The Contribution of Green Buildings in the fight against COVID-19

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Abstract In December 2019, the 2019 Novel Coronavirus Disease (COVID-19) broke out. As the important place for people's work and living, building is regarded as the crucial links in the COVID-19 prevention and control. Chinese national standard *Assessment Standard for Green Building (GB/T 50378-2019)* (hereinafter shortly referred to as "GB/T 50378-2019*"*) expands the connotation of green building, which pays more attention to the safety, health and livability on the basis of "four savings and environmental protection". This paper firstly puts forward the contribution of GB/T 50378-2019 during the process of COVID-19 prevention and control under five aspects, which are the basic functions regarding epidemic prevention and control, the convenience and facilities for carrying out epidemic prevention and control, reducing the risk of infection and preventing cross infection, promoting and ensuring the health of occupants as well as providing a stable work and living environment. Then, this paper discusses the deficiencies of GB/T 50378-2019 in epidemic prevention and control. Finally, the consideration of what should be done for the epidemic prevention and control in buildings are put forward in order to deal with major public health event in the future.

Keywords green building, novel coronavirus, epidemic, prevention and control

1 Introduction

In December 2019, the Novel Coronavirus Disease 2019(COVID-19) broke out and spread from Wuhan to various regions of China in a short time. On January 20, 2020, the National Health Commission of China issued the No. 1 Announcement of 2020, which designated COVID-19 as a legal infectious disease and implemented "Class B management as well as Class A prevention and control". With the increasing number of new cases of COVID-19, many provinces have initiated first-level responses to major public health emergencies.

Currently, the patients infected by the novel coronavirus are the main source of infection; asymptomatic infected people can also be an infectious source. Transmission of the virus happens mainly through respiratory droplets and close contact; there is the possibility of aerosol transmission in a relatively closed environment for a long-time exposure to high concentrations of aerosol; as the novel coronavirus can be isolated in feces and urine, attention should be paid to feces or urine contaminated environment that may lead to aerosol or contact transmission; people are generally susceptible [1]. According to the reports, this novel coronavirus can survive for several hours on smooth surfaces, or even survive for several days if the temperature and humidity are appropriate [2]. Some researchers have detected this novel coronavirus in patients' stools [3-4] and urine [5]. To curb the spread of the epidemic, the areas of residents' activities are mostly restricted in communities and indoors. Therefore, as a place with the most people gathering, the building is significant in the COVID-19 prevention and control. Community and building-based prevention and control measures have become one of the important guarantees for victory against the epidemic, such as home

observation, community management, elevator disinfection, environmental cleaning, etc. Architectural Society of China had issued *Guidelines for office buildings to deal with "new coronavirus" operational management emergency measures (T/ASC 08-2020)* to further guide the prevention and control of COVID-19 during the operation of buildings.

Whether COVID-19 or SARS, epidemic prevention and control is a key link in the face of major public health emergencies. Green building is an important milestone in the building technology development process in China, especially the National Standard of the People's Republic of China *Assessment Standard for Green Building (GB/T 50378-2019)* (hereinafter shortly referred to as "GB/T 50378-2019"), issued in March 2019, pays more attention to the safety, health and livability on the basis of "four savings and environmental protection" which is beneficial to the prevention and control of COVID-19. This article focuses on the provisions in GB/T 50378-2019 which have positive effects to the prevention and control of COVID-19. The consideration of what should be done for the epidemic prevention and control in buildings are put forward in order to deal with major public health event in the future.

2 Technical system of GB/T 50378-2019

GB/T 50378-2019 adheres to the technical route of people-oriented, performance-highlighted and quality-improved, at the same time implements the concept of green development and fully expands the connotation of green buildings [6]. GB/T 50378-2019 takes "four savings and environmental protection" as the basic constraint, absorbs new technologies and new concepts in the development of building technology and takes into account the safety, durability, service, health, livability, and all-age friendly. With Chinese characteristics and new era characteristics, GB/T 50378-2019 established green building assessment index system with five performances(Fig.1), which are safety and durability, health and comfort, occupant convenience, resources saving as well as environment livability. GB/T 50378-2019 is widely applicable to various civil buildings.

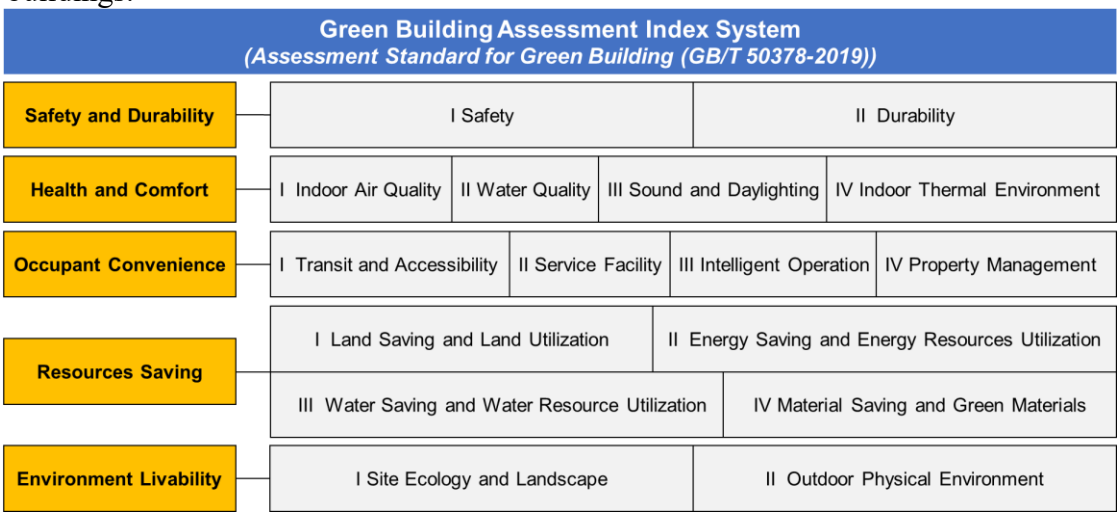

Fig.1 Green building assessment index system of GB/T 50378-2019

3 Positive requirements for COVID-19 prevention and control

3.1 The roles of a building in the epidemic prevention and control

The positive effects of a building in the prevention and control of COVID-19 can be summarized into five aspects:

(1) providing the basic functions for epidemic prevention and control;

(2) providing conveniences and facilities for epidemic prevention and control;

(3) reducing the risk of infection and preventing cross infection;

(4) promoting and protecting the health of occupants;
(5) providing a stable work and living environment during the epidemic prevention and control.

3.2 Provisions in GB/T 50378-2019 and positive effects

(1) Providing the basic functions for epidemic prevention and control

For the occupants, the measures of COVID-2019 prevention and control in building and site include reasonable natural ventilation, indoor cleaning and avoiding aggregation; for property management, measures include waste management, information publicity, informationization management of prevention and control and stable operation of building equipment. The above-mentioned measures can be fully and effectively implemented only if the building has perfect basic functions. Table 1 shows the provisions in GB/T 50378-2019 related to basic functions for COVID-2019 prevention and control.

Table1 Requirements in GB/T 50378-2019 related to basic functions for epidemic prevention and control

No.	Provisions	Positive effects
1	4.2.9 Rationally use durable and easy-to-maintain decorative building materials.	Conducive to the disinfection and cleaning of the epidemic prevention room and ordinary function rooms.
2	5.2.10 Optimize the building space and plane layout to enhance the effectiveness of natural ventilation.	Focus on the natural ventilation, conducive to the ventilation during the epidemic period to improve the air exchange rate.
3	6.1.1 Accessible barrier-free walking system shall be provided between buildings, outdoor sites, public green spaces and urban roads. 6.1.4 Bicycle parking lot shall be located in a rational and convenient place.	Focus on the accessibility of the pedestrian system and the convenience of bicycle parking, encourages walking and bicycle travel, increases travel options during the epidemic and reduces the potential cross infection caused by intensive contact during travelling.
4	6.1.5 The building equipment management system shall have automatic monitoring and management functions.	Through the automatic monitoring management function, the non-contact and off-site management of construction equipment can be realized, which is conducive to the remote management of construction equipment by the property management personnel during the epidemic; the automatic control of relevant equipment makes it possible to the linkage between the construction equipment operation and the epidemic prevention and control.
5	6.1.6 The building shall be equipped with an information network system.	By using information network system, monitoring equipment, information release and other equipment can be linked together, which is beneficial to the assistance of epidemic prevention and control as well as information interconnection. Setting up information network system can also realize home office during the epidemic period.

6	6.2.7 Set the air quality monitoring system of PM_{10}, $PM_{2.5}$, CO_2 concentration, and have the functions such as storing monitoring data for at least one year and real-time display.	Helps to guarantee indoor air quality, learn about fresh air supply through CO_2 monitoring and reduce the chance of infection.
7	6.2.8-3 Set up an online water quality monitoring system to monitor the water quality indexes of drinking water, fine drinking water, swimming pool water, non-traditional water and air conditioning cooling water, record and preserve the water quality monitoring results that are available for users to inquire anytime.	Provide convenience for property management personnel to monitor water quality at any time and take emergency measures in time to effectively ensure the water safety under the epidemic situation.
8	6.2.9 Intelligent service system is equipped: 1 At least 3 types of service functions are provided, such as home appliance control, lighting control, security alarm, environmental monitoring, building equipment control, work and life service; 2 Remote monitoring function is provided; 3 Functions accessible to Smart City (District, Community) is provided.	Conducive to the control of equipment system and the non-direct contact operation of relevant equipment during the epidemic; conducive to the effective information management of people and vehicles during the epidemic.
9	6.2.12 Evaluate the operation effect of the building regularly and optimize the operation according to the evaluation result.	This is the basic guarantee that green buildings can play an important role during the epidemic and also the basic ability of the property management department to respond to the epidemic
10	6.2.13 Establish the green education publicity and practice mechanism, develop a green facility manual, form a good green atmosphere, and regularly conduct user satisfaction surveys.	Conducive to the establishment of a good authority image among property management departments and the masses; Beneficial to the management and information release to occupants during the epidemic.
11	8.1.7 Municipal solid waste shall be collected and disposed by classification. Garbage containers and collection sites shall be set up reasonably and in harmony with the surrounding landscape.	Garbage classification is conducive to creating a good sanitation environment, classifying, collecting, and transporting hazardous garbage and kitchen waste and in time can reduce the spread of viruses and bacteria and facilitate the disinfection of garbage collection points.

(2) Providing conveniences and facilities for epidemic prevention and control

As the epidemic breakout, providing conveniences such as enable buildings and surrounding sites to provide rapid access to medical equipment and facilities, conducted effective personnel and vehicle control, change the room function when necessary (used in epidemic prevention and control) are the basic guarantee for the orderly development of epidemic prevention and control. Table 2 shows the requirements in GB/T 50378-2019 related to providing convenience and facilities in epidemic prevention and control.

Table2 Requirements in GB/T 50378-2019 related to providing convenience in epidemic prevention and control

No.	Provisions	Positive effects
1	4.1.7 Passage spaces such as corridors and evacuation passages shall meet the requirements of emergency evacuation and emergency rescue, and shall be kept unblocked.	Conducive to personnel evacuation, emergency rescue, material transportation, etc.
2	4.1.8 The warning and guidance signage system for safety protection shall be installed in the building.	Conducive to add relevant signs to remind people to be vigilant.
3	4.2.5 Separate pedestrian system from vehicle system, and provide the walking and bicycle transportation system with sufficient lighting.	Conducive to the personnel and vehicles evacuation and control during the epidemic.
4	4.2.6 Take measures to improve the structural adaptability of buildings: 1 Take a general open, flexible and variable space design, or adopt measures of variable building function; 2 The building structure is separated from the construction equipment pipeline; 3 Adopt layout or control methods of equipment facilities that are compatible with building functions and spatial changes.	During epidemic prevention and control, room function and size can be changed to medical rooms, transitional residential rooms, isolation and observation rooms, supplies storage rooms, etc. according to the needs of prevention and control.
5	6.2.2 The indoor and outdoor public areas of the building meet the requirements of the all-age design: 1 Indoor public areas, outdoor public events venues and roads of the building meet the barrier-free design requirements; 2 The corners of the walls, columns, etc. in the indoor public areas of the building are round, and are provided with safety grab bars or handrails; 3 Barrier-free elevator that can accommodate a stretcher is provided.	Facilitate the use of emergency stretcher and wheelchair; facilitate the quick access of medical resources.

(3) Reducing the risk of infection and preventing cross infection

In addition to providing the basic functions and convenient conditions for epidemic prevention and control, the building itself should also “isolate” the virus to the greatest extent and reduce the risk of infection . At the same time, minimize the spread of virus in the building, so as to minimize the possibility of cross infection. Table 3 shows the requirements in GB/T 50378-2019 related to reducing the risk of infection and prevent cross infection.

Table3 Requirements in GB/T 50378-2019 related to reducing the risk of infection and prevent cross infection

No.	Provisions	Positive effects

1	5.1.2 Measures shall be taken to avoid the air and pollutants in the kitchen, dining room, printing and copying room, bathroom, underground garage and other areas from going into other spaces; the exhaust backflow of kitchen and bathroom shall be prevented.	By controlling the collusion of air and pollutants and the exhaust backflow of the kitchen and bathroom, it is beneficial to effectively control the potential virus spread, therefore, reduce the risk of cross-infection caused by virus spread.
2	5.1.3-3 The toilet with built-in water seal inside the structure shall be used, and its water seal depth shall be not less than 50mm.	Set up effective water seals help to reduce the risk of virus transmission through drainage pipes and the risk of virus transmission caused by stools.
3	3.2.8-3Airtight performance of exterior windows. 5.2.1 Control the concentration of main air pollutants in the room: 2 The annual average concentration of $PM_{2.5}$ in the room is not higher than 25μg/m^3, and the annual average concentration of PM_{10} in the room is not higher than 50μg/m^3.	Viruses in the environment adhere to the surface of dust particles that are several times larger than themselves, survive on aerosol particles but rarely exist as monomers [7]. By controlling the air tightness of the external windows to reduce the $PM_{2.5}$ penetration through the windows [8]; by taking measures such as indoor air purification or ventilation, the concentration of $PM_{2.5}$ and PM_{10} indoors can be controlled to reduce the vector carrying virus.
4	5.2.10 Optimize the building space and plane layout to enhance the effectiveness of natural ventilation.	Focus on the natural ventilation, which is conducive to obtain outdoor fresh air and reduce the indoor virus concentration during the epidemic period.
5	7.1.2-1 Room orientation and heating and air conditioning area shall be distinguished carefully, and the system shall be controlled by zones.	Conducive to the partition control of air conditioning system during the epidemic to reduce the risk of cross infection.
6	7.2.11-2 Adopt water-saving equipment or technologies for air conditioning cooling water system.	Beneficial to avoid the spread of virus and bacteria due to the floating water of cooling tower.
7	8.2.8 Wind environment in the site is conductive to travel and move outdoors and natural ventilation of buildings.	Creating a good wind environment is conducive to the dissipation of viruses and harmful gases and is conducive to the natural ventilation of the building.

(4) Promoting and protecting the health of occupants

Currently, there is no specific antiviral drug against the novel coronavirus. COVID-2019 is actually a self-limiting disease [9], which mainly depends on the body's immunity. GB/T 50378-2019 regulates water quality, air quality, fitness and antibacterial function building materials to promote occupants health (shows in Table 4) in order to reduce the risk of getting disease and enhance the ability of resisting viruses.

Table4 Requirements in GB/T 50378-2019 related to promoting and protecting the health of occupants

No.	Provisions	Positive effects

1	3.2.8-3 Reduce the concentration of major indoor air pollutants. 5.1.1 The concentration of pollutants such as ammonia, formaldehyde, benzene, total volatile organic compounds and radon in indoor air shall meet the requirements of the current national standard *Indoor Air Quality Standard (GB/T 18883)*. Smoking shall be prohibited in the rooms and at the main entrances and exits of the building and non-smoking signs shall be set up in conspicuous positions. 5.2.1 Control the concentration of main air pollutants in the room: 1 The concentrations of ammonia, formaldehyde, benzene, total volatile organic compounds, radon and other pollutants are 10% lower than the limits stipulated in the current national standard *Indoor Air Quality Standard (GB/T 18883)*. 2 The annual average concentration of $PM_{2.5}$ in the room is not higher than 25μg/m^3, and the annual average concentration of PM_{10} in the room is not higher than 50μg/m^3.	Control indoor air pollutant concentration and promote physical health of building occupants.
2	5.1.7 The thermal performance of the building envelope shall meet the following requirements: 1 Under the condition of indoor design temperature and humidity, dew shall not appear on the inner surface of the non-transparent building envelope. 2 Condensation shall not exist on the roof and the inside of exterior walls of the heating building.	Mold can induce the diseases of asthma, allergies, rhinitis, respiratory infections [10]. This requirement is beneficial to avoid the growth of pathogenic bacteria such as mold due to the dew and condensation on the building envelope to ensure the health of the occupants.
3	5.1.3 The setting of water supply and drainage system shall be in accordance with the following requirements: 1 The quality of drinking water shall meet the requirements of current national standard GB 5749 Standards for drinking water quality. 2 The regular cleaning and disinfection plan for water storage facilities such as water reservoirs and water tanks shall be formulated and implemented, and the drinking water storage facilities shall be cleaned and disinfected at least once every six months. 5.2.3 The water quality of fine drinking water, central domestic hot water, swimming pool water, heating and air conditioning system water, waterscape, etc. meet the	Ensure the water safety, avoid the health and safety risks caused by the wrong connection of pipes; reduce the cross infection risk caused by the water quality problems of different kinds of water.

	requirements stipulated in the current relevant standards of the nation. 5.2.4 Measures are taken for water storage facilities such as drinking water reservoirs and water tanks to meet the hygiene requirements. 5.2.5 All water supply and drainage pipes, equipment and facilities are provided with definite, clear and permanent marks.	
4	6.2.5 The fitness field and space are reasonably set.	Appropriate exercise is the cornerstone of health [11]. Setting sports and fitness venues to promote physical exercise is favorable for people's physical fitness.
5	7.2.18 Use green building materials.	"Health" is one of the characteristics of green building materials. Green building material with antibacterial function is good for health.

(5) Stabilize work and living environment during the epidemic prevention and control

During epidemic period, maintaining a stable work and living environment is essential for the epidemic prevention and control. Table 5 shows the requirements in GB/T 50378-2019 related to maintaining a stable work and living environment.

Table5 Requirements in GB/T 50378-2019 related to maintaining a stable work and living environment

No.	Provisions	Positive effects
1	5.1.3-1 The quality of drinking water shall meet the requirements of current national standard *Standards for Drinking Water Quality (GB 5749)*. 5.2.3 The water quality of fine drinking water, central domestic hot water, swimming pool water, heating and air conditioning system water, waterscape, etc. meet the requirements stipulated in the current relevant standards of the nation. 6.2.8-3 Set up an online water quality monitoring system to monitor the water quality indexes of drinking water, fine drinking water, swimming pool water, non-traditional water sources, and air conditioning cooling water, record and preserve the water quality monitoring results that are available for users to inquire anytime.	Ensure occupants' health from water quality, which plays an important role in maintaining the stability of work and living during the epidemic
2	6.2.3 Convenient public service facilities are provided.	Equip with supermarkets, vegetable markets, hospitals and other public service facilities around the building or site to ensure the basic living needs during the epidemic period.

4 Discussion

GB/T 50378-2019 expands the connotation of green buildings in terms of safety, health, and livability, and covers the main demands for COVID-2019 prevention and control which is beneficial to the victory against COVID-2019. However, the requirements

focus on COVID-2019 prevention and control are still inadequate in GB/T 50378-2019, which mainly reflect in the aspect of building operation management, including the inadequate of the operation strategies of central air-conditioning systems, the water seal installation and daily maintenance management (such as washing basins, sinks and floor drains), the waste management (temporary storage and transportation), insufficient requirements for disinfection of the main functional areas and public facilities (public areas, handrails, elevators, garbage sites, etc.), as well as lack of the building emergency mechanism for similar epidemic.

It is known that GB/T 50378-2019 itself is not a special standard for epidemic prevention and control, and all kinds of epidemic have their own characteristics as well as key points of prevention and control, which means that GB/T 50378-2019 cannot thoroughly cover everything. In order to achieve better jointly epidemic prevention and control between the building and public health, it is necessary to formulate the targeted technical documents for epidemic prevention and control at the time of outbreak. Taking the COVID-2019 as an example, GB/T 50378-2019 mainly creates good conditions for epidemic prevention and control in the building design stage while is insufficient in the operation management stage, *Guidelines for office buildings to deal with "new coronavirus" operational management emergency measures (T/ASC 08-2020)* issued by the Architectural Society of China makes up for this deficiency and provides guidance for epidemic prevention and control in building operation management stage, which demonstrates the advantage of technical standards joint application.

5 Conclusions and consideration

Facing to COVID-19, GB/T 50378-2019 plays an active role in providing basic guarantee and convenient conditions for COVID-2019 prevention and control, the contribution includes reducing the risk of infection and preventing cross infection, promoting people's health, maintaining the stability of work and living during the epidemic.

With the development of building technologies in China, buildings starts to emphasize the health performance. The most representative event is "health and comfort" regarded as one of the assessment index in GB/T 50378-2019. Moreover, China has issued *Assessment Standard for Healthy Building (T/ASC02-2016)* [12] which special focus on the health performance of building, and *Assessment Standard for Healthy Community* (submitted for approval) as well as serial standards of healthy building for different buildings types are under drafting [13]. It is inspired by COVID-19 that more attention should be paid to the performance of health protection of buildings, especially highlight the different health protection needs of different building types, to exert greater contribution in responding to major public health events. Furthermore, it is also necessary to carry out research on the building emergency mechanism in response to various public health events so as to constantly supplement "emergency deficiencies" for existing situation. In order to improve the ability of epidemic protection and control in buildings, we hope the seamlessly scenario adaptation with "peace-time use" and "epidemic-time use" of buildings can be realized as soon as possible.

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References

1. National Health Commission & State Administration of Traditional Chinese Medicine (2020) Diagnosis and Treatment Protocol for COVID-19 (Trial Version 7). https://covid-19.chinadaily.com.cn/a/202003/27/WS5e7c25baa310128217282337.html. Accessed 5 May 2020 (*Online document*)
2. Health Commission of Hubei Province (2020) "COVID-19 prevention and control" The 13th Press Conference. http://wjw.hubei.gov.cn/fbjd/xxgkml/hygq/202002/t20200204_2019147.shtml. Accessed 23 February 2020 (*Online document*)
3. Holshue ML, DeBolt C, Lindquist S et al (2020) First case of 2019 novel coronavirus in the United States. N Engl J Med. doi: 10.1056/NEJMoa2001191 (*Article by DOI*)
4. Information Office of People's Government of Guangdong Province(2020) Nineteenth press release on epidemic prevention and control. http://gdio.southcn.com/g/2020-02/13/content_190320546.htm. Accessed 23 February 2020 (*Online document*)
5. Fang Q (2020) Zhong Nanshan's research team isolated novel coronavirus from a patient's urine specimen. https://gzdaily.dayoo.com/pc/html/2020-02/23/content_127574_683801.htm. Accessed 23 February 2020 (*Online document*)
6. Wang QQ, Li GZ, Meng C et al (2019) Introduction to compilation of GB/T 50378-2019 *Assessment standard for green building*. J HV&AC 49(8):1-4 (*Journal article*)
7. Si P, Rong X, Fan Y et al (2012) Health effect and control standards of indoor particulate matter. Refrig Air-conditioning 12(5): 8-12 (*Journal article*)
8. Wang QQ, Li GZ, Meng C et al (2015) Penetration of outdoor fine particulate matter (PM2.5) through building envelope and passive control methods. J HV&AC 45(12): 8-13 (*Journal article*)
9. Health Commission of Hubei Province (2020). "COVID-19 prevention and control" The 20th Press Conference. http://wjw.hubei.gov.cn/fbjd/xxgkml/hygq/202002/t20200211_2023794.shtml. Accessed 23 February 2020 (*Online document*)
10. WHO Regional Office for Europe (2009) WHO guidelines for indoor air quality: dampness and mould. https://www.who.int/airpollution/guidelines/dampness-mould/en/. Accessed 23 February 2020 (*Online document*)
11. Yang Z (2013) The application value of health concept determined by behavior. Chin Med News 28(16): 5 (*Journal article*)
12. Wang QQ, Meng C, Li GZ (2017) Brief introduction of Architectural Society of China Standard entitled with *Assessment Standard for Healthy Building*. Build Sci 33(2):163-166 (*Journal article*)
13. Wang QQ, Deng YC, Li GZ et al (2020) The current situation and trends of healthy building development in China. Chin Sci Bull 65(4): 246-255 (*Journal article*)