

IMPROVING INDOOR ENVIRONMENTS FOR LOW-INCOME SETTLEMENTS

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Abstract

This article intends to clarify the importance of indoor environments in low-income settlements, which considered as marginal group of people, and to explore the possibility of indoor environmental improvement, which normally limit in financial resources, choices and alternatives. Regarding to their constraints, basic knowledge about sources of pollutants in the existing condition of low-income settlements are necessary as well as general condition of residential characteristics and their surroundings. By conducting the available core strategies, the prioritized major sources of pollutants are identified, simultaneously with investigating through the potential and strength of any resource in hand as solutions for alleviating this problem. Finally, plan and mechanism will be suggested on the basis of applicability and reasonableness in the real world.

Keywords: Indoor air quality, Sick building syndrome, Low-income settlements, “Chumchon Aai-aat”(crowded community [1]), Shelter improvement

Introduction

There are number of studies about improving indoor environments in standard type of living place, but still limited in low-income living place (known as “Chumchon Aai-aat”[2]). Unlike the standard dwelling type, which building accessories such as air-conditioner, building materials, building equipment, etc. are affordable, people who live in low-income settlements can hardly afford these because of financial reason despite of living environmental condition is one of the significant issues for low-income settlements.

In 1994, numbers of populations in Bangkok (permanent residences) are approximately 6.5 million and 8% from this live in Chumchon Aai-aat (around 0.58 million [3]). The three-fifth of this number live in lower standard of living [4] or in other words, in the poor environmental condition. Commonly, like other crowded communities, it is the poor level of the infrastructure standard [5] in community. Shelter condition, solid waste management, drainage, sewage and sanitation systems are the major causes and relatively affect to health of the inhabitants. Precisely, two concerned aspects, which affect to indoor environmental quality, are the first is shelter condition and the other is its surroundings quality.

Significant relevant development authorities, organizations, and institutions widely discuss to the concept of “Green Building”. Minimizing internal pollution and harmful to health is one part of this [6]. However, Spengler and Chen [7] cited that the paradigm of people and building relation’s have just dramatically shifted for a couple of decades, which holistically concern for multilateral perspectives and approaches to accomplish better built environment (Fig.1).

	Paradigm	Pollution Sources
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Fig.1: Paradigm shifts in the philosophy of ventilation since 1800 (Spengler and Chen: 2002)

Sick building syndrome

Previous studies have shown that poor indoor environments can seriously be harmful to human health. The common symptoms of the “sick building syndrome (SBS)” are irritation in nose and throat, skin rashes in face and on torso, fatigue, headache and general in disposition, and weak but persistent perceptions of smell [8]. Furthermore, Johnson’s study indicated that the main sources, making poor indoor air quality, are from pollutants supplied to the premises from outside, from building material, microorganism from air humidifier, pollutants from chemical used in building, etc. Moreover, the significance causes are from insufficient ventilation (64%), dirty air treatment apparatus (63%), ineffective filters in the ventilation system (57%), dirty ventilation ducts (38%), and no supply of outdoor air (35%), respectively [9].

However, the broad concepts to alleviate SBS are summarized by Edwards according to these [10].

- Constructed, finished and furnished using natural materials rather than man-made materials.
- Lit the ventilated by natural means.
- Managed so that the cleanliness of interior is maintained.
- Designed to give occupants control over their interior environment.
- Located where external air quality is high.
- Designed to avoid interior condensation.

The three strategies for controlling indoor contaminants

In the same direction of Johnson and Edwards, Spengler and Chen also developed three systematic strategies [11], those are

- *Source elimination*: Avoid directly use of toxic and chemical building materials
- *Local source control*: Maintain, control, and manage surroundings in a good condition
- *Dilution of the indoor contaminants by ventilation*: Reduce and eliminate indoor pollutants by enhancing natural ventilation through the shelters

Sources of air pollutants in crowded community

By applying three demonstrated core strategies and regarding to specific characteristic of focused area, concerned issues are raised up and indicated as significant scope of polluting sources in indoor environments, those are summarized in Table 1.

Table.1: Building Component Potentially Affecting Indoor air Quality of Crowded Community. (Adapted from Spengler and Chen [12])

Sources of Pollutants	Potential contributors to Indoor Air Quality
Siting	<ul style="list-style-type: none"> • Traffic • Upwind sources or change of air flow • Soil emission of radon • Moisture/Drainage
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Material used for internal furnishings furnishing equipment, and cleansing	<ul style="list-style-type: none"> • Sources of volatile organic compounds (VOC[13]), aldehydes, phthalates, and particles • Sources of nutrients for microorganism

Profiles of typical crowded community

National Housing Authority's definition for "Cumchon Aai-aat" is that "the area for living within unhealthy condition and very high density [14]. General characteristic of them in specific will be elaborated from the followings.

Materials of shelter

Although the choices of building material use for shelter in crowded community is limited, compare to typically used in general buildings; it's still necessary to be investigated in order to find out the possibility of more appropriate materials, which still regarding unpolluted. As mention before, building materials are one of the major sources, which cause adverse impact to health. Scrutiny in this item will be one way to alleviate this impact. The following information will investigate through the compartments of shelters in crowded community classified in element by element.

- Roofing

Corrugated galvanized steel sheet and asbestos cement roof are two most used as roofing materials. Existing conditions of both are poor and impractical. Corrugated galvanized steel sheets are covered with rust as bad as asbestos cement roofs. Both are exposedly used without any insulation and ceiling, so small particles of dust, rust, fiber directly

become cause of respiratory disease, especially asbestos. The fibrous particles from them are the cause of cancer [15].

- Wall panel

There are numerous types of material that used as wall panels. The typical selections are gypsum board, fiber cement panel, plywood panel as well as corrugated galvanized steel sheet (same as roofing) and those are also exposedly used without insulations. The toxic substances from corrugated galvanized steel sheet has been already discussed before, while for the rests, formaldehyde [16], toxic chemical particles, is usually found.

- Toilet/Sewage

Like other standard residents, toilet/WC becomes ordinarily located inside the shelters. Toilet with septic tank is commonly applied. The difference is that in crowded community shelters are situated and little lifted upon marshy land, while in the common urban residents are not. According to this poorer condition of sewage system, germs and microorganism vectors will easily become sources of airborne disease. In addition, the condition of toilet's material used are more permanent and durable, while in crowded community they are not those good. Timber is basically used as toilet wall and always wet, so fungi and mold can widespreadly grow on that condition.

Table 2. is the checklist format for investigating through building materials used in crowded community. According to this the seriousness of pollutants of indoor environments will be identified (The seriousness arrange from *(lowest) to *****(highest)). Obviously, they are all in quite low cost for applying

Table 2. Building materials usually applied in crowded community (Edited and summarized from Woolley. et. al. [17]).

		Health Impact	Unit Price Multiplier*
Roofing			
<i>Cement Based Tile</i>			
- Concrete tile		*	0.6
- Fiber Cement Tile	Glass Fiber	*	1
	Synthetic Fiber	*	1
	Cellulose Fiber	***	1
- Rasin Bonded (reconstructed) Slate		**	1.0-1.6
- Polymer Modified Cement Slates			-
- Ferro Cement		**	-
<i>Metal Sheet</i>			
- Steel sheet	Alu. Coated	**	-
	Galvanized	***	0.7
	PVC	**	-
	Polyester	***	-
	Acrylic	****	-
- Stainless Steel Sheet		**	2.4
- Aluminium Sheet		*	1.4
- Lead Sheet			2.0-3.7
Wall Panel			
<i>Concrete Blocks</i>			
- Ordinary Dense Block			0.3

- Lightweight Aggregated	****	-
- Aerated		3.2
- Composite Insulation		1.4
Composite board		
- Corrugated galvanized steel sheet	***	
- Plywood	**	1.0
- Chipboard	***	0.5
- Soft board	*	0.3
- Wood-cement Particle board	**	
- Woodwood Cement Slabs	**	
- Tropical Hardwood		4.0
Toilet & Sewage		
- WC+ septic tank & land drain	**	1.4
- Composting toilet- De-watering type		1.5

* Unit price multiplier is the materials plus labour cost per in square meter. This is in order to account for materials, which have low purchase costs, but high labor cost [18].

The painted areas (in grey) are building materials typically used in crowded community.

Nearby outdoor environment

The surroundings of crowded community, which often very tight in layout arrangement and orientation of the shelters makes indoor environmental conditions indispensably much depend on outdoor environmental conditions. The issue that has to be focus about realted outdoor environment are;

- *Ventilation control*

Ventilation is considered as one of the best tools to alleviate the SBS, especially, in the hot-humid region. By the way, crowded community has insufficient open spaces to provide effective airflow, while airflow equipment, generally used, is fan/ventilator. None of them applies air-conditioning system. In other words, cross and natural ventilation is preferred and be the only ventilating tool for indoor environments.

- *Surroundings/Environmental Conditions*

General character of low-income settlements is crowded. According to field survey in some communities, most of the houses are two storied houses situated on a marshy land built, wooden and reinforced concrete platforms supported by piles. Some of the houses are, however, located in the non-marshy part of the area. Some of the houses are dilapidated condition of both roofs and walls, even worse for the shelters near the fringe of community [19]. The surrounding of low-income settlements, especially in the infrastructure system, is considered as one of the sources. Improperly managing solid waste creates stagnant water. Accordingly, odor and smell disturb the inhabitants including germs and microorganism vectors.

Spacing among shelters is also the concerned issue. In average, each household obtains around 80 square meters piece of land for locating the shelter. According to Building Code 1995, each of the shelter/house has to set the wall with openings back at least 2 meters from its land periphery, but all cannot applied in crowded community because the need of space mismatch with the land size. In reality, each of the shelter is very close together.

The distance between shelters is no more than a meter. It means that the outdoor spaces, which significantly required for effective ventilation, are insufficient. Whatever pollutants like smoking, cooking, odor, and even worse, airborne disease occurred in one place can easily affect to the others

- *Motor vehicle*

Because of narrow pathway (See Picture. 1), air pollution from motorcycle is identified as serious source, which directly degrades outdoor environmental condition in community. Matters such as smoke and hydrocarbon gases almost immediately ventilate into the residents, especially in compact residents like this.



Picture 1. Narrow pathway and compact shelter orientation inside community

Utilization of space

As cited before, it's not only building materials and outdoor environmental condition, as active factors, but also utilization of space as passive factor, which can be roughly classified from the followings.

- *Indoor activities*

Some activities inside the households can directly affect to inhabitant's health. Smoking and cooking are one of the causes, especially for cooking because for low-income settlements, which traditionally use wood cinder as energy source for cooking, it unavoidably creates dust and toxic gas after combustion like CO, CO₂, sulfur and nitrogen oxidants. Moreover, Laquata's study found that the homes of lower income residents had higher level of CO because of not functioning of kitchen exhaustion [20]. Together with poor ventilation, this makes the inhabitants unavoidably inhale such toxic gases and particles.

- *Interior space arrangement*

In most of the houses, their interior space, in crowded community, is a single multipurpose space (See Picture. 2) with separated toilet/WC area. All activities like sleeping, sitting, feeding, and, cooking are utilized in the common space. The problems are that some of shelters do not properly oriented their functional space with direction of airflow, so indoor air quality can be unintentionally degraded from unventilated air and stagnation.



Picture 2. A single multipurpose space as all functions of living

Coming across constraints

To alleviate indoor environmental problems, general analysis to sources of pollutants and contriants in term of physical condition and finance in the real situations will give some clues to step further to set up appropriate plans and machanisms for the solutions

Conflict between required building materials and their cost

On one hand, all require materials that none or less impact to health, while on the others, they are always costly. It is the obvious dichotomy that the safeguard quality of building material and their price often dependent vary. Building materials in the market are considered too expensive for low-income community. In other words, the need of good building material quality is prioritized that nearly last necessity compared to other needs such as expenses for food, tap water, electricity, etc.

Conflict between surrounding and its size

Not only of building materials available on the market are constraints, but also the site's size. As the explanations before, ventilation is the most significant factor to achieve better indoor environments, but it crucially requires enough surrounding space in order to make indoor air circulates efficiently, while applying ventilator is not as the most sustainable solution because of paying higher electricity cost.

Conflict between utilixation of space and its area

Appropriate space arrangement can alleviate and avoid pollutants both from indoor activities and outdoor pollutants from air intake, but because of limited land and room area in shelters, there is not any alternative for orientation of functional spaces. That means ventilation to dilute indoor pollutants is uncontrollable and unpredictable.

Conflict between HVAC system requirement and its cost

From discussions in conflict between surroundings and its size with genral physical condition in reality, it sounds that natural ventilation is hardly effectively adopted in crowded community; the only left item is to use mechanical equipment for air circulating. On the other hands, air-conditioning system is considered nearly impossible to apply from

both financing for electricity and maintenance cost and environmentally-unfriendly reasons.

According to the previous discussions, major problem for poor indoor environments tends to come from unstandardized use of building materials and outdoor environmental condition, while effective natural ventilation in low-income settlements seems to be hardly to utilize as main technique, while mechanical equipment is uneconomic. Furthermore, indoor activities and interior space arrangement are individual behavior that uncontrollable. From these constraints, the directions of solutions and choice will be narrow and limited to focus only to two questions; the first is what can be the alternative materials in order to maintain indoor environmental quality? , and the other is what are the management schemes for controlling acceptable outdoor environment for good indoor environmental condition?

Suggestions

Although choices and alternatives are very limited, there are some solutions that are at least can alleviate indoor environmental pollution. From previous studies and experiences, some suggestions are

Planting

As we know, plants can improve air quality because of its transforming CO₂ to O₂ and absorb dust and suspended particular matters as well. However, the importance of planting is not only just planted, but also their position. The effective planting position should be outside around the resident rather than inside. The previous study's shown that planting around the exterior environment can reduce heat and dust gain into the interior space [21,22]. Nevertheless, because of the space constraint, this can be adopted by integrating with the shelter compartments such as planted wall. On the other hands, plants like tomato and cucumber can be the effective indoor air quality indicator [23].

Alternative materials

Considering to alternative materials, which may not market based, is one of the practical and possible solutions. Recently, there is vigorous activity movement in shelter alternatives by applying natural materials (non-industrialized materials) like Adobe (unburned mud brick), Cob, Wattle and Daub, Rammed earth [24,25] and any other non-chemical construction techniques [26], which are based on labor incentive and very low cost. By substitution for toxic born materials like roofing and wall panel materials, this can alleviate some sources of pollutants, but it has to be ensured that the sunlight can reach to the exterior wall and surroundings

Non-motorized scheme

Non-motorized campaign and organizing activities are necessary. Instead of motorcycle use as mode of transportation, walking in short distances, bicycling in longer distances, and push carting for goods and product distribution are the alternatives.

Clean surroundings

As mention before that outdoor environment as important as indoor, so those community surroundings requires to be maintained in good condition. The concerned environmental conditions are minimizing spread of microorganism vectors and odors by maintaining

drainage, sanitary, and sewage system including solid waste management and avoid open combustion.

Mechanism

Not only understanding what are the alternatives to achieve better indoor environment for crowded community, but also how to practically launch the process as well. The following paragraphs will elaborate to the essential concerned issue to come across the purposes.

Community building

The item, which is considered as the most effective and efficient among development tools for community, is strengthening community action groups. Encouraging community to form up groups in development activities can gain many benefits such as monitoring system, labor contribution (recommended) for shelter improvement, etc. By the way, stronger organizations like public and community development agencies have to be the key actors to initiate and facilitate at the beginning.

Educating / Informing / Regulating

Concerned government or non-organization organizations should inform and educate people in the community in term of training to understand the effects from the poor indoor environment. Indicating the sources of pollutant and related activities that affect to health including practical alleviating methods. Campaigning, organizing activities, or even forming up local rules and regulations (in term of agreements) to control either intended or unintended activities, which finally result as environmental quality degradation.

Promoting cooperative of community for the housing development

Community can establish cooperative group for shelters and dwellings development with financial and materials subsidized from government and non-government organizations (NGO) like Human Development Center (HDC), Community Origination Development Institute (CODI), and Community Architects for Shelter and the Environments (CASE). There are some case studies from some community (e.g. Romklao and Utradith). In Rom Klao, HDC provides material loans for shelter development [27] and CODI, in national level, which provides housing improvement loans for community [28]. In Utradith, the community has founded “saving group for any community development project” including shelter and environment with facilitated by CASE and Urban Community Development Office [29]. From this sharing program, each of households spends less money than individually developed. Moreover, each can be beneficial from neighbor’s labor incentive.

Encouraging community environmental programs and projects

Only indoor environmental quality improvement in community is not sound worthy to adopted because it is not as serious problems compare to other crowded community problems. However, it’s obvious from this stage that there are many issues that relate to broader environmental concerns. The programs and projects for indoor environment issues will not be directly adopted and established, but will be associated with other environmental improvement program instead. From this standpoint, community will gradually recognize indoor environmental problem as one of other general environment problems.

Fig. 2 will summarize for action process to run indoor environmental condition improvement.

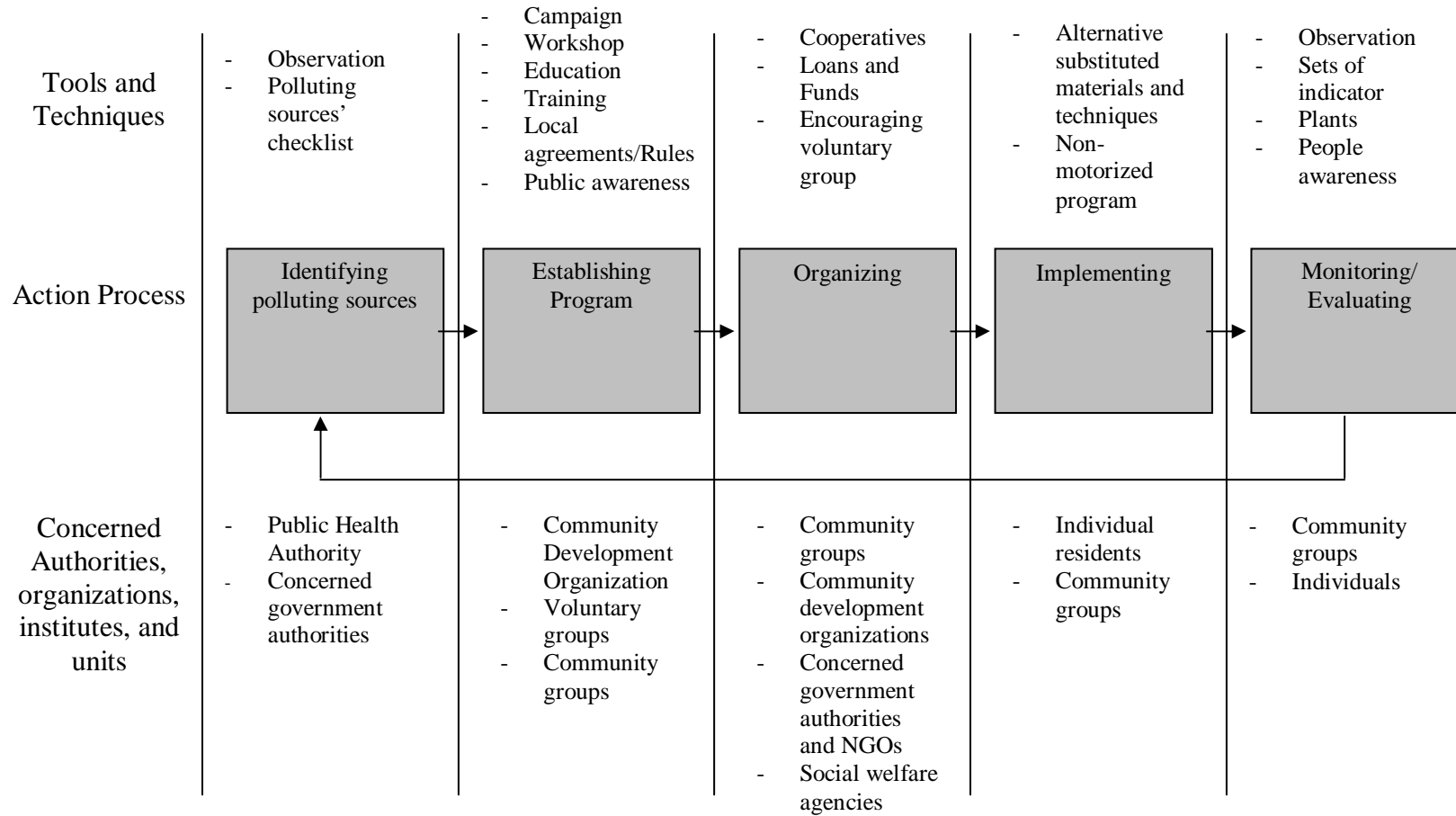


Fig. 2 Conceptual model for improving indoor environments for low-income settlements (Applied from Zimmermann, 2000 [30])

Conclusions

The issues, which seem to be significantly concerned to improve indoor environmental condition in practice, is improvement of building materials and outdoor environmental condition. To be more realistic, neither almost step forward for solution without initiation from concerned organizations and corresponding from community itself. Moreover, implementation crucially requires contribution of labor and community awareness including continuingly monitor and evaluation.

One thing that needs to be in mind is that indoor environmental problems are not isolated from others. In contrast, it essentially requires to be integrated as one part of other aspects for community environmental development programs and projects. Interdisciplinary approaches, financial and organizational management skill, technical skill, participation, grassroots development, and community building are essentially required to accomplish and sustain healthy indoor air quality of low-income settlements.

Notes

- [1] The author considers that the word “crowded community” is more appropriate than “slums and squatter because the basic need of existing infrastructures are legally provided but merely below standard condition.
- [2] The old term used by government officials is “Cumchon Bukruk”(illegal community), but changed into “Chumchon Aai-aat” as the official government term in 1982 (See ACHR. 1999. Housing By People in Asia. Number 12. April. pp. 22)
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Like other standard residents, toilet/WC becomes ordinarily located inside the shelters. Toilet with septic tank is commonly applied. The difference is that in crowded community shelters are situated and little lifted upon marshy land, while in the common urban residents are not. According to this poorer condition of sewage system, germs and microorganism vectors will easily become sources of airborne disease. In addition, the condition of toilet's material used are more permanent and durable, while in crowded community they are not those good. Timber is basically used as toilet wall and always wet, so fungi and mold can widespreadly grow on that condition.

Table 2. is the checklist format for investigating through building materials used in crowded community. According to this the seriousness of pollutants of indoor environments will be identified (The seriousness arrange from *(lowest) to *****(highest)). Obviously, they are all in quite low cost for applying

Table 2. Building materials usually applied in crowded community (Edited and summarized from Woolley. et. al. [17]).

		Health Impact	Unit Price Multiplier*
Roofing			
<i>Cement Based Tile</i>			
- Concrete tile		*	0.6
- Fiber Cement Tile	Glass Fiber	*	1
	Synthetic Fiber	*	1
	Cellulose Fiber	***	1
- Rasin Bonded (reconstructed) Slate		**	1.0-1.6
- Polymer Modified Cement Slates			-
- Ferro Cement		**	-
<i>Metal Sheet</i>			
- Steel sheet	Alu. Coated	**	-
	Galvanized	***	0.7
	PVC	**	-
	Polyester	***	-
	Acrylic	****	-
- Stainless Steel Sheet		**	2.4
- Aluminium Sheet		*	1.4
- Lead Sheet			2.0-3.7
Wall Panel			
<i>Concrete Blocks</i>			
- Ordinary Dense Block			0.3

- Lightweight Aggregated	****	-
- Aerated		3.2
- Composite Insulation		1.4
Composite board		
- Corrugated galvanized steel sheet	***	
- Plywood	**	1.0
- Chipboard	***	0.5
- Soft board	*	0.3
- Wood-cement Particle board	**	
- Woodwood Cement Slabs	**	
- Tropical Hardwood		4.0
Toilet & Sewage		
- WC+ septic tank & land drain	**	1.4
- Composting toilet- De-watering type		1.5

* Unit price multiplier is the materials plus labour cost per in square meter. This is in order to account for materials, which have low purchase costs, but high labor cost [18].

The painted areas (in grey) are building materials typically used in crowded community.

Nearby outdoor environment

The surroundings of crowded community, which often very tight in layout arrangement and orientation of the shelters makes indoor environmental conditions indispensably much depend on outdoor environmental conditions. The issue that has to be focus about realted outdoor environment are;

- *Ventilation control*

Ventilation is considered as one of the best tools to alleviate the SBS, especially, in the hot-humid region. By the way, crowded community has insufficient open spaces to provide effective airflow, while airflow equipment, generally used, is fan/ventilator. None of them applies air-conditioning system. In other words, cross and natural ventilation is preferred and be the only ventilating tool for indoor environments.

- *Surroundings/Environmental Conditions*

General character of low-income settlements is crowded. According to field survey in some communities, most of the houses are two storied houses situated on a marshy land built, wooden and reinforced concrete platforms supported by piles. Some of the houses are, however, located in the non-marshy part of the area. Some of the houses are dilapidated condition of both roofs and walls, even worse for the shelters near the fringe of community [19]. The surrounding of low-income settlements, especially in the infrastructure system, is considered as one of the sources. Improperly managing solid waste creates stagnant water. Accordingly, odor and smell disturb the inhabitants including germs and microorganism vectors.

Spacing among shelters is also the concerned issue. In average, each household obtains around 80 square meters piece of land for locating the shelter. According to Building Code 1995, each of the shelter/house has to set the wall with openings back at least 2 meters from its land periphery, but all cannot applied in crowded community because the need of space mismatch with the land size. In reality, each of the shelter is very close together.

The distance between shelters is no more than a meter. It means that the outdoor spaces, which significantly required for effective ventilation, are insufficient. Whatever pollutants like smoking, cooking, odor, and even worse, airborne disease occurred in one place can easily affect to the others

- *Motor vehicle*

Because of narrow pathway (See Picture. 1), air pollution from motorcycle is identified as serious source, which directly degrades outdoor environmental condition in community. Matters such as smoke and hydrocarbon gases almost immediately ventilate into the residents, especially in compact residents like this.



Picture 1. Narrow pathway and compact shelter orientation inside community

Utilization of space

As cited before, it's not only building materials and outdoor environmental condition, as active factors, but also utilization of space as passive factor, which can be roughly classified from the followings.

- *Indoor activities*

Some activities inside the households can directly affect to inhabitant's health. Smoking and cooking are one of the causes, especially for cooking because for low-income settlements, which traditionally use wood cinder as energy source for cooking, it unavoidably creates dust and toxic gas after combustion like CO, CO₂, sulfur and nitrogen oxidants. Moreover, Laquata's study found that the homes of lower income residents had higher level of CO because of not functioning of kitchen exhaustion [20]. Together with poor ventilation, this makes the inhabitants unavoidably inhale such toxic gases and particles.

- *Interior space arrangement*

In most of the houses, their interior space, in crowded community, is a single multipurpose space (See Picture. 2) with separated toilet/WC area. All activities like sleeping, sitting, feeding, and, cooking are utilized in the common space. The problems are that some of shelters do not properly oriented their functional space with direction of airflow, so indoor air quality can be unintentionally degraded from unventilated air and stagnation.



Picture 2. A single multipurpose space as all functions of living

Coming across constraints

To alleviate indoor environmental problems, general analysis to sources of pollutants and contriants in term of physical condition and finance in the real situations will give some clues to step further to set up appropriate plans and machanisms for the solutions

Conflict between required building materials and their cost

On one hand, all require materials that none or less impact to health, while on the others, they are always costly. It is the obvious dichotomy that the safeguard quality of building material and their price often dependent vary. Building materials in the market are considered too expensive for low-income community. In other words, the need of good building material quality is prioritized that nearly last necessity compared to other needs such as expenses for food, tap water, electricity, etc.

Conflict between surrounding and its size

Not only of building materials available on the market are constraints, but also the site's size. As the explanations before, ventilation is the most significant factor to achieve better indoor environments, but it crucially requires enough surrounding space in order to make indoor air circulates efficiently, while applying ventilator is not as the most sustainable solution because of paying higher electricity cost.

Conflict between utilixation of space and its area

Appropriate space arrangement can alleviate and avoid pollutants both from indoor activities and outdoor pollutants from air intake, but because of limited land and room area in shelters, there is not any alternative for orientation of functional spaces. That means ventilation to dilute indoor pollutants is uncontrollable and unpredictable.

Conflict between HVAC system requirement and its cost

From discussions in conflict between surroundings and its size with genral physical condition in reality, it sounds that natural ventilation is hardly effectively adopted in crowded community; the only left item is to use mechanical equipment for air circulating. On the other hands, air-conditioning system is considered nearly impossible to apply from

both financing for electricity and maintenance cost and environmentally-unfriendly reasons.

According to the previous discussions, major problem for poor indoor environments tends to come from unstandardized use of building materials and outdoor environmental condition, while effective natural ventilation in low-income settlements seems to be hardly to utilize as main technique, while mechanical equipment is uneconomic. Furthermore, indoor activities and interior space arrangement are individual behavior that uncontrollable. From these constraints, the directions of solutions and choice will be narrow and limited to focus only to two questions; the first is what can be the alternative materials in order to maintain indoor environmental quality? , and the other is what are the management schemes for controlling acceptable outdoor environment for good indoor environmental condition?

Suggestions

Although choices and alternatives are very limited, there are some solutions that are at least can alleviate indoor environmental pollution. From previous studies and experiences, some suggestions are

Planting

As we know, plants can improve air quality because of its transforming CO₂ to O₂ and absorb dust and suspended particular matters as well. However, the importance of planting is not only just planted, but also their position. The effective planting position should be outside around the resident rather than inside. The previous study's shown that planting around the exterior environment can reduce heat and dust gain into the interior space [21,22]. Nevertheless, because of the space constraint, this can be adopted by integrating with the shelter compartments such as planted wall. On the other hands, plants like tomato and cucumber can be the effective indoor air quality indicator [23].

Alternative materials

Considering to alternative materials, which may not market based, is one of the practical and possible solutions. Recently, there is vigorous activity movement in shelter alternatives by applying natural materials (non-industrialized materials) like Adobe (unburned mud brick), Cob, Wattle and Daub, Rammed earth [24,25] and any other non-chemical construction techniques [26], which are based on labor incentive and very low cost. By substitution for toxic born materials like roofing and wall panel materials, this can alleviate some sources of pollutants, but it has to be ensured that the sunlight can reach to the exterior wall and surroundings

Non-motorized scheme

Non-motorized campaign and organizing activities are necessary. Instead of motorcycle use as mode of transportation, walking in short distances, bicycling in longer distances, and push carting for goods and product distribution are the alternatives.

Clean surroundings

As mention before that outdoor environment as important as indoor, so those community surroundings requires to be maintained in good condition. The concerned environmental conditions are minimizing spread of microorganism vectors and odors by maintaining

drainage, sanitary, and sewage system including solid waste management and avoid open combustion.

Mechanism

Not only understanding what are the alternatives to achieve better indoor environment for crowded community, but also how to practically launch the process as well. The following paragraphs will elaborate to the essential concerned issue to come across the purposes.

Community building

The item, which is considered as the most effective and efficient among development tools for community, is strengthening community action groups. Encouraging community to form up groups in development activities can gain many benefits such as monitoring system, labor contribution (recommended) for shelter improvement, etc. By the way, stronger organizations like public and community development agencies have to be the key actors to initiate and facilitate at the beginning.

Educating / Informing / Regulating

Concerned government or non-organization organizations should inform and educate people in the community in term of training to understand the effects from the poor indoor environment. Indicating the sources of pollutant and related activities that affect to health including practical alleviating methods. Campaigning, organizing activities, or even forming up local rules and regulations (in term of agreements) to control either intended or unintended activities, which finally result as environmental quality degradation.

Promoting cooperative of community for the housing development

Community can establish cooperative group for shelters and dwellings development with financial and materials subsidized from government and non-government organizations (NGO) like Human Development Center (HDC), Community Origination Development Institute (CODI), and Community Architects for Shelter and the Environments (CASE). There are some case studies from some community (e.g. Romklao and Utradith). In Rom Klao, HDC provides material loans for shelter development [27] and CODI, in national level, which provides housing improvement loans for community [28]. In Utradith, the community has founded “saving group for any community development project” including shelter and environment with facilitated by CASE and Urban Community Development Office [29]. From this sharing program, each of households spends less money than individually developed. Moreover, each can be beneficial from neighbor’s labor incentive.

Encouraging community environmental programs and projects

Only indoor environmental quality improvement in community is not sound worthy to adopted because it is not as serious problems compare to other crowded community problems. However, it’s obvious from this stage that there are many issues that relate to broader environmental concerns. The programs and projects for indoor environment issues will not be directly adopted and established, but will be associated with other environmental improvement program instead. From this standpoint, community will gradually recognize indoor environmental problem as one of other general environment problems.

Fig. 2 will summarize for action process to run indoor environmental condition improvement.

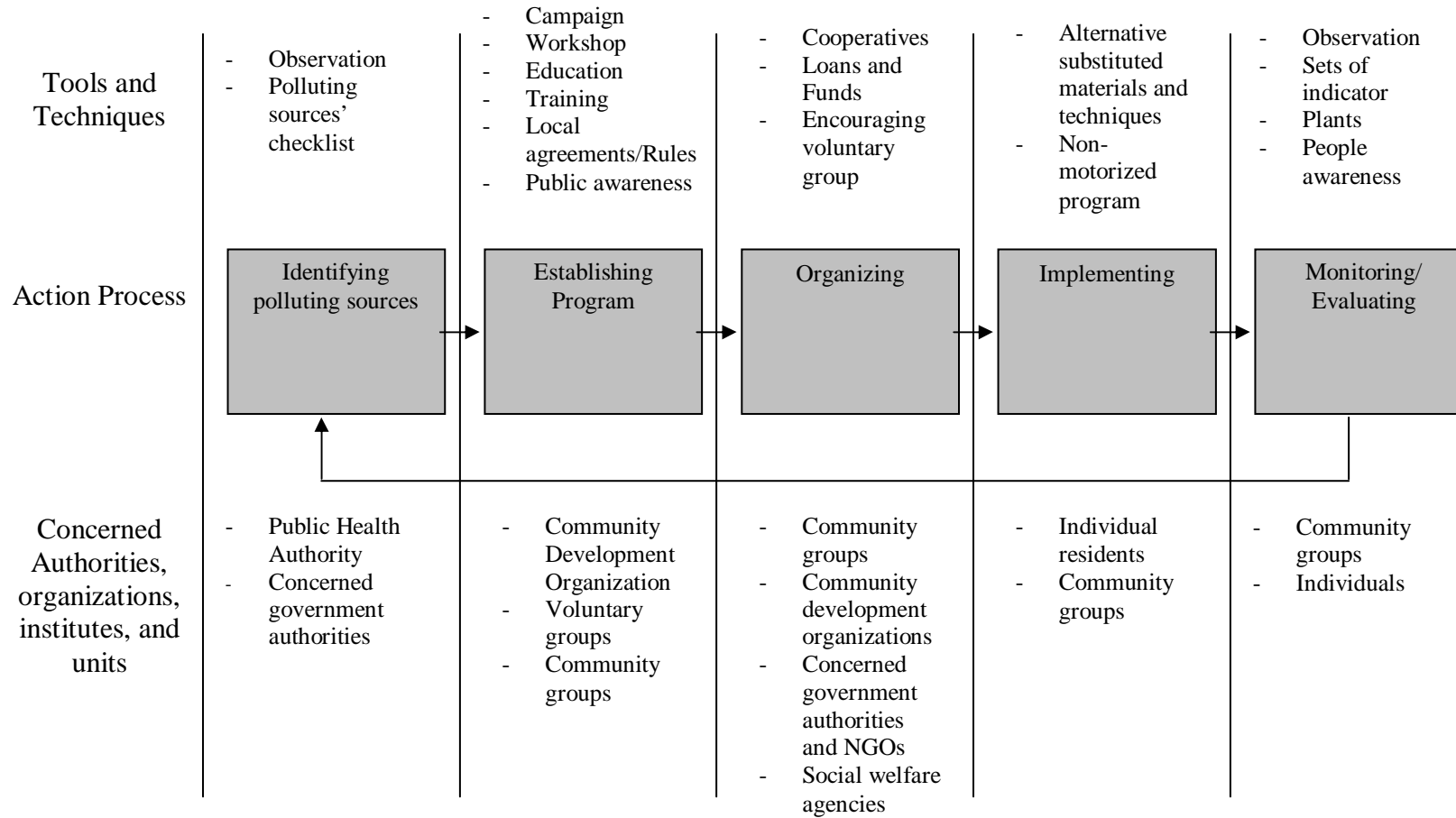


Fig. 2 Conceptual model for improving indoor environments for low-income settlements (Applied from Zimmermann, 2000 [30])

Conclusions

The issues, which seem to be significantly concerned to improve indoor environmental condition in practice, is improvement of building materials and outdoor environmental condition. To be more realistic, neither almost step forward for solution without initiation from concerned organizations and corresponding from community itself. Moreover, implementation crucially requires contribution of labor and community awareness including continually monitor and evaluation.

One thing that needs to be in mind is that indoor environmental problems are not isolated from others. In contrast, it essentially requires to be integrated as one part of other aspects for community environmental development programs and projects. Interdisciplinary approaches, financial and organizational management skill, technical skill, participation, grassroots development, and community building are essentially required to accomplish and sustain healthy indoor air quality of low-income settlements.

Notes

- [1] The author considers that the word “crowded community” is more appropriate than “slums and squatter because the basic need of existing infrastructures are legally provided but merely below standard condition.
- [2] The old term used by government officials is “Cumchon Bukruk”(illegal community), but changed into “Chumchon Aai-aat” as the official government term in 1982 (See ACHR. 1999. Housing By People in Asia. Number 12. April. pp. 22)
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IMPROVING INDOOR ENVIRONMENTS FOR LOW-INCOME SETTLEMENTS

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Abstract

This article intends to clarify the importance of indoor environments in low-income settlements, which considered as marginal group of people, and to explore the possibility of indoor environmental improvement, which normally limit in financial resources, choices and alternatives. Regarding to their constraints, basic knowledge about sources of pollutants in the existing condition of low-income settlements are necessary as well as general condition of residential characteristics and their surroundings. By conducting the available core strategies, the prioritized major sources of pollutants are identified, simultaneously with investigating through the potential and strength of any resource in hand as solutions for alleviating this problem. Finally, plan and mechanism will be suggested on the basis of applicability and reasonableness in the real world.

Keywords: Indoor air quality, Sick building syndrome, Low-income settlements, “Chumchon Aai-aat”(crowded community [1]), Shelter improvement

Introduction

There are number of studies about improving indoor environments in standard type of living place, but still limited in low-income living place (known as “Chumchon Aai-aat”[2]). Unlike the standard dwelling type, which building accessories such as air-conditioner, building materials, building equipment, etc. are affordable, people who live in low-income settlements can hardly afford these because of financial reason despite of living environmental condition is one of the significant issues for low-income settlements.

In 1994, numbers of populations in Bangkok (permanent residences) are approximately 6.5 million and 8% from this live in Chumchon Aai-aat (around 0.58 million [3]). The three-fifth of this number live in lower standard of living [4] or in other words, in the poor environmental condition. Commonly, like other crowded communities, it is the poor level of the infrastructure standard [5] in community. Shelter condition, solid waste management, drainage, sewage and sanitation systems are the major causes and relatively affect to health of the inhabitants. Precisely, two concerned aspects, which affect to indoor environmental quality, are the first is shelter condition and the other is its surroundings quality.

Significant relevant development authorities, organizations, and institutions widely discuss to the concept of “Green Building”. Minimizing internal pollution and harmful to health is one part of this [6]. However, Spengler and Chen [7] cited that the paradigm of people and building relation’s have just dramatically shifted for a couple of decades, which holistically concern for multilateral perspectives and approaches to accomplish better built environment (Fig.1).

	Paradigm	Pollution Sources
2050	Personal aesthetics	People Buildings Outside Environment
2025		
2000	Health, productivity, comfort	
1975	Comfort (+Health)	People + Building
1935	Comfort	People
1900	Contagion	
1800	Poison	

Fig.1: Paradigm shifts in the philosophy of ventilation since 1800 (Spengler and Chen: 2002)

Sick building syndrome

Previous studies have shown that poor indoor environments can seriously be harmful to human health. The common symptoms of the “sick building syndrome (SBS)” are irritation in nose and throat, skin rashes in face and on torso, fatigue, headache and general in disposition, and weak but persistent perceptions of smell [8]. Furthermore, Johnson’s study indicated that the main sources, making poor indoor air quality, are from pollutants supplied to the premises from outside, from building material, microorganism from air humidifier, pollutants from chemical used in building, etc. Moreover, the significance causes are from insufficient ventilation (64%), dirty air treatment apparatus (63%), ineffective filters in the ventilation system (57%), dirty ventilation ducts (38%), and no supply of outdoor air (35%), respectively [9].

However, the broad concepts to alleviate SBS are summarized by Edwards according to these [10].

- Constructed, finished and furnished using natural materials rather than man-made materials.
- Lit the ventilated by natural means.
- Managed so that the cleanliness of interior is maintained.
- Designed to give occupants control over their interior environment.
- Located where external air quality is high.
- Designed to avoid interior condensation.

The three strategies for controlling indoor contaminants

In the same direction of Johnson and Edwards, Spengler and Chen also developed three systematic strategies [11], those are

- *Source elimination*: Avoid directly use of toxic and chemical building materials
- *Local source control*: Maintain, control, and manage surroundings in a good condition
- *Dilution of the indoor contaminants by ventilation*: Reduce and eliminate indoor pollutants by enhancing natural ventilation through the shelters

Sources of air pollutants in crowded community

By applying three demonstrated core strategies and regarding to specific characteristic of focused area, concerned issues are raised up and indicated as significant scope of polluting sources in indoor environments, those are summarized in Table 1.

Table.1: Building Component Potentially Affecting Indoor air Quality of Crowded Community. (Adapted from Spengler and Chen [12])

Sources of Pollutants	Potential contributors to Indoor Air Quality
Siting	<ul style="list-style-type: none"> • Traffic • Upwind sources or change of air flow • Soil emission of radon • Moisture/Drainage
Building Envelope	<ul style="list-style-type: none"> • Unintended infiltration of untreated air
Waste Service	<ul style="list-style-type: none"> • Odor from waste • Particle intake and possible health risk(e.g. soot)
Kitchen, exhaust, fume hoods	<ul style="list-style-type: none"> • Entrainment into air intakes of present and neighborhood buildings
Material used for internal furnishings furnishing equipment, and cleansing	<ul style="list-style-type: none"> • Sources of volatile organic compounds (VOC[13]), aldehydes, phthalates, and particles • Sources of nutrients for microorganism

Profiles of typical crowded community

National Housing Authority's definition for "Cumchon Aai-aat" is that "the area for living within unhealthy condition and very high density [14]. General characteristic of them in specific will be elaborated from the followings.

Materials of shelter

Although the choices of building material use for shelter in crowded community is limited, compare to typically used in general buildings; it's still necessary to be investigated in order to find out the possibility of more appropriate materials, which still regarding unpolluted. As mention before, building materials are one of the major sources, which cause adverse impact to health. Scrutiny in this item will be one way to alleviate this impact. The following information will investigate through the compartments of shelters in crowded community classified in element by element.

- Roofing

Corrugated galvanized steel sheet and asbestos cement roof are two most used as roofing materials. Existing conditions of both are poor and impractical. Corrugated galvanized steel sheets are covered with rust as bad as asbestos cement roofs. Both are exposedly used without any insulation and ceiling, so small particles of dust, rust, fiber directly

become cause of respiratory disease, especially asbestos. The fibrous particles from them are the cause of cancer [15].

- Wall panel

There are numerous types of material that used as wall panels. The typical selections are gypsum board, fiber cement panel, plywood panel as well as corrugated galvanized steel sheet (same as roofing) and those are also exposedly used without insulations. The toxic substances from corrugated galvanized steel sheet has been already discussed before, while for the rests, formaldehyde [16], toxic chemical particles, is usually found.

- Toilet/Sewage

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On one hand, all require materials that none or less impact to health, while on the others, they are always costly. It is the obvious dichotomy that the safeguard quality of building material and their price often dependent vary. Building materials in the market are considered too expensive for low-income community. In other words, the need of good building material quality is prioritized that nearly last necessity compared to other needs such as expenses for food, tap water, electricity, etc.

Conflict between surrounding and its size

Not only of building materials available on the market are constraints, but also the site's size. As the explanations before, ventilation is the most significant factor to achieve better indoor environments, but it crucially requires enough surrounding space in order to make indoor air circulates efficiently, while applying ventilator is not as the most sustainable solution because of paying higher electricity cost.

Conflict between utilixation of space and its area

Appropriate space arrangement can alleviate and avoid pollutants both from indoor activities and outdoor pollutants from air intake, but because of limited land and room area in shelters, there is not any alternative for orientation of functional spaces. That means ventilation to dilute indoor pollutants is uncontrollable and unpredictable.

Conflict between HVAC system requirement and its cost

From discussions in conflict between surroundings and its size with genral physical condition in reality, it sounds that natural ventilation is hardly effectively adopted in crowded community; the only left item is to use mechanical equipment for air circulating. On the other hands, air-conditioning system is considered nearly impossible to apply from

both financing for electricity and maintenance cost and environmentally-unfriendly reasons.

According to the previous discussions, major problem for poor indoor environments tends to come from unstandardized use of building materials and outdoor environmental condition, while effective natural ventilation in low-income settlements seems to be hardly to utilize as main technique, while mechanical equipment is uneconomic. Furthermore, indoor activities and interior space arrangement are individual behavior that uncontrollable. From these constraints, the directions of solutions and choice will be narrow and limited to focus only to two questions; the first is what can be the alternative materials in order to maintain indoor environmental quality? , and the other is what are the management schemes for controlling acceptable outdoor environment for good indoor environmental condition?

Suggestions

Although choices and alternatives are very limited, there are some solutions that are at least can alleviate indoor environmental pollution. From previous studies and experiences, some suggestions are

Planting

As we know, plants can improve air quality because of its transforming CO₂ to O₂ and absorb dust and suspended particular matters as well. However, the importance of planting is not only just planted, but also their position. The effective planting position should be outside around the resident rather than inside. The previous study's shown that planting around the exterior environment can reduce heat and dust gain into the interior space [21,22]. Nevertheless, because of the space constraint, this can be adopted by integrating with the shelter compartments such as planted wall. On the other hands, plants like tomato and cucumber can be the effective indoor air quality indicator [23].

Alternative materials

Considering to alternative materials, which may not market based, is one of the practical and possible solutions. Recently, there is vigorous activity movement in shelter alternatives by applying natural materials (non-industrialized materials) like Adobe (unburned mud brick), Cob, Wattle and Daub, Rammed earth [24,25] and any other non-chemical construction techniques [26], which are based on labor incentive and very low cost. By substitution for toxic born materials like roofing and wall panel materials, this can alleviate some sources of pollutants, but it has to be ensured that the sunlight can reach to the exterior wall and surroundings

Non-motorized scheme

Non-motorized campaign and organizing activities are necessary. Instead of motorcycle use as mode of transportation, walking in short distances, bicycling in longer distances, and push carting for goods and product distribution are the alternatives.

Clean surroundings

As mention before that outdoor environment as important as indoor, so those community surroundings requires to be maintained in good condition. The concerned environmental conditions are minimizing spread of microorganism vectors and odors by maintaining

drainage, sanitary, and sewage system including solid waste management and avoid open combustion.

Mechanism

Not only understanding what are the alternatives to achieve better indoor environment for crowded community, but also how to practically launch the process as well. The following paragraphs will elaborate to the essential concerned issue to come across the purposes.

Community building

The item, which is considered as the most effective and efficient among development tools for community, is strengthening community action groups. Encouraging community to form up groups in development activities can gain many benefits such as monitoring system, labor contribution (recommended) for shelter improvement, etc. By the way, stronger organizations like public and community development agencies have to be the key actors to initiate and facilitate at the beginning.

Educating / Informing / Regulating

Concerned government or non-organization organizations should inform and educate people in the community in term of training to understand the effects from the poor indoor environment. Indicating the sources of pollutant and related activities that affect to health including practical alleviating methods. Campaigning, organizing activities, or even forming up local rules and regulations (in term of agreements) to control either intended or unintended activities, which finally result as environmental quality degradation.

Promoting cooperative of community for the housing development

Community can establish cooperative group for shelters and dwellings development with financial and materials subsidized from government and non-government organizations (NGO) like Human Development Center (HDC), Community Origination Development Institute (CODI), and Community Architects for Shelter and the Environments (CASE). There are some case studies from some community (e.g. Romklao and Utradith). In Rom Klao, HDC provides material loans for shelter development [27] and CODI, in national level, which provides housing improvement loans for community [28]. In Utradith, the community has founded “saving group for any community development project” including shelter and environment with facilitated by CASE and Urban Community Development Office [29]. From this sharing program, each of households spends less money than individually developed. Moreover, each can be beneficial from neighbor’s labor incentive.

Encouraging community environmental programs and projects

Only indoor environmental quality improvement in community is not sound worthy to adopted because it is not as serious problems compare to other crowded community problems. However, it’s obvious from this stage that there are many issues that relate to broader environmental concerns. The programs and projects for indoor environment issues will not be directly adopted and established, but will be associated with other environmental improvement program instead. From this standpoint, community will gradually recognize indoor environmental problem as one of other general environment problems.

Fig. 2 will summarize for action process to run indoor environmental condition improvement.

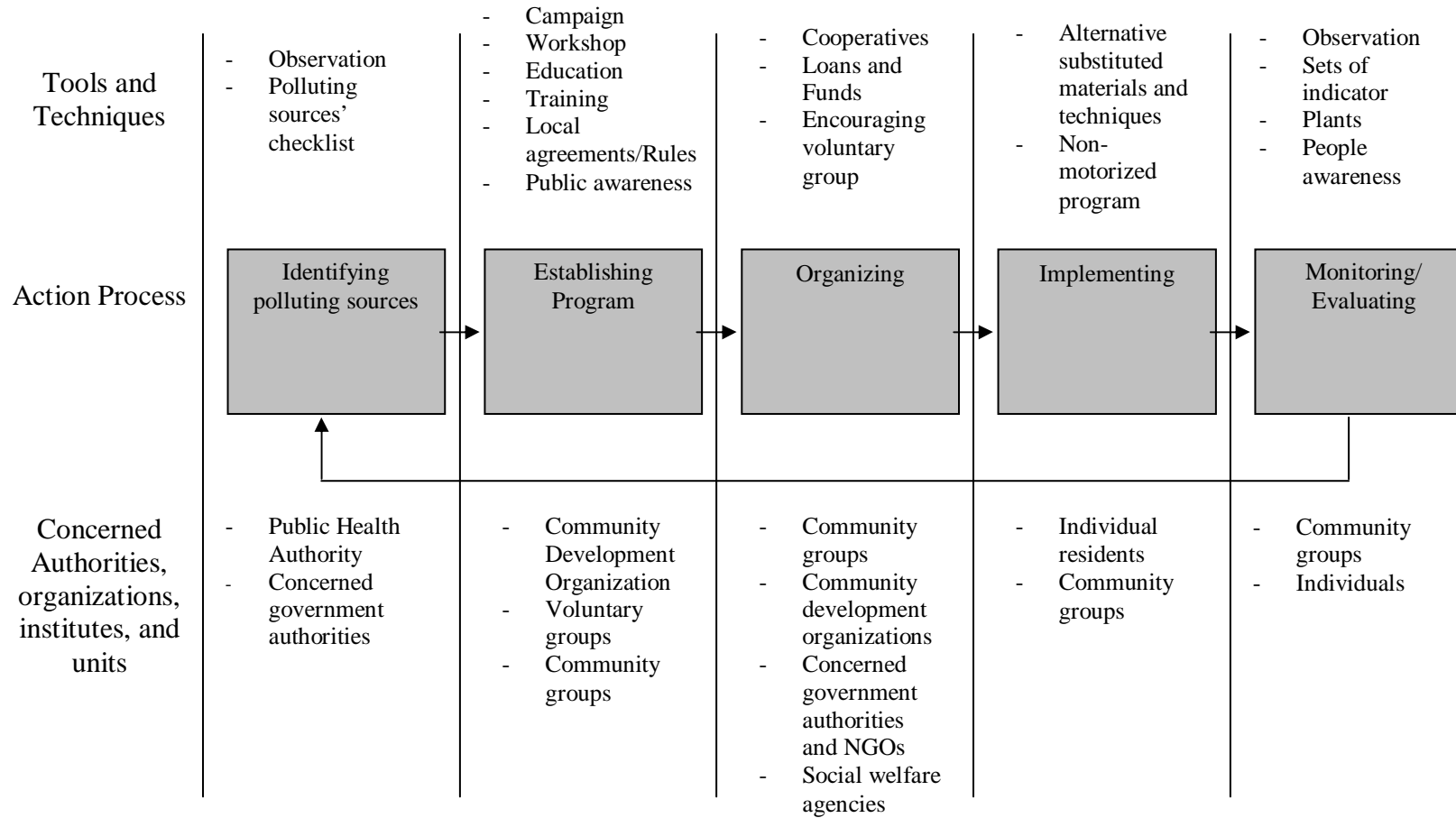


Fig. 2 Conceptual model for improving indoor environments for low-income settlements (Applied from Zimmermann, 2000 [30])

Conclusions

The issues, which seem to be significantly concerned to improve indoor environmental condition in practice, is improvement of building materials and outdoor environmental condition. To be more realistic, neither almost step forward for solution without initiation from concerned organizations and corresponding from community itself. Moreover, implementation crucially requires contribution of labor and community awareness including continuingly monitor and evaluation.

One thing that needs to be in mind is that indoor environmental problems are not isolated from others. In contrast, it essentially requires to be integrated as one part of other aspects for community environmental development programs and projects. Interdisciplinary approaches, financial and organizational management skill, technical skill, participation, grassroots development, and community building are essentially required to accomplish and sustain healthy indoor air quality of low-income settlements.

Notes

- [1] The author considers that the word “crowded community” is more appropriate than “slums and squatter because the basic need of existing infrastructures are legally provided but merely below standard condition.
- [2] The old term used by government officials is “Cumchon Bukruk”(illegal community), but changed into “Chumchon Aai-aat” as the official government term in 1982 (See ACHR. 1999. Housing By People in Asia. Number 12. April. pp. 22)
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