond to external forces, in this case, pollution, which includes the active process, the passive process, and reactivation. It expands the notion of materiality, specifically in response to environmental issues. The scenario of "active materiality" allows living materials to undergo the passive process before they can be re-activated. It does not stop the material from growing, but rather pauses the process for a short period of time to allow it to adapt to external forces (pollution).The study of the properties and the growth process of living materials' performance shifts our understanding in the developing architectural design process, which begins by reading the living materials' behaviours and requirements, then investigating the pollution behaviours by observing the source of pollution and other related physical properties in the context, then generating scenarios and mechanisms (split and absorb), which include injecting the living materials' growth process into the context.

The proposed design scenario not only detects and detoxifies pollution, but it also fosters closer interactions between living materials, humans, and the surrounding environment.Humans could understand the growth process and the active behaviours of living materials (such as sweating, moving with turbulence, gathering, etc.) towards pollution since they also participate in preparing and exploring the growing medium. This active engagement has the possibility of creating a narrative ecosystem (Loverich, 2016), allowing human and non-human relations to emerge. However, this study is speculative because the performance of the chosen living materials is based on

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literature. More research is needed to determine which specific types of living materials are suitable for responding to pollution in context.It also has to consider the technological aspect to maintain that the scenario could work. Further quantitative research is needed in terms of the design's applicability and context reading, especially in measuring the pollutants' levels.

Authors statement

The authors hereby declares that this research is free from conflicts of interest with any party

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Ruth Kartika Purnasasmita contributed to research design preparation and literature review, data collection, data visualization, data analysis, and article drafting.

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