

Study on the Construction Model of Xi'an Ecological Community from the Perspective of Material Metabolism

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Abstract—This paper established an ecological community model to improve the current linear material metabolism model in communities. Through the case study and evaluation criteria of ecological community, the ecological indicators were constructed. The community material circulation metabolism model was established by combining the indicators with the method of material metabolism. Taking Shuizhai community as an example, it was found that most of the materials currently outputted by the community could be processed appropriately and reentered the community to reduce pollution and decrease the demand for new materials. This paper hopes to provide reference for the future ecological community research, and also hopes to reduce the pressure of human activities on the ecological environment.

Keywords—ecological community; material metabolism; cycle metabolism model; sustainable development

I. INTRODUCTION

In recent years, with the acceleration of human activities, the contradiction between people and the natural environment has become increasingly prominent. China attaches great importance to environmental issues. The report of the 19th National Congress advocated a simple, moderate, green and low-carbon lifestyle, and carries out actions such as creating green families, green communities and green transportation. In the meantime, people have higher requirements for a better living environment. The community is the basic unit of the city,

connecting the city and the residents, and is also an important level in the study of human settlements. Therefore, the construction of ecological communities is of great significance.

This paper takes Shuizhai community as an example, based on the research method of material metabolism, constructs the research framework of ecological community, and provides reference for the construction of ecological community in Xi'an.

II. LITERATURE REVIEW

A. Material Metabolism

The concept of material metabolism originated in the life sciences. Moleshott proposed in the book "Circulation of Life" that life is a metabolic phenomenon, an exchange process of energy, material and environment^[1]. After the twentieth century, with the acceleration of urbanization, the destruction of the ecological environment intensified, and research began to combine urban and material metabolism. In 1965, the concept of urban material metabolism was first proposed by Wolman, which regarded the city as an ecosystem and studied urban material input and output^[2]. Since then, in the 1970s, research began to rise and develop, declined in the 1980s and rose again in the 1990s, in the 21st century, it entered the diversification stage^[3]. During this period, Girardet combined urban material metabolism with urban sustainable development in 1992, and believed that sustainable cities should have ten goals including reducing resource consumption and energy efficient use^[4]. In 1999, Newman introduced comfortable and livable concepts of

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urban metabolism^[5]. At the same time, Stimson studied the relationship between urban material metabolism and quality of life^[6]. Fernandez and others at the Massachusetts Institute of Technology's School of Architecture use material metabolism to conduct urban design studies in New Orleans^[7]. Students at the University of Toronto's School of Civil Engineering use the concept of material metabolism for community-scale urban design^[3]. These methods of combining material metabolism with urban research provide important guidance for the integration of this with the community.

B. Ecological Community

There is no unification definition of ecological communities in the world. In China, it is mainly called "ecological communities", "sustainable communities", and "green communities". China's ecological communities cover a wide range, mainly from people, architecture, society, and the environment. There are also many concepts in foreign countries, such as "ecological village", "ecological community", "low-carbon community" and "sustainable community". Different communities have different research directions. For example, the ecological village mainly studies the energy, resources and architecture of the village. Ecological communities mainly involve natural ecological research at the community scale; Low-carbon communities start with how to reduce carbon emissions in the community and study the carbon footprint to reduce the pressure of the greenhouse effect. The ecological community of this paper is mainly to establish an ecologically sustainable modern community from the perspective of people and environment.

C. Case Study

At abroad, there are some mature cases of ecological communities based on the perspective of material metabolism. Vauban District, the European Eco-model Demonstration Zone, plans to implement low-carbon practices in terms of energy use, rainwater harvesting, waste disposal, building materials, and on-site construction^[8]. The UK's Beddington Zero-Energy Development project conducts ecologically sustainable research in building energy efficiency, cogeneration plants, water resources, clean energy, building materials, etc^[9-11]. The Freiburg ecological community in Germany allows enterprises and residents to participate in the construction of ecological communities, to save energy through the use of cogeneration technology and renewable energy, and the community focus on waste management and reuse^[12]. To a certain extent, these ecological communities reflect the concept of material metabolism, improve the use efficiency of materials, reduce the demand for nonrenewable resources, and realize the recycling of materials as much as possible.

D. Ecological Community Evaluation Criteria

This paper selects the national standard "Outlines and technical principles for Green Ecological Residential Quarter Construction" of 2001, the Shaanxi Provincial Standard "Evaluation standard for ecological residential district designs" of 2014, and the Association Standard "Standard of sustainable residential areas" of 2018. By summarizing, the current assessment of ecological communities in China mainly includes resources, energy, building, transportation, facilities and natural environment. These ecological indicators should be combined in the study.

TABLE I. COMMUNITY EVALUATION CRITERIA

Ecological community evaluation criteria	Outlines and technical principles for Green Ecological Residential Quarter Construction	Evaluation standard for ecological residential district designs	Standard of sustainable residential areas
Number	/	DBJ61T 83-2014	T/CECS 377-2018, T/CREA 001-2018
Evaluation standard	Residential Power Systems	Section and outdoor environment	Quality of site and ecology
	Water Environmental Systems	Energy and environment	Quality of energy and resource
	Air Power Systems	Residential water environment	Quality of city regional
	Sound Power Systems	Material and resources	Quality of green transportation
	Light Power Systems		Quality of livable planning
	Thermal Power Systems		Sustainable quality of building
	Afforest Systems		Assessment of sustainable residential area
	Waste Disposition and Management Systems		
Green Construction Material Systems			
Total	9 Aspects 33 Indicators	4 Aspects 24 Control items 52 Categories items	7 Aspects 21 Indicators 186 Subitems

III. RESEARCH ON SHUIZHAI COMMUNITY IN CHANG'AN DISTRICT OF XI'AN CITY

The Shuizhai community is located in the northern foot of the Qinling Mountains. The community is a new type of rural community, and the residents are villagers of East Shuizhai Village and West Shuizhai Village. At present, the villagers have not moved in completely. Shuizhai community has been

built community committees, community activity centers, community kindergartens, sports venues and squares. There are 3 parking lots, and each home is equipped with a garage. Existing solar street lamps and some solar water heaters in the community. Public service facilities and municipal infrastructure have been basically completed. In terms of transportation, Most of the villagers in the community are elderly and children, mainly relying on buses. There is only

one bus stop and one travel route beside the community. In addition, the next bus stop is located 1.3 km from the community.

The current situation shows that the facilities and natural environment of the Shuizhai community basically meet the ecological community standards. Buildings are newly built, and there is no possibility of renovation of building materials and structures. Therefore, this article does not do research on buildings. The case is mainly based on the study of community material metabolism, combines renewable energy and green transportation to create a modern ecological community.

A. Analysis of the Current Situation Based on Material Metabolism

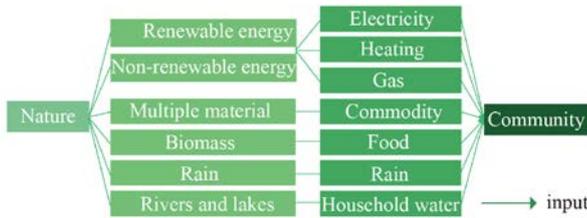


Fig. 1. Shuizhai Community Material Input Map

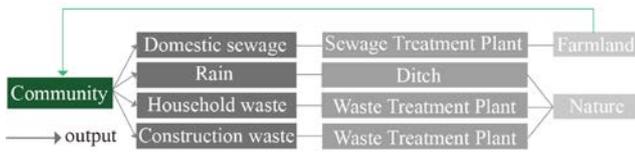


Fig. 2. Shuizhai Community Material Output Map

The Shuizhai community is mainly a linear metabolic model, only a small amount of material is reentered the community. It should be noted that commodity in this article does not contain food, which is conducive to subsequent analysis.

B. Current Problems

- The wastewater and stormwater engineering planning of the community is mainly reflected in two aspects: (1)after the rainwater enters the community, it is directly discharged into the rainwater pipeline, and finally connected to the side ditch of road.(2) domestic sewage is exported to the sewage treatment plant, and then temporarily connected to the rainwater pipeline in the planning. While, after investigation, it was found that the water treated by the sewage treatment plant is currently used to irrigate farmland and realize the recycling of this part of water.
- When food is imported into the community, they are metabolized by the human body and exported as excreta or kitchen waste. The former enters the sewage treatment plant through the sewage pipeline, and enters farmland after treatment, while the latter mostly mixes with other waste for comprehensive treatment in China,

neither of them realizes the maximum utilization of organic matter.

- At present, Shuizhai community adopts two kinds of classification methods: construction waste and domestic waste. Domestic garbage has not been classified.
- According to the current situation, the nearest bus stop has a single route and a long time interval. Although the other bus stop has more routes, it is far away.

C. Strategies

- Water recycling. We collect, treat rainwater in a unified manner, using it to clean roads, irrigate trees and create landscapes. After all the villagers move in, the amount of domestic sewage will increase. The treated domestic sewage can be used to irrigate the farmland and reenter the community for flushing the toilet. Increasing the awareness of residents to save water and using water-saving facilities are also important for the sustainable development of the community.
- Waste recycling. The first step is to classify waste. It can be divided into kitchen waste, recyclable waste, harmful waste and other waste. Kitchen waste mainly includes leftovers, peel, leaves and so on. Composting in the Sunshine Composting Room of Ziwu Street. the kitchen waste is converted into organic fertilizer and supplied to the farmland. Recyclable waste mainly includes paper products, glass products, plastic bottles, cans, metals, household appliances and so on. The recyclable waste is handed over to a professional waste disposal company and converted into new commodities to enter the market. Harmful waste mainly includes batteries, expired drugs, agricultural drugs, and pesticides and so on. Harmful waste should be handled with care by a specialized agency. Other waste is the waste that has not been mentioned in the above three kinds of waste. It mainly includes non-recyclable fabrics, heavily polluted paper, disposable lunch boxes, plastic bags and so on. Other waste is mainly processed in China by incineration and landfill. Therefore, villagers should be encouraged to use more recyclable and degradable items.
- Utilization of renewable energy. Xi'an belongs to the third category of solar energy resources, which is rich in solar energy resources. Meantime, Xi'an Municipal Government is advancing geothermal energy to meet people's demand for energy. Xi'an belongs to a region with poor wind energy resources^[13], so this paper mainly studies solar energy and geothermal energy.

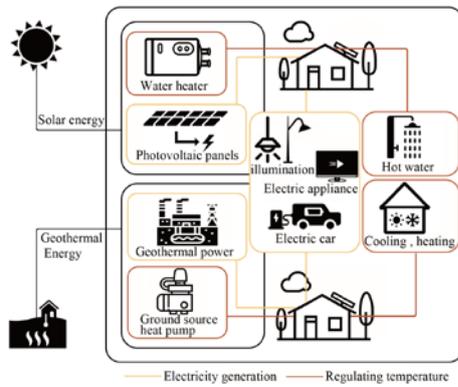


Fig. 3. Renewable energy utilization map

- Green transportation. First, reduce the departure time interval, increase the bus line and adopt electric bus. Encouraging villagers to travel by bus. Secondly, It is recommended that the villagers choose bicycles and walking when they are not far away. Finally, for private cars, choose an electric car as much as possible.

D. Data Analysis

Due to the Shuizhai community has not yet fully moved in and some data are insufficient, the data in this paper are mainly from the following three aspects.

- Rainfall calculation. By counting the precipitation in Xi'an in the past five years, the annual average precipitation in Xi'an is 548.2mm. We collect the rainwater catchment area and the corresponding runoff coefficient in the community, and the annual rainwater harvest of the community is about 68826.5m³. After the rainwater is collected and treated, It can be fully utilized. The rainwater output is zero.
- Sewage volume calculation. The total number of East Shuizhai Village and West Shuizhai Village is 1695, and it is currently moving to 270 households. According to the survey, the average daily water consumption per villager is about 78L. According to the specifications, we can see that rural domestic sewage drainage in Xi'an is generally 60% to 80% of water consumption. And this calculation selects 75%. It is estimated that the daily sewage production of all villagers in the future will be about 99m³, and the annual sewage volume will be 36135m³. The treated sewage can be used to irrigate farmland or flush toilets. The sludge can be used in farmland after dehydration and composting. The domestic sewage is fully utilized, and the output is zero.
- Kitchen waste volume calculation. The community is not yet mature, so the amount of domestic waste is difficult to count. According to the relevant literature, this paper selects each villager to produce 0.9kg of domestic garbage every day. Therefore, it is estimated that in the future, the amount of domestic waste will be 1525.5kg every day after all villagers move in. The kitchen waste accounts for more than 50% of domestic waste, and the daily kitchen waste is at least 762.8kg.

The kitchen waste can produce biogas or compost, which is calculated separately: (1) Assume that this part of the kitchen waste is completely converted into biogas, according to the relevant literature^[14-16]. The calculated total solids of this calculation is 10.17%, from table 2 we found the biogas is 36.6m³ every day, so the annual biogas volume is 13359 m³. (2) Assume that all of the kitchen waste is composted. According to the relevant literature^[17], we found the normal fermentation ratio is 3:1, so producing 254kg of organic fertilizer per day, and the annual organic fertilizer amount is 92710kg. It could be totally used, the output of kitchen waste volume is zero.

TABLE II. CALCULATION OF BIOGAS PRODUCTION FROM KITCHEN WASTE

Material	Number(kg/d)	Total solids (%)	Biogas production (m ³ /kg)	Biogas production (m ³ /d)
Kitchen Waste	762.8	10.17	0.472	36.6

The analysis found that we can reduce the community's material output through some methods, or even zero in some aspects.

E. Construction of Shuizhai Ecological Community

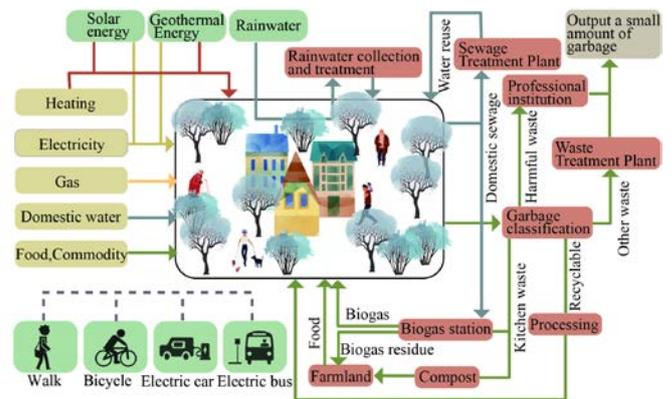


Fig. 4. Schematic diagram of sustainable development model of shuizhai ecological community

IV. CONCLUSION

At present, most of communities are linear metabolic models in Xi'an. A few materials are reused. Most of the potential resources are wasted, and there has been considerable pressure on the natural environment. The study of material metabolism in the community has an important role in realizing self-sufficiency in the community, improving residents' satisfaction and happiness, and living in harmony with nature.

The purpose of this paper is to propose an ecological community material circulation model, provide new ideas for the future community construction. Subsequent research should focus more on the calculation of quantity, and redirect the material metabolism model of the community in Xi'an.

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