Vinnytsia National Technical University

Faculty of Construction, Civil and Environmental Engineering

Department of Ecology, Chemistry and Environmental Protection Technologies

MASTER THESIS

«Environmental impact assessment of pollution with formaldehyde»

Student of 2Т3Д-21м group
specialty 183 "Environmental protection technologies"
Pei Xiu
Supervisor: PhD, Dr. V. Ishchenko
«20» 06 2024
Reviewer: PhD, Dr. T. Titov
«20» 06 2024

Accepted for defense
Head of the Department ECEPT
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INDIVIDUAL TASK

Vinnytsia National Technical University
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Department Ecology, Chemistry and Environmental Protection Technologies
Level of study II (master)
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TASK

FOR MASTER THESIS

Pei Xiu

1. Topic «Environmental impact assessment of pollution with formaldehyde»
supervisor Vitalii Ishchenko
approved by the order of VNTU on «14» 09 2022 No. 203

2. Deadline for thesis subsmission – 20.06.2024

3. Input data: maximum allowable concentration of formaldehyde – 0.08 mg/m^3

4. Content:
Introduction
1. Indoor air quality evaluation
2. Pollution with formaldehyde
3. Formaldehyde treatment technologies
4. Formaldehyde pollution control
5. Economic effectiveness of environmental measures
Conclusions
References

5. Illustrations
1. Activated Carbon
2. Photocatalytic degradation of formaldehyde by fluorine-doped rutile TiO_2 nanorods arrays on carbon fiber cloth

3. Reaction mechanism of HCHO oxidation by Rh/TiO_2 under hum condition

4. Schematic diagram of fresh air system

6. Consultants

Chapter	Name and title of the consultant	Signature	
		task is assigned	task is accepted
5 Economical feasibility of environmental measures	Alla Kraevska		

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CALENDAR PLAN

No.	Stages of master thesis	Deadline	
1.	Technical task	30.09.2022	
2.	Indoor air quality evaluation	08.10.2022	
3.	Pollution with formaldehyde	15.10.2022	
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5.	Formaldehyde pollution control	25.11.2022	
6.	Conclusions, literature list		

Student _____ Pei Xiu
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Supervisor _____ V. Ishchenko
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ABSTRACT

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English language. Bibliogr.: 28 references; 5 figures; 1 table.

In this thesis, the indoor formaldehyde pollution and treatment technologies are analyzed. Sources of formaldehyde pollution are identified. A comprehensive analysis and research, layer by layer in-depth, from a practical point of view, was carried out to assess formaldehyde treatment technologies. The indoor ventilation, plant purification, air purification technology and other technologies are comprehensively discussed. A deep analysis was carried out in order to reduce the content of formaldehyde, indoor purification effect, and efficient control of formaldehyde pollution.

Keywords: formaldehyde, treatment technology, pollution, environment.

SUPERVISOR'S REVIEW OF MASTER THESIS

Pei Xiu «Environmental impact assessment of pollution with formaldehyde»

Formaldehyde is the most important carcinogen in outdoor air among hazardous air pollutants. The negative impact of indoor formaldehyde pollution has become a growing interest, especially in severe cold areas, since most residential buildings do not have enough ventilation and people are unwilling to open windows. Therefore, study on assessment of pollution with formaldehyde is highly relevant.

Master thesis contains a thorough analysis of indoor air quality parameters, including formaldehyde. Sources and pollution with formaldehyde are analyzed (use, toxicity, factors, etc.). Also, formaldehyde treatment technologies performance was assessed.

Besides, one should note that measures for formaldehyde pollution control were prepared.

Master thesis are written at a high level and is of scientific and practical relevance. Master student Pei Xiu has done all the tasks in time. Therefore, I recommend to accept the master thesis with "A" grade.

Scientific supervisor,
PhD, Head of the Department of Ecology,
Chemistry and Environmental Protection Technologies Vitalii ISHCHENKO

MASTER THESIS REVIEWER'S REPORT

Student: Pei Xiu

Thesis title: Environmental impact assessment of pollution with formaldehyde

The aim of the thesis of Pei Xiu was to analyze pollution with formaldehyde in indoor environments.

The thesis meets the goal and results in a valuable theoretical study and successful practical implementation. The report itself is very well written, using an appropriate language and thesis structure, which makes the thesis easy to follow. Based on the state-of-the-art and state-of-the-practice investigation, it proposes measures for formaldehyde pollution control.

The practical part is systematically discussed, including assessment of Indoor formaldehyde treatment technology, microbial degradation method, material sealing technology, etc., as well as calculation of the financial profit of environmental measures.

The following shortcomings can be noted in the master thesis:

- the investigation of formaldehyde impact on climate change would be also valuable.

Overall the thesis is very interesting with very high practical value, and is hence in my opinion worth grade A.

Reviewer,
Ph.D., Associate Professor of the Department of Ecology, chemistry and environmental protection technologies

Taras TITOV

CONTENT

INTRODUCTION

Relevance. At present, the indoor air pollution problem has been paid more and more attention. Many researchers have listed the indoor air pollution problem as the third generation of air pollution marked by "indoor air pollution" after the coal smoke pollution and photochemical smog pollution brought by the industrial revolution. Formaldehyde, nitrogen oxide and other toxic substances contained in building materials pollute indoor air for a long time and cause a great threat to indoor health. At the same time, with the progress of society and economic development, people's living standards continue to improve, modern people on the living environment is increasingly high requirements, so the indoor environment quality also put forward higher requirements. Therefore, the study of indoor environmental safety not only has great theoretical significance, but also has far-reaching practical significance and application prospect.

With the wide application of building decoration materials, the continuous improvement of building airtightness, indoor air pollution is increasingly serious, and the number of people suffering from "Sick building Syndrome" SBS (Sick Building Syndrome) increases. IAQ (Indoor Air Quality) has aroused public attention, and indoor air quality evaluation has become a hot topic of research. In recent years, national environmental protection agencies have found a more disturbing pollution situation in the process of air pollution control, namely indoor air pollution. Modern people have more than 80% of the time a day in indoor activities, indoor air capacity is small, circulation conditions are not as good as outdoor, especially indoor pollution components are more complex, more serious harm. Therefore, the analysis of influencing factors of indoor air quality in buildings and indoor air quality evaluation and understanding of indoor environmental quality can provide a scientific basis for improving indoor air quality in buildings and carrying out indoor comprehensive environmental quality evaluation.

Indoor air pollution is due to the introduction of indoor pollution sources that can release harmful substances or poor ventilation of indoor environment, resulting in the increasing number and types of harmful substances in indoor air, causing a series of uncomfortable symptoms. The pathogen of infectious diseases in indoor air was

known earlier, but other harmful factors were less known. In fact, there was smoke pollution as long ago as humans lived in caves and lit fires to warm them [1]. However, at that time, the range of such effects was very small, the duration was very short, and people's outdoor activities were also very frequent, so indoor air pollution was not obvious harm. With the rapid development of human civilization, especially since the middle of the 20th century, due to the increase in the consumption of civil fuel, the increase in the types and quantities of chemical products and electrical equipment entering the room, and the construction of houses in cold areas in order to save energy, indoor pollution factors are increasing and ventilation capacity is weakened. As a result, the concentration of some indoor pollutants is dozens of times higher than that outside.

Formaldehyde is one of the contaminants generated in indoor environment. This requires a special attention.

Connection of master thesis with scientific programs, plans, topics. The master thesis was prepared according to research area of the Department of Ecology, Chemistry and Environmental Protection Technologies in Vinnytsia National Technical University.

The goal of master thesis is to analyze pollution with formaldehyde in indoor environments.

Tasks of master thesis:

1.Analysis of indoor air quality

2. Analysis of sources of formaldehyde pollution

3. Analysis of formaldehyde treatment technologies

3. Development of formaldehyde pollution control.

Object of the research – pollution with formaldehyde in indoor environments.

Subject of the research – parameters of environmental pollution with formaldehyde.

Novelty of the results. Further development of scientific substantiation of environmental protection measures in formaldehyde pollution control. This helps to reduce the environmental impact of formaldehyde.

Practical value includes preparing the recommendations on reducing the negative impact of formaldehyde on the environment.

Approbation of research results. Results of the master thesis were presented at LII Conference of Vinnytsia National Technical University.

Publications. The materials of this master thesis were published in:

Pei Xiu, V. Ishchenko. Indoor formaldehyde pollution and treatment technology // Proceedings of LII Conference of Vinnytsia National Technical University, Vinnytsia, 21-23.06.2023. – 2023

1 INDOOR AIR QUALITY EVALUATION

The importance of indoor air quality (IAQ) is self-evident. Sick building syndrome (SBS) and the consequent decline in labor productivity are directly or indirectly related to IAQ. Through indoor air quality evaluation, indoor air quality status and change trend can be mastered, and the relationship between pollution sources (such as building paint) and indoor air quality can be made clear to provide a basis for architectural design, epidemic prevention and pollution control. At present, chemical pollution is the most serious in indoor air. The main toxic and harmful gases are volatile organic gases such as formaldehyde, benzene and benzene series, ammonia, radon gas and so on.

The assessment of indoor air quality has not been established with impartiality, authority and comparability. As a comparable objective evaluation method, index model has been widely used in outdoor environmental quality evaluation. However, indoor air quality evaluation is still in the stage of application research.

1.1 Definition of indoor air quality assessment

People often regard indoor air quality as a series of indicators of pollutant concentration. But in recent years, the definition of indoor air quality has been constantly developed. Professor P.O.Anger of the Technical University of Denmark and Chartered Institute of Building Services of the United Kingdom have made indoor air quality completely subjective. The new concept of acceptable indoor air quality is put forward in ASHRAE62-1989 standard of the American Society of Heating, Refrigeration and Air Conditioning Engineers: the known concentration of pollutants in indoor air does not reach the harmful concentration index determined by the recognized authority, and the vast majority of people in the space (≥ 80%) do not express dissatisfaction with the indoor air [2]. This definition combines objective evaluation with subjective evaluation, is relatively scientific and comprehensive, and has been widely adopted and applied by the international community. It covers both objective evaluation and people's subjective feelings, so that it is more scientific and

comprehensive. This definition is also used in the international standard ISO-DIS-16814, which is currently under development.

Indoor air quality evaluation is aimed at specific objects, the use of scientific evaluation methods, analysis of the main influencing factors of indoor air quality, forecast its change trend in a certain period of time, determine the degree of harm it may cause, and put forward economic and feasible control measures. Since indoor air quality assessment involves knowledge of many disciplines, it should be completed jointly by a comprehensive research team with multidisciplinary knowledge of construction technology, construction equipment engineering, medicine, chemistry, physics, environmental monitoring, hygiene, social psychology, etc. At present, indoor air quality assessment is generally carried out by a combination of quantitative monitoring and subjective investigation, among which quantitative monitoring refers to the direct measurement of indoor pollutant concentration, while subjective evaluation refers to the use of human sensory organs for description and evaluation.

People pay attention to indoor air quality, the purpose is to prevent and control indoor air pollution, fundamentally improve indoor air quality, create a comfortable and healthy living environment. Therefore, detection and evaluation must be well combined to achieve the above purpose. In construction engineering, design is fundamental, material selection is the foundation, construction is the key, test is inspection, evaluation is diagnosis, of course, good indoor air quality must also rely on daily operation and maintenance to ensure. Testing provides useful data for indoor air quality evaluation, but simple testing cannot solve indoor air quality, especially cannot meet the needs of high-end users, nor can it provide economic and feasible quantitative control measures. Only by establishing the evaluation work, can the detection work be effectively supported, and the detection work can be carried out in a more in-depth and lasting way, so as to form a virtuous cycle. The organic combination of detection and evaluation is conducive to creating a good indoor environment for people as soon as possible. The factors involved in the evaluation include: building structure, pollution source (release source), adsorption sink (air

purifier can also be regarded as adsorption sink), ventilation and air conditioning system, human activities and individual sensitivity.

1.2 Indoor air quality evaluation standards, grades and factors

Although there is no such law as the Environmental Protection Law and the Environmental Impact Assessment Law, the Law on the Prevention and Treatment of Infectious Diseases, the Regulations on the Health Administration of Public Places, the Measures on the Health Administration of Centralized Air Conditioning Systems in Public Places and other relevant health norms are the main basis for health departments to carry out preventive health supervision and evaluation in public places. There are "consumer rights and interests protection Law" and "Residential interior decoration management Measures" and other management measures, some departments and local also issued a series of management measures, such as "Beijing family room decoration – construction contract (standard text)" proposed: "In the design scheme, the indoor environmental pollution control pre-evaluation calculation must be provided, and must meet the requirements of" Civil Building engineering indoor environmental pollution Control Code ", which can be used as the basis for indoor air quality evaluation. Indoor air quality involves sanitation, environmental protection, engineering construction and other standards. From the point of view of protecting the health of the population and ensuring the quality of life, the standards set forth the quantitative provisions for various health-related (physical, chemical and biological) factors in legal form, as well as the provisions on technical codes of conduct for realizing the quantitative values, which have been approved and promulgated by the competent department of standardization of the State.

A series of standards and norms concerning indoor air quality have been promulgated in health, environmental protection and engineering construction. For example, the Ministry of Health supervision issued No. 53 and No. 58 [2006], promulgating the management measures and supporting documents concerning the centralized air conditioning system in public places, among which there is a Hygiene Evaluation Standard. The Ministry of Construction and the Ministry of Health also

jointly formulated GB50365-2005 "Air conditioning and ventilation system Operation Management Standards" and so on. These standards are the basis for indoor air quality assessment [3]. For the pollution caused by construction and decoration, according to the national standard "civil building engineering indoor environmental pollution control Code" GB 50325-2001 provisions, civil building engineering acceptance, must carry out indoor environmental pollutant concentration detection, a class of buildings (residential, hospital, elderly buildings, kindergartens, school classrooms, etc.) and second class buildings (office buildings, The concentration of indoor pollutants in shops, hotels, cultural and entertainment places, bookstores, libraries, exhibition halls, gymnasiums, public transportation places, restaurants, barbershops, etc., shall not exceed the requirements (but after civil buildings are put into use, indoor environmental pollution generated by non-building materials shall not be controlled by this code).

The new version of the standard stipulates the sanitary limits and detection methods of 4 physical indicators, 16 chemical indicators, 1 biological index and 1 radioactive index in indoor air, which is applicable to residential and office buildings. Other indoor environments can refer to the standard.

The Indoor Air Quality Standard is a Chinese national standard that came into effect on February 1, 2023. Major changes in the new version of the standard:

(1) Three new chemical indicators (fine particulate matter, trichloroethylene, tetrachloroethylene) and limit requirements were added, and indoor air quality indicators were changed from 19 to 22;

(2) The requirements of 5 chemical indexes (nitrogen dioxide, carbon dioxide, formaldehyde, benzene, inhalable particulate matter), 1 biological index (total number of bacteria) and 1 radioactive index (radon) were adjusted. Although the limit value of carbon dioxide was not adjusted, it was changed from "daily average value" to "1h average value", and the limits of other indexes were all lower than the requirements of the 2002 standard;

(3) Added the related contents of indoor air quality index evaluation;

(4) Environmental requirements, sample transportation and storage, parallel sample detection, result representation, laboratory safety and other technical contents are added to the testing technical guidelines. 11 indexes such as temperature, relative humidity, wind speed, fresh air volume, ozone, nitrogen dioxide, sulfur dioxide, carbon dioxide, carbon monoxide, ammonia, formaldehyde (spectrophotometry) are updated. Synchronous adoption of published test method standards.

(5) Formaldehyde (high performance liquid chromatography), benzene, toluene, xylene, total volatile organic compounds (TVOC), Benz[a]pyrene, inhalable particulate matter (PM10), fine particulate matter (PM2.5), total bacteria, radon and other 10 indicators are listed in the appendix form a complete test method; The calculation method of TVOC is refined. Trichloroethylene and tetrachloroethylene can be directly referred to the test method of TVOC.

In view of the above detection methods, the relevant technical measures have been able to meet the overall detection of indoor air quality, and the methods have also been expanded in continuous practice. Most of the methods have been relatively mature, and the detection data can also be applied to the evaluation process. However, it should be noted that differences in detection methods, time and place will lead to differences in detection results. Usually, 7 days after the interior decoration in civil buildings, the indoor environment pollution should be tested. During the field test, the indoor environment should be kept closed for more than 24 hours, and the meteorological conditions should be stable during the test, and there should not be more than grade 5 wind. The measured point should be set in accordance with the national standard, such as the field test room area of less than 50 square meters should be set up 1 measuring point, if more than 50 square meters and less than 100 square meters should be set up 2 measuring points, if greater than 100 square meters should be facilities 3-5 measuring points, at the same time in the detection point should be 0.5-1m distance from the inner wall, And the height is 0.8-1.5m, and ensure uniform distribution. The measurement point should avoid the effective vent, because the indoor environment detection parameters are more and the measurement methods are different, so the detection technology and methods,

instruments and other reasonable and effective methods are selected in the measurement.

In recent years, with the rapid development of interior decoration industry, indoor environmental pollution is becoming more and more serious. Formaldehyde is regarded as the main cause of indoor air pollution due to its wide range of pollution, long duration and great harm. How to improve indoor environment and eliminate the harm caused by formaldehyde has become a thorny problem, which has attracted the attention of scientists and the country.

The improvement of living standard makes indoor decoration more and more popular. While people pursue perfect living room, it causes serious indoor air pollution. Formaldehyde is one of the most serious and common pollutants of indoor air pollution. It is known as the number one "killer" of indoor decoration because of its wide range of pollution, long duration and great harm. According to statistics, within 1~6 months after decoration, the formaldehyde exceeding standard rate reached 80% in the room, close to 100% in the conference room and office; Decoration 3 years later, the exceed rate is still more than 50%, which directly affects people's health, so the world is very concerned about this, strengthen indoor formaldehyde pollution control is particularly important.

1.2 Definition of formaldehyde

Formaldehyde is a colorless aqueous gas. It has a pungent smell. The liquid is easy to turbidity when it is stored for a long time in cold, and the formation of triformaldehyde precipitation at low temperature. Some formaldehyde escapes during evaporation, but most of it becomes triformaldehyde. Formaldehyde is a strong reducing agent, which is stronger in the trace alkaline, and can be slowly oxidized into formic acid in the air. It can be miscible with water, ethanol and acetone. pH 2.8-4.0. The relative density is 1.081-1.085. Melting point -118℃, boiling point -19.5℃. The refractive index is 1.3746. Flash point 60℃. Flammable. Low toxicity, median lethal dose (rats, oral) 800m, its vapor can strongly stimulate mucous membranes.

Organic compound, a simple chemical substance composed of hydrogen, oxygen and carbon, formaldehyde, also known as formal. Soluble in water, alcohol and ether. Formaldehyde is a gaseous state at room temperature, usually in the form of aqueous solution, has the function of coagulate proteins. It has antiseptic properties and is often used as a solution for dipping specimens. Formaldehyde is a highly toxic substance. It is the second most toxic chemical on the priority control list. Formaldehyde is mainly used in building materials, decoration supplies and daily necessities. Formaldehyde is a necessary component of many adhesives, and has the function of strengthening the hardness of the plate and insect prevention and corrosion protection. Reducibility, especially in alkaline solution, reducing ability is stronger. Can burn, vapor and air form explosive mixture, explosion limit 7%-73% (volume), ignition point about 300℃.

Formaldehyde can be prepared by the dehydrogenation or oxidation of methanol under the catalysis of silver, copper and other metals, and can also be separated from the oxidation products of hydrocarbons. It can be used as raw materials of phenolic resin, urea-formaldehyde resin, Vinylon, Ulotropine, pentaerythritol, dyes, pesticides and disinfectants. Industrial formaldehyde solution generally contains 37% formaldehyde and 15% methanol, as an inhibitor, boiling point 101℃.

At present, all kinds of particle board, medium density fiberboard and plywood on the market all use the pulse aldehyde resin with formaldehyde as the main component as the adhesive, so it inevitably contains formaldehyde. In addition, adhesives should be used in the decoration auxiliary facilities of new furniture, walls and ground. Therefore, where adhesives are useful, formaldehyde gas is often released, causing harm to the indoor environment.

In addition, formaldehyde may also come from cosmetics, cleaners, pesticides, disinfectants, preservatives, printing ink, paper, textile fibers, a variety of clothing and other chemical light products. Because the formaldehyde release period in the adhesive is very long, generally as long as 15 years, resulting in formaldehyde becoming the main pollutant in the indoor air. Formaldehyde has been identified as a

carcinogen and teratogenic substance by the World Health Organization. It is a recognized allergen and one of the potential strong mutants. Formaldehyde has a strong stimulating effect on the skin and mucous membrane, which can make the proteins coagulate and denature in cells. So it is very important to understand the content of formaldehyde in our lives and indoors for our health. Phenolic resin (bakelite) can be obtained by aldehyde polycondensation in formaldehyde molecules. Formaldehyde is a kind of air pollutant from a wide range of sources. In nature, formaldehyde is an intermediate product of methane cycle. The background value is generally less than 0.031 mg/m^2, and the annual average concentration of formaldehyde in urban air is about 0. 005-0.01 mg/m^3.

Studies have shown that formaldehyde is a highly toxic substance. The effects of formaldehyde poisoning on human health are mainly manifested in the abnormal smell, irritation, allergy, abnormal lung function, abnormal liver function and abnormal immune function, and it has strong pain-inducing and carcinogenic effects. Has been identified by the World Health Organization as carcinogenic and deformable substances, is a recognized allergen, is also one of the potential strong mutants.

1.3 Characteristics of formaldehyde

Formaldehyde is a colorless, strong odor irritant gas, slightly heavier than air, easily soluble in water, formaldehyde (HCHO), molecular weight: 30.03, density 1.083, folding 5261 radiation rate 1.3755-1.3775, flash point 60℃, boiling point -19.5℃, melting point -118 ℃. Its 35-40% formaldehyde solution is called formalin. Formaldehyde is a volatile organic compound, one of the main pollutants in indoor environment, with many pollution sources and high pollution concentration [4].

Formaldehyde is a kind of plasma reading material, can be combined with protein, people inhale high concentration of formaldehyde, there will be severe respiratory irritation, edema, eye pain, headache, also can occur bronchial asthma, skin direct contact with formaldehyde, can be hard gas dermatitis, stains, necrosis, often inhaled a small amount of formaldehyde, can cause chronic poisoning, mucosal

congestion, skin irritation, allergic dermatitis, Nail keratosis and weakness, nail bed fingertip pain, etc. General symptoms include headache, fatigue, poor stomach appetite, palpitation, insomnia, weight loss, and autonomic nerve disorders.

Carbon atoms form three sigma bonds with three sp^2 hybrid orbitals. One of them is to form a sigma bond with oxygen. These three bonds are in the same plane. A p orbital of carbon and a p orbital of oxygen overlap each other to form a π bond, perpendicular to the plane formed by the three sigma bonds. Bond Angle HCH=111.5° and HCO=121.8°. Bond length: C-H bond: 120.3pm, C-O double bond: 110pm. Dipole moment $7.56 \times 10^{-}$ after DHS m. C.

It is a colorless aqueous solution or gas with pungent odor. Easy to dissolve in water and ether, the concentration of aqueous solution can be up to 55%, pH value: 2.8-4.0, can be miscible with water, ethanol, acetone and other organic solvents in any proportion. The liquid is easy to turbidity when it is stored for a long time in cold, and the formation of triformaldehyde precipitation at low temperature. Some formaldehyde escapes during evaporation, but most of it becomes triformaldehyde.

Pure formaldehyde has strong reducing effect, especially in alkali solution. Formaldehyde itself can be slow condensation reaction, especially prone to polymerization.

Formaldehyde chemical formula HCHO, molecular weight: 30.03, is a colorless, strong pungent odor gas. Soluble in water, alcohol ether. Formaldehyde is a gaseous state at room temperature and usually occurs as an aqueous solution. Its 40% aqueous solution is called formalin. The boiling point of this solution is 19℃. Therefore, it is extremely volatile at room temperature, and the volatilization rate increases with the rise of temperature.

The main functional group of formaldehyde is the carbonyl group, which dominates the chemical reactivity of formaldehyde. The carbonyl group contains a C=O double bond. Due to the electronegativity of oxygen is greater than that of carbon, the ability to absorb bond electrons is relatively strong, so that the easily flowing π electron cloud is strongly pulled toward the oxygen atom. The polarity of the carbon-oxygen double bond has a great effect on the properties of the carbonyl

compound, because it is a double-bond plane, this part of the molecule is open to attack from above and below it, that is, from a solid perpendicular to the carbonyl plane, with little resistance. In addition, the partially negatively charged oxygen is more stable than the partially positively charged carbon, so first the negatively charged reagent is added to the partially positively charged carbon, and then the positively charged carbon

The charged group is then added to the partially negatively charged oxygen, which is most susceptible to the attack of an electron-rich nucleophile, a base.

Formaldehyde is a highly toxic substance and ranks second in the priority control list of toxic chemicals in China. Formaldehyde has been identified by the World Health Organization as a carcinogenic and deformation-causing substance, is a recognized allergen, and is one of the potential strong mutants.

Studies have shown that formaldehyde has strong carcinogenic and cancer-promoting effects. A large number of documents have documented that the effects of formaldehyde on human health are mainly manifested in the abnormal smell, irritation, allergy, abnormal lung function, abnormal liver function and abnormal immune function [5].

Mild asthma occurs in children when the concentration is between 0.06 and 0.07 mg/m^3 of air. When the formaldehyde content in indoor air is 0.1 mg/m^3, there is odor and discomfort; When it reaches 0.5 mg/m^3, it can stimulate the eyes and cause tears. Up to 0.6 mg/m^3 can cause throat discomfort or pain. Higher concentration, can cause nausea and vomiting, cough chest tightness, asthma and even pulmonary edema; At 30 mg/m^3, it kills instantly. Long-term exposure to low doses of formaldehyde can cause chronic respiratory diseases, nasopharyngeal cancer, colon cancer, brain tumors, menstrual disorders, gene mutations in the nucleus, DNA single strand cross-linking and DNA and protein cross-linking and inhibit DNA damage repair, pregnancy syndrome, neonatal chromosome abnormalities, leukemia, cause memory and intelligence decline in adolescents.

2 POLLUTION WITH FORMALDEHYDE

2.1 Sources of formaldehyde

2.1.1. Indoor

Mainly from a variety of artificial panels, wall cloth, paint and other decorative materials and smoke produced by smoking, decorative materials and new composite furniture; Formaldehyde produced by adhesives in decoration materials and furniture, such as plywood, large core board, medium fiber board, flower board, (scrap board), such as Figure 1; UF foam insulation material for building heat and cold protection; Coatings with formaldehyde as preservative, chemical fiber carpets, cosmetics and other products and other organic materials.

Formaldehyde is of great harm to human health. When the content of formaldehyde in indoor air is greater than 0.1mg/m3, it will cause harm to the respiratory system. High concentration of formaldehyde will cause harm to the nervous system, immune system and liver. "Health standard for formaldehyde in the air of living room" stipulated that the amount of formaldehyde in the living room should be less than 0.08mg/m3, but the formaldehyde concentration of general residential decoration is 0 mg/m3 on average, up to 0.81mg/m3, seriously beyond the standard. At present, a variety of technical methods will reach the free formaldehyde in building materials, although a certain achievement, but due to the limitations of technology and economy, Indoor formaldehyde pollution is still very serious. Therefore, it is very important to control and treat indoor formaldehyde pollution.

Artificial panels such as plywood, joinery board, medium density fiberboard and particleboard for interior decoration. Formaldehyde is the main component of the adhesive used in the production of wood-based board. The formaldehyde that remains in the board and does not participate in the reaction will gradually be released to the surrounding environment, which is the main body of formaldehyde in the indoor air.

Furniture made of wood-based panels. In order to pursue profits, some manufacturers use unqualified boards, or use inferior glue when bonding veneer materials, and formaldehyde in boards and glues seriously exceed the standard.

Other kinds of decorative materials that contain formaldehyde and may be distributed to the outside world, such as wall cloth, wall paper, chemical fiber carpet, paint and coatings.

The formaldehyde concentration in indoor air is related to the following four factors: indoor temperature, indoor relative humidity, indoor material loading degree (that is, the surface area of formaldehyde emitting materials per cubic meter of indoor space), indoor air flux. Under high temperature, high humidity, negative pressure and high load conditions, the intensity of formaldehyde emission will be intensified. Normally, the release period of formaldehyde can be as long as 3-10 years [6].

Research shows that people spend 4/5 of their life indoors, indoor air quality is one of the important factors affecting people's life safety. However, due to excessive decoration and other reasons, indoor pollutants exceed the standard, especially formaldehyde pollution. According to different indoor uses, we discuss the possible formaldehyde pollution sources.

Formaldehyde pollution in households

At present, people not only generally pay attention to the comfort, beauty and utility of the home, but also attach great importance to the harm of indoor formaldehyde pollution, the use of environmental protection materials in the decoration, in spite of this, the newly decorated house formaldehyde will still exceed the standard. In addition, the release cycle of formaldehyde is 3 to 15 years, and because of the different indoor temperature, humidity, formaldehyde release speed is different, there is a certain number of years of the house may still exceed the indoor formaldehyde, usually the formaldehyde pollution sources in the family are mainly as follows:

Furniture: Studies have shown that the formaldehyde content released by furniture accounts for a high proportion of formaldehyde pollution in indoor air. The raw materials used in the board furniture of wooden furniture are mainly plywood

and other synthetic board materials. The adhesive used in the processing process of this kind of board and the paint used in the later beautification process will release different contents of formaldehyde, which is one of the main sources of indoor formaldehyde pollution.

Kitchen: Formaldehyde will be produced in cooking fumes. Incomplete combustion of energy fuels such as kerosene in the kitchen will also produce a certain amount of formaldehyde, resulting in formaldehyde pollution.

Interior decoration materials: Textile decorative products such as indoor wallpaper, wallpaper, curtains, wall cloth and so on release formaldehyde pollution, the reason is that in the production process of such products in order to achieve the purpose of bright color and add a lot of fixing agent, fixing agent is often added a lot of formaldehyde, in order to enhance the function of color fixation, resulting in the formaldehyde concentration of such decorative materials exceed the standard. In addition, the common curtain in the family due to paint and dye material problems will also release a certain amount of formaldehyde.

Daily necessities: cosmetics, cleaners, paper, clothes, shoes and so on all contain a certain amount of formaldehyde, toilet paper belongs to a dangerous carcinogen, which contains formaldehyde is one of the carcinogens.

Formaldehyde pollution in stores

With the continuous improvement of people's pursuit of beauty, the decoration wind in many public places is becoming more and more popular, inevitably resulting in the worsening of formaldehyde pollution in public places. Clothes and shoes are our commonly used intimate clothing, they can directly or indirectly contact with our skin, long-term exposure to products with excessive formaldehyde content will damage human function, endanger life safety. Formaldehyde has functions of anti-shrinkage, wrinkle removal, non-ironing and stain removal for clothing, so it is widely used in textile and cotton clothing products, which means that in many cases, our intimate clothing will release formaldehyde [7]. The crosslinking agent used in the production and processing of footwear products is formaldehyde crosslinking agent. If the reaction is incomplete, formaldehyde pollution will be caused [8]. In

addition to decoration pollution and furniture pollution in clothing stores, the goods sold in such stores are also one of the sources of formaldehyde pollution. The average concentration of indoor formaldehyde pollution in most shoe wholesale markets in the morning and afternoon is more than 0.1~ 0.12 mg/m^3, which is higher than the safety emission standard of indoor formaldehyde.

Formaldehyde pollution in recreational places

At present, the formaldehyde pollution of bars, KTV, song and dance halls, cafes, game halls, bath massage rooms and other places is not optimistic. Zhao Shufang's investigation of indoor formaldehyde pollution in such entertainment places showed that the indoor formaldehyde concentration in KTV, karaoke, coffee shop, tea house and other entertainment places was 0.35~ 0.37 mg/m^3, which was more than three times higher than the existing indoor formaldehyde standard in China. The dense crowd in bars, Internet cafes, video game halls, smokers, and airtight business environment are all excellent conditions for breeding formaldehyde pollution. Therefore, we can speculate that the level of formaldehyde pollution in such entertainment places with complex environment is more serious.

Formaldehyde pollution in school classrooms

In 2010, the number of school-age students in our country has reached 486 million, but the safety factor of schools has not followed the growth of the number of students, due to indoor formaldehyde pollution caused by personal safety accidents are still common. Many schools choose to decorate classrooms, cafeterias and student dormitories during holidays, and the buildings are put into use shortly after students return to school for decoration [9], while the release period of formaldehyde is as long as 3 to 15 years [10], which greatly increases the chance for students to suffer from formaldehyde. In recent years, a campus safety incident occurred in a kindergarten in Nanchang City, which caused intensive nosebleeds and coughs among students due to excessive indoor formaldehyde concentration [11]. Wang Hao et al. found in the research on the establishment and evaluation of formaldehyde pollutant database of indoor school buildings that the extreme excessive formaldehyde concentration mainly occurred in school classrooms. The boards and

decorative coatings used for emissions-intensive desks and chairs in classrooms, as well as other decorative materials with low environmental protection (such as curtains) would all produce formaldehyde, resulting in a large number of students. Not conducive to air circulation is also one of the causes of formaldehyde pollution; Most of the building materials used in student dormitories are cheap materials with high formaldehyde content; In addition, students' daily necessities will also release a small amount of formaldehyde, and ventilation time is not guaranteed, so the student dormitory has become the worst disaster area of formaldehyde pollution on campus. Wang Yulei et al. [12] detected formaldehyde in 56 dormitories, and found that the formaldehyde concentration in male and female dormitories was more than 0.1mg /m3 in each period of the weekend, while the formaldehyde concentration was lower than 0.10mg /m3 in only one or two periods of the weekend. This also reflects that more than 90% of the time in the dormitory students are exposed to formaldehyde pollution hazards. To sum up, the indoor formaldehyde pollution in schools is very serious.

2.1.2. Outdoor

Formaldehyde in the outdoor air mainly comes from the products of oil, coal, natural gas and other fuels combustion and the oxidation and decomposition of lubricating oil, exhaust gas from vehicles, atmospheric photochemical reactions, etc. The formaldehyde in the atmosphere also comes from the production of formaldehyde, urea formaldehyde resin, chemical fibers, fuels, rubber products, plastics, ink, paint, paint factories, the production process of formaldehyde into the atmosphere [13].

Oil, coal, natural gas and other fuel combustion products and lubricating oil oxidation decomposition, automobile emissions, atmospheric photochemical reaction. The formaldehyde in the atmosphere also comes from the production of formaldehyde, urea formaldehyde resin, chemical fibers, fuels, rubber products, plastics, ink, paint, paint factories, the production process of formaldehyde into the atmosphere.

2.1.3 Industry

Formaldehyde is mainly used in industry to manufacture resin (phenolic resin, urea formaldehyde resin, etc.), plastic, leather, paper, artificial fiber, plywood, corrosion and fumigant, etc., these industries often produce wastewater containing formaldehyde, so the source of formaldehyde wastewater is very wide.

In industry, formaldehyde is prepared by catalytic oxidation of methanol. In other words, the mixture of methanol vapor and air at 600-700℃ is used as a silver catalyst to absorb formaldehyde and inactive methanol with water. After steaming part of methanol from the solution, formaldehyde aqueous solution is obtained, which contains 40% formaldehyde and 8%-10% methanol. This solution, called formalin, needs to be kept at a low temperature, otherwise formaldehyde tends to self-polymerize into oligomers. The product obtained by this process contains high formic acid and produces a large amount of flammable gas. Can use the modified gas boiler, combustion tail gas, produce a lot of steam, can be self-sufficient.

If the air containing 5%-10% methanol vapor (volume fraction) through ferric oxy-molybdenum oxide catalyst, tail gas cycle absorption method to get formaldehyde basically does not contain methanol, and low formic acid content, high yield.

2.2 Chinese standard of formaldehyde pollution control for indoor environment

In order to protect people's health, the first standard of formaldehyde pollution Prevention and Control was proposed by the Ministry of Health and drafted by Institute of Environmental Health Monitoring, Chinese Academy of Preventive Medicine, Beijing Medical University, Liaoning Provincial Health and Epidemic Prevention Station and Shandong Provincial Health and Epidemic Prevention Station. On December 15, 1995, the former State Bureau of Technical Supervision approved and issued the first formaldehyde pollution control standard in indoor environment, GB/T16127-1995 "Health Standard for Formaldehyde in the air of Living Room GB/T16127-1995", which was implemented on July 1, 1996.

The standard specifies the maximum allowable concentration of formaldehyde in indoor air, which is not more than 0.08 mg (0.08 mg/m3) per cubic meter of air. At the same time indicate that this standard is applicable to all kinds of urban and rural residential air environment.

Health standard for formaldehyde in the air of living rooms GB/ T1612-19955 0.08 mg/m^3 (maximum allowable concentration)

In December 2002, according to the instructions of The State Council leadership, the Standard committee of the State Quality Supervision, Inspection and Quarantine Bureau organized the Ministry of Health and the State Environmental Protection Bureau formulated GB/T18883-2002 "Indoor Air quality Standards" issued and implemented.

The standard requires the control of 19 indicators in four categories of indoor air, including formaldehyde pollution.

The 2002 implementation of Chinese GB50325-2001 "Code for indoor environmental Pollution Control of civil building engineering", to improve the indoor environmental quality of civil building engineering, control the indoor environmental pollution of building engineering, develop the domestic indoor environment pollution detection and treatment industry, improve consumers' awareness of indoor environment, Protecting consumers' indoor environmental rights and interests has played a positive role. The specifications put forward concentration limits for five pollutant indexes including formaldehyde: radon, benzene, ammonia and total volatile organic compounds. In particular, the classification and concentration limits of indoor environmental pollutants for different construction projects are proposed. Control pollutants Class I civil construction engineering Class II civil construction engineering Free formaldehyde ≤0.08 mg/m^3≤0.12 mg/m^3.

It mainly includes construction housing, hospitals, buildings for the elderly, kindergartens, school classrooms and other office buildings, shops, hotels, cultural and entertainment places, bookstores, libraries, exhibition halls, gymnasiums, waiting rooms for public transportation, restaurants, barbershops, etc.

2.3 National health standards for indoor formaldehyde

The national standard of the People's Republic of China "Hygienic Standard for Formaldehyde in the air of Living Room" (GB 16127-1996) and "Indoor Air Quality Standard" (GB/T18883.2002) stipulate that the maximum allowable concentration of formaldehyde in the air of living room is 0.08 mg/m^3 and 0.1 mg/m^3 respectively. In 2020, the Ministry of Housing and Urban-Rural Development of the People's Republic of China approved and issued the Code for Indoor Environmental Pollution Control in Civil Construction Process (GB 50325-2020), which stipulates that the formaldehyde concentration of a civil building is less than 0.07 mg/m^3, and that of a civil building is less than 0.08 mg/m^3. And the formaldehyde content of the materials involved in common interior decoration has a clear regulation. In spite of this, there are still shortcomings in supervision. Some businesses ignore laws and regulations in order to make profits, or because they know little about the harm of formaldehyde to human health, they still sell and buy indoor furniture and decoration materials with excessive formaldehyde content, which leads to the frequent occurrence of vicious incidents caused by formaldehyde pollution, resulting in extremely bad social impact.

2.4 Use of formaldehyde

2.4.1 Uses of formaldehyde in daily life

Textile industry

Formaldehyde in fiber products, mainly used in dyeing additives and improve the effect of anti-wrinkle, anti-shrinkage resin finishing agent. Formaldehyde can make the color of textiles bright, maintain the durability of printing and dyeing, and can make cotton fabric wrinkle, shrink and flame retardant. Therefore, formaldehyde is widely used in the textile industry. Formaldehyde printing and dyeing auxilaries are more pure cotton textiles, because pure cotton textiles are easy to wrinkle, the use of formaldehyde auxilaries can improve the stiffness of cotton cloth, the market for "pure cotton anti-wrinkle" clothing or ironing shirts, most of the use of formaldehyde

auxilaries, may release formaldehyde when wearing. The formaldehyde in children's clothing mainly comes from the bright and beautiful dyes and auxiliaries that maintain the color of children's clothing, as well as the adhesives used in clothing printing. Therefore, the formaldehyde content of bright and printed clothes is generally high, while the formaldehyde content of plain clothes and children's clothes without printed patterns is lower. These clothes containing formaldehyde will release formaldehyde in the storage and wearing process, especially the formaldehyde released by children's clothes and underwear is the most harmful. Textiles containing formaldehyde, in the process of wearing and using, will gradually release free formaldehyde, through human respiratory tract and skin contact cause respiratory tract inflammation and skin inflammation, but also produce irritation to the eyes. Formaldehyde can cause allergies and cancer. Manufacturers use formaldehyde dyeing auxiliaries, especially some manufacturers in order to reduce costs, the use of cheap auxiliaries with very high formaldehyde content is very harmful to human body.

Food industry

Formaldehyde is an additive that is expressly prohibited in food by the state. It can not be detected in food, but the presence of formaldehyde is detected in various degrees in many foods.

Waterborne food

Because formaldehyde can keep the surface color of water hair food bright, can increase toughness and crispness, improve taste, can also be anticorrosion, if it is used to soak seafood, can fix the shape of seafood, keep the color of fish. Therefore, formaldehyde has been widely used in all kinds of aquatic products by illegal traders. In the market, formaldehyde has been detected in the water hair food mainly include duck feet, beef veneer, shrimp, sea cucumber, fish maw, pomfret, octopus, cuttlefish, hairtail, squid head, hamstring, jellyfish, snail meat, cuttlefish, etc., among which the formaldehyde content in shrimp, sea cucumber and squid is high.

Pasta, mushroom or soy products

Formaldehyde can whiten, change color, so formaldehyde is often used by illegal traders to fumigate or directly added to pasta, mushrooms or soy products, illegal traders with "white" fumigation of food brightening, can also be in food residual formaldehyde. Formaldehyde has been detected in the related food are: mushroom, mushroom, rice noodles, vermicelli, bean curd bamboo, etc.

Alcoholic Drinks

Formaldehyde is added to alcoholic beverages to prevent turbidity and increase transparency.

2.4.2 Uses of formaldehyde in industry

Wood industry

Used for the production of urea-formaldehyde resin and phenolic resin. Urea formaldehyde resin is formed by the reaction of formaldehyde mixed with urea according to a certain molar ratio. Phenolic resin was prepared by mixing formaldehyde with phenol at a certain molar ratio. Formaldehyde's irreplaceable place in the wood processing industry is being replaced by MDI glue.

Textile industry

Formaldehyde should be used in the process of garment ester finishing. The production of clothing fabric, in order to achieve anti-wrinkle, anti-shrinkage, flame retardant, or in order to maintain the durability of printing and dyeing, or in order to improve the feel, it is necessary to add formaldehyde in the additives. Cotton textiles are more used with formaldehyde printing and dyeing auxilia, because cotton textiles are easy to wrinkle, the use of formaldehyde auxilia can improve the stiffness of cotton cloth. Textiles containing formaldehyde, in the process of wearing and using, will gradually release free formaldehyde, through human respiratory tract and skin contact cause respiratory tract inflammation and skin inflammation, but also produce irritation to the eyes. Formaldehyde can cause allergies and cancer. Manufacturers use formaldehyde dyeing auxiliaries, especially some manufacturers in order to

reduce costs, the use of cheap auxiliaries with very high formaldehyde content is very harmful to human body.

Antiseptic solution

Formaldehyde is a substance released by the decomposition of formaldehyde sodium bisulfite above 60℃. It is colorless, has a stimulating smell and is easily soluble in water. 35%-40% formaldehyde aqueous solution, commonly known as formalin, has antiseptic and bactericidal properties. It can be used to dip biological specimens and sterilize seeds, but it is easy to make the specimens brittle due to the denaturation of proteins. The main reason why formaldehyde has antiseptic properties is that the amino group on the protein of the organism (including bacteria) itself can react with formaldehyde.

2.5 The toxicity of formaldehyde

When formaldehyde reaches a certain concentration, it can cause bloodshot eyes, itching, throat discomfort, or pain, hoarseness, even sneezing, runny nose, and severe chest tightness, shortness of breath and difficulty breathing symptoms. Sometimes skin irritation, rashes and itching may occur.

Formaldehyde is a colorless and odorless gas, can be diffused in the air, and long-term contact with the skin can cause redness, ulcers, necrosis and other skin symptoms.

Long-term exposure to formaldehyde in the air can cause burning in the eyes, accompanied by redness, tears and other symptoms, and may induce conjunctivitis, keratitis and so on.

Long-term inhalation of formaldehyde gas can produce respiratory irritation symptoms, causing pharyngeal edema, pharyngitis, cough, etc., and can cause bronchospasm, even bronchial asthma when serious.

Formaldehyde is toxic, in long-term exposure will cause neurological damage symptoms, the human body can appear headache, dizziness, insomnia, irritability and other uncomfortable reactions, but also may induce mental disorders.

Long-term inhalation of formaldehyde can damage the immune system and cause damage to immunity. Patients are prone to repeated symptoms such as cold and fever, and even lead to the occurrence of tumors, especially leukemia and lymphoma.

Can cause human body weight loss, hair loss, loss of appetite, fatigue and other discomfort.

Formaldehyde as a carcinogen, if long-term exposure, the chance of human body cancer relative to the general population will be increased, such as nasopharyngeal cancer, lung cancer, liver cancer, etc. If women are exposed to formaldehyde for a long time, it may also cause pregnancy syndrome, neonatal chromosome abnormalities, abortion and other problems, and children may have a decline in memory and intelligence.

The development of tumors, such as nasopharyngeal tumors.

There will be loss of appetite, insomnia, dreaminess, memory loss symptoms.

The main harm of formaldehyde is the irritation effect on the skin mucosa. Formaldehyde is a protoplasmic substance, which can bind with protein. When inhaled in high concentration, severe respiratory irritation and edema, eye irritation and headache may occur.

Formaldehyde can produce strong irritation to the eyes, causing eye conjunctiva congestion, eyes stinging, tears and other symptoms.

Direct skin contact with formaldehyde can cause allergic dermatitis, stains, necrosis, inhalation of high concentration of formaldehyde can induce bronchial asthma, excessive formaldehyde in the environment to stimulate human skin, mucous membranes, etc.

High concentrations of formaldehyde are also a genotoxic substance. Nasopharyngeal tumors can be caused by high concentrations of inhalation in laboratory animals.

Headache, dizziness, fatigue, nausea, vomiting, chest tightness, sore eyes, sore throat, poor stomach appetite, palpitation, insomnia, weight loss, memory loss and phytonervous disorders. Long-term inhalation by pregnant women may lead to fetal

malformation and even death. Long-term inhalation can lead to sperm malformation and death in men.

Can cause chronic respiratory diseases, may cause nasopharyngeal cancer, colon cancer, brain tumors, menstrual disorders, nuclear gene mutations, inhibit DNA damage repair, pregnancy syndrome, neonatal chromosome abnormalities, leukemia, but also can cause adolescent memory and intelligence decline.

Formaldehyde is also harmful to plants. The chemical reacts with plant proteins, nucleic acids and lipids to harm plant cells. Plants that are sensitive to formaldehyde gas, such as bougainwort (also known as leaf flower in some places), sorrel safflower, and rice lily, can also be injured, severely and even killed, when exposed to high concentrations of formaldehyde.

2.6. Factors affecting formaldehyde

2.6.1. Factors affecting formaldehyde release

Temperature

Temperature is a major factor in the release of formaldehyde, it may also be known that the higher the temperature, the more formaldehyde will be released, the boiling point of formaldehyde at 19 degrees Celsius, generally speaking, every rise in one degree, formaldehyde volatile release can accelerate 0.4 times, so the best season to remove formaldehyde is in summer or winter, summer indoor and outdoor temperature itself is very high, The indoor temperature is also very high after the winter heating is opened, but remember to open the window for ventilation.

Humidity

Humidity is also a factor affecting the release of formaldehyde, if the home is very humid, it will increase the amount of formaldehyde volatilization, formaldehyde and urea catalyzed in the chemical reaction to form urea formaldehyde resin, and urea formaldehyde resin is used in many places of our indoor decoration, such as the floor, storage cabinet and so on, indoor humidity, urea formaldehyde resin will be

decomposed into urea and formaldehyde, So that formaldehyde is released, so put a large pot of water in the room to absorb formaldehyde effect is also good

Air Flow

The premise of air flow is to open the window, but not only open the window, need to carry out air flow, then formaldehyde release will be more, discharged to the outdoor formaldehyde will be more, for formaldehyde removal is more effective, because the density of formaldehyde is heavier than air, generally floating below, if only open the window, there is no air flow, then the formaldehyde below is almost motionless. So it's a waste of time to open a window.

Releasing the Source

Many places in our indoor contain formaldehyde, different materials contain different amounts of formaldehyde, volatilization time is not the same. General wall paint about a week to half a month time volatile, wallpaper is at least 1 year, the core board is 1 to 5 years, there are some artificial board even 15 years of time volatile.

2.6.2. Factors affecting formaldehyde detection

Formaldehyde is widely used in our life, especially the widespread application of artificial panels, which increases the amount of formaldehyde, resulting in increasingly serious indoor air formaldehyde pollution caused by artificial panels. Select the sampling point at different time periods. Select the location with the most serious pollution. Select the sampling point near the door when there is no sunlight and select the sampling point near the pollution source when there is direct sunlight. The sampling point should be more than 0.5 m away from the wall, away from the air duct and air vent. The height of the sampling point is consistent with the height of human breath in principle, and the relative height is between 0.8m and 1.5m.

Long decoration years, indoor pollution is relatively low, the number of sampling points can be correspondingly less; The number of sampling points should be increased correspondingly for luxury households whose decoration years are less than one year; The decoration period is less than one year, but the ordinary decoration is adopted and the householder pays great attention to the selection of materials in the

decoration, because the indoor pollutant concentration is at a low level, the number of sampling points can be less accordingly. The acceptance of indoor environmental quality of a fully renovated residential project shall be carried out at least 7 days after the completion of the project or before the project is put into use.

3 FORMALDEHYDE TREATMENT TECHNOLOGIES

3.1 Formaldehyde detection methods

Formaldehyde detection methods, at present, at home and abroad, textiles, food formaldehyde detection methods mainly include electrochemical method, chromatography, sensor detection method, etc. First we introduce a laboratory method ----- phenol reagent spectrophotometry.

3.1.1 Phenol reagent spectrophotometry

The formaldehyde in the air reacts with the phenol reagent to form the zine, which is oxidized by high iron ions in the acidic solution to form the blue green compound. According to the color of light, color comparison quantitative. Reagent, the water used in this method is heavy distilled water or deion exchange water: the reagent purity used is generally analytical pure.

Absorption liquid stock

Weigh 0.10g phenol reagent and dissolve it with water. Pour it into a 100ml stopper cylinder and add water to the scale. Store in the refrigerator for up to three days.

Absorption solution

Measure 5ml of absorption stock solution and add 95ml of water to make absorption solution. Sampling, temporary use of the match. 3.1% ammonium ferric sulfate solution: Weigh 1.0g ferric sulfate and dissolve with 0.1mol/L hydrochloric acid, and dilute to 100ml.

Iodine solution

Weigh 30g potassium iodide, dissolve in 25ml water, add 127g iodine. After the iodine is completely dissolved, the water is filled to 1000ml. Transfer to a brown bottle and store in the dark.

1 mol/L sodium hydroxide solution

Weigh 40g sodium hydroxide, dissolve in water, and dilute to 1000ml.

0.5 mol/L sulfuric acid solution

Take 28ml concentrated sulfuric acid and slowly add it to water. After cooling, dilute it to 1000ml.

Sodium thiosulfate standard solution

0.5% starch solution

Add 0.5g soluble starch into paste with a small amount of water, then add 100ml boiling water, and boil for 2-3min until the solution is clear. After cooling, add 0.1g hydroacid or 0.4g zinc chloride for storage.

Formaldehyde standard reserve solution

Take 2.8ml of 36-38% formaldehyde solution, put it into 1L volumetric bottle, and dilute it to the scale with water. 1ml of this solution is equivalent to 1mg of formaldehyde.

Formaldehyde standard solution

When necessary, dilute the standard reserve solution of formaldehyde with water into 1.00 ml containing 10 μg formaldehyde, immediately take 10.00 ml of this solution, add it into a 100 ml volumetric bottle, add 5ml of absorbent stock solution, and fix it with water to 10 0ml. The liquid 1.00ml contains 1.00 μg formaldehyde, and place it for 30 minutes before preparing the standard color tube. This standard solution can be stable for 24h.

3.1.2 Electrochemical method

Electrochemical analysis method is based on the changes of current (voltammetry), electric quantity (coulomb method) and potential (potentiometric method) generated in chemical reaction, to determine the concentration of analytes in

the reaction system for quantitative analysis. There are two kinds of polarography and potentiometric method for formaldehyde detection.

Oscillopolarography. Oscillopolarography, referred to as polarography, is a method of analysis and determination by obtaining a current - voltage curve that is polarographic wave. Formaldehyde produced a clear polarographic wave in the bottom solution of phenylhydrazine hydrochloride sodium chloride, and the peak current was proportional to the content of formaldehyde. The quantitative detection was carried out according to the comparison between the sample peak current and the standard peak current of formaldehyde. Or in acetic acid-sodium acetate medium with pH value of 5, the reaction products of formaldehyde and hydrazine sulfate produce a sensitive adsorption reduction wave, the peak height of which is linear with the concentration of formaldehyde in a certain range, according to this relationship for the quantitative detection of formaldehyde. This method is simple to operate and has good selectivity, but polarographic analysis has high requirements for sample pretreatment, and the mercury drop electrode used is polluted. Currently, it is often used for the detection of formaldehyde in food and food packaging materials.

Potentiometric method. Potentiometric method, also known as ion selective electrode method, is a method to measure the activity of measured ions by converting them into electrode potential using membrane electrodes. In sulfuric acid medium, formaldehyde can promote the oxidation of potassium iodide by potassium bromate. The kinetic potential method for the determination of trace formaldehyde can be established by using iodide ion as electrode for potential tracking. (The linear range of the method was 0–5mg/L, and the detection limit was 0.055mg/L) This method is a new research method, but it is seldom used in practice.

3.1.3 Chromatography

Chromatography has strong separation efficiency, not easy to be affected by the sample matrix and reagent color interference, sensitive and accurate detection of complex samples, can be directly used for the analysis and detection of formaldehyde in living rooms, textiles, food. The formaldehyde in the sample can also be derivated

and then determined. The commonly used derivatives are 2,4, 1, 2 nitrophenylhydrazine, squinazole, ethyl mercaptan, hydrazine sulfate, etc. Sui Xueyan et al. extracted the formaldehyde in the sample to produce 2,4, 1-1-nitrophenylhydrazone, which was extracted by toluene or n-hexane, separated by capillary or packed column gas phase, and then detected by electron capture detector. Qualitative and quantitative detection was carried out according to retention time and peak height, and the detection limit was 0.00156mg /L. Among them, ethanol, acetone, sulfur dioxide, nitrogen oxide and so on will not cause interference. The formaldehyde in the sample was derivated, extracted, separated by high performance liquid chromatography, detected by UV detector, qualitative and quantitative detection according to the retention time and peak area, the detection limit can reach 0.05mg. The sample components in the living room, textiles, food are generally more complex, interference components, formaldehyde content is low, conventional detection methods need to spend a lot of time and energy separation, concentration and other pretreatment before detection. The chromatography is sensitive, accurate quantitative, strong anti-interference, can be directly used for the detection of formaldehyde in the living room, textiles, food. If the flow rate of 0.2 L/min is 20L, the measurement circumference is 0.02~1 mg/m^3, and the detection limit is 0.01 mg/m^3. However, the chromatographic method has high requirements on equipment, long derivatization time, extraction and other steps and operation process, so it is not suitable for the field rapid detection in general laboratories and families, and it is difficult to meet the market demand.

3.1.4 Sensor Detection

The sensors used to detect formaldehyde include electrochemical sensors, optical sensors and photobiochemical sensors. The structure of electrochemical sensors is relatively simple, relatively low cost, high quality products stable performance, measurement circumference and resolution can basically meet the requirements of laboratory environment detection. But the disadvantage is that the interfered substances, and due to the electrolyte and the measured formaldehyde gas

irreversible chemical reaction and consumption, so its working life is generally relatively short.

Optical sensors are expensive and bulky, and are not suitable for online real-time analysis, which limits their wide use. Although the optical sensor improves the selectivity, but due to the enzyme activity and other factors lead to the sensor instability, lack of practicality, and the price of the general formaldehyde gas sensor is too high, difficult to popularize, increasingly serious, so it is necessary to establish a simple, sensitive, rapid, intuitive, accurate and economic formaldehyde detection method. In each family, residents can realize their own living room, textiles, food online real-time detection of formaldehyde is required by the market, popular.

At present, there is not a more ideal formaldehyde field rapid detection method, spectrophotometry is limited by water bath or concentrated sulfuric acid and other operating conditions, electrochemical detection method has higher requirements for sample pretreatment, chromatography is limited by instruments and equipment, sensor detection of formaldehyde cost is high, short life, and the formaldehyde rapid detection box on the market now requires professional operation, high cost, the general family is difficult to general. Therefore, it is timely and necessary to establish a simple, rapid and sensitive on-line formaldehyde detection method. The introduction of existing emerging technologies, such as microcomplete analysis system and solid phase microextraction, can reduce the detection limit of formaldehyde detection, avoid interference, and provide greater possibility for the portability of formaldehyde field rapid detection.

3.2 Indoor formaldehyde treatment technology

The formaldehyde in the decoration materials can be continuously released, and the release cycle is long, the cycle can be up to 15 years, the direct result is that the formaldehyde in the indoor air is difficult to eradicate. After a detailed analysis of the existing data and research, generally 3 days after the completion of the decoration, the concentration of formaldehyde will appear a peak, and within 7 months the concentration will maintain a high level, and then the concentration gradually decreases, about 5 years after the decoration can reach the concentration level before the decoration. Therefore, the general treatment method can only achieve the palliative effect, in order to eradicate only discard the source of pollution. In the common way, by changing the nature of decoration materials to improve indoor air, the use of low-emission formaldehyde materials or decoration materials with high formaldehyde emissions by technical transformation. The search for low pollution or non-aldehyde replacement decoration materials is also a hot research at home and abroad.

The indoor formaldehyde control technology in foreign countries started relatively early, has been widely promoted and developed rapidly. The main fields involved are aldehyde capture materials, low emission aldehyde materials and non-aldehyde materials. Its main aspects are: the production of paper containing formaldehyde trapping agent, because the water-soluble sodium bisulfite can react with formaldehyde in the air, hydroxymethyl, attached to the paper water-soluble formaldehyde, can achieve the purpose of capturing formaldehyde; The production of decorative board with formaldehyde capture function. Formaldehyde trapping agent is mixed in the protective layer of its surface, or formaldehyde trapping layer is generated on its paper substrate, which can be used to effectively capture the formaldehyde released from particle board and medium density fiberboard and plywood, and also can capture the formaldehyde released from other decoration materials; The production of low aldehyde wood cement, and then the tourmaline powder mixed into formaldehyde resin, after hydrolysis reaction generated hydrogen can react with free formaldehyde, to achieve the smell of strong toxic formaldehyde

into methanol, so as to reduce the concentration of formaldehyde; Extraction of natural aldehyde trapping materials, such as plant polyphenols and essential oil containing terpenes, etc.; The production of acetyl ethyl ether-based thermosetting resins to achieve the purpose of absorbing aldehydes, and such substances have a good absorption effect on wood products (containing aldehydes) : the production of non-aldehyde resin wood adhesives, wood cutting boards made of non-aldehyde adhesives can well control the emission of aldehydes, such as some fiber boards made of copolymers.

The main direction of domestic researchers is to study how to reduce formaldehyde content and emissions in the synthesis of urea-formaldehyde resin. Its general categories such as: accelerate cationic methylene alcohol and cationic methylene polycondensation reaction, reduce the composition of dimethylene ether or ether in the tissue; Add urea in batches, reduce the ratio of F/U, increase the amount of urea, so as to improve the conversion of formaldehyde, to reduce the content of formaldehyde in the glue; In the later stage of the synthesis of urea-formaldehyde resin, the middle water of the glue solution is removed to remove the free aldehyde. In the decoration materials to add formaldehyde trapping agent, such as polyvinyl alcohol urea, melamine, starch and low alcohol capture substances; Use ammonia, urea or ammonium chloride aqueous solution for post-treatment of decoration materials, such as cleaning or dipping, in order to reduce the emission of formaldehyde in the products.

The release period of indoor formaldehyde is generally 3 to 15 years. It is related to indoor temperature, relative humidity, indoor air exchange number, indoor building materials and other factors. According to the main source and emission characteristics of indoor formaldehyde in order to reduce formaldehyde pollution, we should start from the decoration.

(1) Adopt environment-friendly materials with low formaldehyde content for decoration.

(2) Design a good scheme to fully consider the overall structural layout of the room, scientific design to ensure good ventilation.

(3) Calculate the bearing capacity of indoor formaldehyde using scientific construction technology moderate decoration.

(4) The chemical method is used to pretreat the plate, so that the total indoor formaldehyde content is reduced.

At present, indoor formaldehyde prevention and control measures are mainly divided into source control methods: for example, in the decoration of the use of natural wood as much as possible, the purchase of qualified products in line with national standards, and the use of biological, physical, chemical methods to remove formaldehyde. The late treatment of indoor formaldehyde pollution mainly goes through mechanical method, physical method, chemical method and biological method.

3.2.1 Ventilation and ventilation purification method

Ventilation is the earliest method used to remove formaldehyde and other indoor harmful gases. It is simple, effective and economical to open Windows for ventilation or install ventilation and air exchangers to strengthen ventilation and air exchange, dilute indoor air pollutants with outdoor fresh air and reduce their concentration. According to the size of the source of pollutants, the types of pollutants and the amount of pollutants, it is decided to adopt comprehensive ventilation or local ventilation, and the size of ventilation.

Just after the decoration, the maximum amount of pollution is released. At this time, the effect of what deodorant is not better than where to go. The best way is to open the window for ventilation. The new house must be ventilated every day after decoration. Just after the decoration, the maximum amount of pollution is released. At this time, the effect of deodorant is not much better. The best way is to open the window for ventilation, as shown in Fig. 3.1. The new house must be ventilated every day after decoration.

Figure 3.1 – Open the window for ventilation

Opening Windows can cause turbulence in air flow, which can carry odors from the bathroom and kitchen into the living room and bedroom. Toilet shaft may produce odor "backfilling" phenomenon; Outdoor air enlivens a large number of outdoor dust, affecting indoor sanitation; Heating can cause a lot of waste of energy, waste of electricity.

Ventilation fan can continuously eliminate indoor odor, can not fully meet the replacement demand of indoor fresh air; Cheap price, late maintenance cost is very small; Continuous ventilation for 24 hours; Loud noise; When there is no fresh air, exhaust resistance increases and the effect is not good. The exhaust fan has large air volume and limited operating range.

This method is mainly used in light pollution occasions, can not play a role in purifying more than moderate indoor pollution, and sometimes will bring outdoor pollutants into the room. In addition, mechanical ventilation has little effect on formaldehyde concentration, and with the increase of ventilation volume, the effect of ventilation on reducing formaldehyde concentration is weakened. This is because indoor formaldehyde concentration is not only related to the formaldehyde content and release rate of articles, but also related to temperature and humidity. The increase of ventilation volume, on the one hand, can reduce the concentration of formaldehyde through air exchange, on the other hand, it may accelerate the release rate of

formaldehyde because of the increase of indoor temperature and humidity, and make formaldehyde soluble in water mist in the room. Therefore, although this method is simple and economical, it has certain limitations.

3.2.2 Physical Technology

Physical technology mainly includes physical adsorption technology, catalytic technology, air negative ion technology and non-equilibrium plasma technology.

Physical Adsorption Technology

Activated Carbon adsorption method

The simple use of activated carbon adsorption of formaldehyde is easy to make the adsorption of carbon particles reach saturation. At present, researchers mostly seek the modification of activated carbon, and use the synergistic effect of physical adsorption and chemical reaction after modification. Yao Weiyi et al. from East China University of Science and Technology studied activated carbon fiber (ACF) products with different specific surface areas, pore structures and oxygen-containing functional groups obtained by heat treatment and oxidation modification. It was concluded that the content of formaldehyde absorbed by the oxidized modified adsorbent increased. Boehm titration experiment and regression analysis showed that the increase of the number of acidic oxygen-containing functional groups (phenolic hydroxyl group, lactone group, carboxyl group, etc.) was the main reason for the improvement of formaldehyde adsorption capacity of ACF samples. Acidic oxygen-containing functional groups rich in C=O, C-OH and other hydrophilic groups are very favorable for formaldehyde adsorption. Among them, the improvement of concentration HNO_3 is the most obvious, and the penetration capacity after modification is 58.21 mg/g, which is 2.5 times of that of the unmodified sample. The study of Liu Yaoyuan and Zou Changwu [14] also concluded that the modified treatment could increase the average pore diameter of activated carbon and prolong the adsorption time and capacity by increasing the surface acid functional group content. CAI Linheng [15] used $KMnO_4$ /$MnSO_4$ to modify bamboo charcoal.

Bamboo charcoal before and after modification was used for formaldehyde adsorption. At the same time, the influence of initial concentration of formaldehyde solution, dosage of adsorbent, adsorption temperature and adsorption time on formaldehyde adsorption performance of bamboo charcoal before and after modification was investigated, and the concentration of formaldehyde solution was 42 mg/mL. Under the conditions of dosage of modified bamboo charcoal 17 mg/mL, temperature 313 K and adsorption time 5 h, the adsorption effect of formaldehyde is the best, reaching 50.25 mg/g. Zhu Yan, Li Liang et al. [16] modified activated carbon with ammonium salt and alkali salt and discussed the efficiency of removing indoor low concentration formaldehyde after modified activated carbon. The results show that the secondary modification of activated carbon improves its adsorption efficiency, and the effect of modification is positively weighted.

In air purification technology, physical adsorption technology refers to activated carbon air purification technology.

Activated carbon is high carbon content and more developed gap materials, such as coal, fruit shell, wood, bone, petroleum residue as raw materials, first through carbonization, and then after 800 to 1500 degrees of high temperature activation treatment, the formation of a developed aperture, specific surface area has a certain adsorption capacity of purification products. Physical adsorption technology can be used for: air purification, decolorization, sewage treatment, heavy metal recovery and other aspects, is very widely used, is the most developed science and technology of adsorbent materials.

The basic principle of physical adsorption technology:

(1) Its own unique pore structure

Activated carbon is a kind of microcrystalline carbon material mainly made of carbon materials with black appearance, developed internal pore structure, large specific surface area and strong adsorption capacity. Activated carbon material has a large number of invisible micro-pores, 1 gram activated carbon material in the micro-pores, the surface area can be up to 800-3000 square meters after the expansion, higher for special purposes. That is, in an activated carbon particle the size of a grain

of rice, the internal surface area of the micropores could be the size of a living room. It is these highly developed, such as human capillaries like pore structure, so that activated carbon has excellent adsorption performance.

(2) Interactions between molecules

Intermolecular forces are also called van der Waals gravitation. Although the speed of molecular motion is affected by temperature and material, it is always in constant motion in the microenvironment. Due to the mutual attraction between molecules, when a molecule is captured by the activated carbon inner pore into the activated carbon inner pore, due to the mutual attraction between molecules, will lead to more molecules continue to be attracted, until fill the activated carbon inner pore so far.

Air purification activated carbon use method: air purification activated carbon for about 20 days, in the sun after 3-5 hours, can be used repeatedly, so can be used for 6-10 months. This step is necessary, air purification activated carbon pores are limited, after a period of time will be saturated, especially a large number of water molecules occupy the air purification activated carbon in the larger space. Therefore, we must regularly explode the sun, so that the air purification activated carbon water molecules evaporation.

Advantages and disadvantages of activated carbon:

(1) Safe, no side effects, long duration of purification.

(2) Easy adsorption saturation, if not timely exposure, may cause secondary pollution.

(3) Purifying the air treats the symptoms rather than the root causes, and can not purify the air from the source.

(4) It is suitable for mild pollution and has limited effect on severe pollution.

(5) For the new house in urgent need of accommodation, it is suggested to combine with other treatment methods, such as the simultaneous use of plant decontamination method: placing plants such as chlorophytum, tigertail orchid and aloe vera; Or use plant extracts as raw materials for pollution control products.

Physical adsorption, also known as van der Waals adsorption, is caused by the intermolecular force between the adsorbent and the adsorbent, which is also known as van der Waals force. Since van der Waals forces exist between any two molecules, physical adsorption can occur on any solid surface.

The molecules on the surface of the adsorbent retain a free force field to attract the adsorbent due to the lack of equilibrium of the action force. Since it is the adsorption caused by the intermolecular suction, the binding force is weak, the adsorption heat is small, and the adsorption and desorption speed are both faster. The adsorbed substance is also easier to desorption, so the physical adsorption is reversible to a certain extent. Such as: activated carbon adsorption of many gases, the adsorption of the gas is easy to release without a change in nature. Adsorption on the solid surface of the gas molecules, do not produce chemical reactions with solids, this adsorption is called physical adsorption, physical adsorption is characterized by: adsorption heat is small, adsorption speed, non-selective, reversible, usually occurs at the temperature close to the gas liquefaction point, is generally multilayer adsorption.

The same substance may undergo physical adsorption at low temperature and chemical adsorption at high temperature, or both. The size of the adsorption is closely related to the nature of the adsorbent and the size of the surface, the nature of the adsorbent and the size of the concentration, and the temperature. Such as activated carbon surface area is large, strong adsorption; Activated carbon is easy to absorb high boiling point gas, difficult to absorb low boiling point gas.

Adsorption by physical force between molecules of adsorbent and surface atoms or molecules of adsorbent. This physical force is the Van der Waals force, which includes dispersion force, electrostatic force, and induction force. For adsorbent and adsorbent with little polarity, dispersion force plays a major role in physical adsorption. When polar molecules interact with the adsorbent surface with static charge, or the adsorbent interacts with the adsorbent surface molecules, resulting in changes in the electronic structure of the two dipole moments, the orientation force and induction force also play an important role in physical

adsorption. Sometimes the adsorbent molecules and the adsorbent surface in the form of hydrogen bond physical adsorption.

Physical adsorption has the following characteristics: (1) The physical adsorption of gas is similar to the liquefaction of gas and condensation of vapor, so the heat of physical adsorption is small and similar to the heat of liquefied gas; (2) The higher the boiling point of gas or vapor or the lower the saturated vapor pressure, the easier they are to liquefy or condense, the greater the physical adsorption capacity; (3) Physical adsorption generally does not require activation energy, so the adsorption and desorption rates are faster; Any gas on any solid as long as the temperature is suitable for physical adsorption, no selectivity; (4) Physical adsorption can be single-molecular layer adsorption, can also be multi-molecular layer adsorption; (5) The structure of adsorbed molecules changes little, no new chemical bonds are formed, so there is no new absorption peak on the infrared and ultraviolet spectra, but there can be displacement; (6) Physical adsorption is reversible; (7) The adsorption of solids from solution is mostly physical adsorption.

Physical adsorption in the chemical industry, petroleum processing industry, agriculture, pharmaceutical industry, environmental protection and other departments and fields have a wide range of applications, the most commonly used from the gas and liquid medium to recover useful substances or remove impurities, such as gas separation, gas or liquid drying, oil decolorization. Physical adsorption is of special significance in heterogeneous catalysis. It is not only a prerequisite for heterogeneous catalytic reaction, but also the principle of physical adsorption can be used to measure the surface area and pore structure of the catalyst. These macroscopic properties are useful for preparing excellent catalysts, comparing catalytic activity, and improving the diffusion conditions of the reactants and products. The selection of catalyst support and catalyst regeneration plays an important role.

Physical adsorption in gas purification is mainly a variety of air purifiers. This kind of product is mainly the strong adsorption of activated carbon adsorption of suspended matter in the air, indoor formaldehyde and other pollutants have a certain purification effect. Commonly used adsorbents are porous carbon materials,

honeycomb activated carbon, spherical activated carbon, activated carbon fiber, new activated carbon and molecular sieve, zeolite, porous clay ore, activated alumina and silica gel. This method is simple and easy to popularize, but the adsorbent needs to be replaced regularly.

Activated carbon can absorb harmful substances, which is black powder or block, granular, honeycomb shaped amorphous carbon, such as Fig. 3.2. But don't immediately assume that activated charcoal will make your home tasteless. Activated carbon lasts for 3 to 6 months, after which it saturates and becomes inactive.

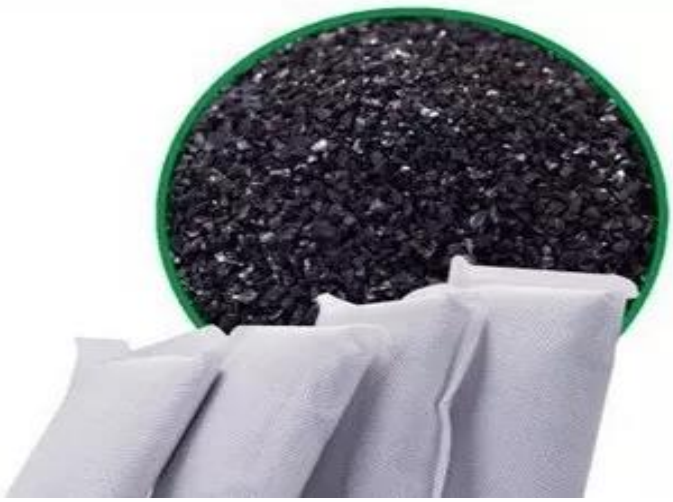

Figure 3.2 – Activated Carbon

Activated carbon is a kind of microcrystalline carbon material made of carbon material with developed internal pore structure, black appearance, strong adsorption capacity and large surface area. And activated carbon also contains many micropores that we can't see with the naked eye, and these micropores have great uses. It is the excellent pore structure of activated carbon, so it has a strong adsorption function. However, due to the inability to decompose formaldehyde, soon the capacity of the gap will disappear, formaldehyde rebound. Therefore, in order to avoid more serious harm after the formaldehyde rebound, it is recommended to replace it between 25 and 1 month.

Molecular sieve adsorption method

Molecular sieve adsorption has stronger adsorbability and can recover better performance after activation. Li Cuihong [17] analyzed the adsorption performance of various adsorption materials, selected zeolite molecular sieve adsorbent for formaldehyde adsorption study, compared the adsorption capacity of activated carbon, activated alumina, HZSM-5 molecular sieve and so on, and concluded that the performance of HZSM-5 molecular sieve was the strongest, which confirmed that the polar adsorbent was more conducive to the adsorption of formaldehyde molecules. Niu Yonghong, Wang Zhongsheng et al. [18] made fly ash zeolite molecular sieve with waste fly ash as raw material and tested its purification performance for formaldehyde in indoor air. The effects of different air temperature, relative humidity, air flow velocity and different formaldehyde content on indoor air formaldehyde purification were studied. The results showed that reducing indoor air temperature, increasing humidity and controlling air flow rate were beneficial to strengthen indoor formaldehyde gas purification effect. When the adsorption temperature was 12ºC, the maximum adsorption capacity of formaldehyde was 1.36 mg/g. When the relative humidity was 40%, the maximum adsorption capacity of formaldehyde was 1.25 mg/g. When the air flow rate is 4 m/s, the maximum adsorption efficiency is 0.675 mg/(g·h). When the formaldehyde content is 0.75 mg/g, the maximum removal rate of formaldehyde gas is 83%. Lv Shuangchun et al., Key Laboratory of Indoor Environmental Control of Tianjin University, used stone runner and regenerative combustion (RTO) or catalytic combustion (RCO) VOCs treatment technology to comprehensively discuss the improvement of Si/Al ratio of molecular sieve, and also analyzed the application of high silicon molecular sieve. Li Huifang et al., Central South University, carried out static adsorption experiments on 4 molecular sieves of 3A, 5A, 13X and MCM-41. The effects of specific surface area, pore size, cation and skeleton structure on the adsorption properties of 5A and 13X zeolites were studied

The results show that the cation and skeleton structure can greatly affect the formaldehyde adsorption performance of molecular sieve. The adsorption properties

of the two molecular sieves have good reproducibility after activation and regeneration.

The modification of molecular sieve is also one of the key research fields in China. Xiao Yanhua took X-type small-grain molecular sieve as the main body to study its adsorption properties of formaldehyde gas under the conditions of drying, calcination and microwave modification. The results showed that the adsorption efficiency of microwave, calcined and dried zeolites for formaldehyde was 99.51%, 85.25% and 61.63%, respectively. Sun Jianping et al., Beijing Institute of Technology, modified 13X zeolite molecules by Ca^{2+} exchange using aqueous solution ion exchange method, and then studied the adsorption performance of 5A, ZSM-5, 13X and CaY zeolite zeolites, and found that CaX zeolite had a higher adsorption capacity of formaldehyde and a longer penetration time. It is concluded that the pore size of zeolite and the cation in zeolite skeleton play a major role in improving the adsorption property of formaldehyde.

Silica adsorption method

Some scholars have studied the use of silica aerogel for formaldehyde adsorption, and also achieved good results. Wang Junting [19] prepared low molecular weight chitosan/silica aerogel (viscosity-average molecular weight 3k Da), high molecular weight chitosan/silica aerogel (viscosity-average molecular weight 200k Da) and O-carboxymethyl chitosan/silica aerogel respectively through amination and acid treatment. Pore size analysis and adsorption experiment results showed that After amination and acid treatment, the adsorption effect of the composite gel on gaseous formaldehyde was significantly enhanced, and the saturation adsorption capacity of O-carboxymethyl chitosan/silica aerogel was greater than that of activated carbon material with the same dosage.

Zeolite

Zeolite is a kind of microporous crystalline aluminum silicate. Because of its strong adsorption capacity, high temperature stability and recycling advantages, zeolite is often used as catalyst, molecular sieve and adsorbent in academic research and industrial base trimethyl ammonium chloride for organic modification of zeolite,

which significantly improves its adsorption performance to formaldehyde. Kalantarifard et al. [20] prepared modified clinoptilolite with macroporous surface structure by adding alkaline earth metals, bentonite, starch and granite, whose adsorption capacity of formaldehyde is much higher than that of commercial clinoptilolite. Niu Yonghong et al. made a zeolite molecular sieve of fly ash by alkali melting-hydrothermal method, and the formaldehyde removal rate was 83% when the relative humidity was 40% and the air flow rate was 4 m/s.

Metallic Organic Framework (MOFs)

Metal-organic frames (MOFs) are a new type of porous crystal materials, which are considered ideal for gas storage, adsorption, sensing and catalysis due to their very large surface area, ordered crystal structure and adjustable pore size. Pei et al. heat treated MIL-100 (Fe) connected by trimers of iron octahedron and carboxylate in N2 atmosphere to prepare a series of ferri-based MOFs. When the calcination temperature is 350ºC, the carbonized M-350 is obtained. Compared with pure MIL-100 and commercial porous adsorbent, it has the best adsorption performance and excellent stability for formaldehyde, methanol and other VOCs [21]. Wang et al. studied a metal-organic framework made of gamma-cyclodextrin and potassium ion. As an excellent formaldehyde adsorbent, its adsorption capacity and adsorption rate are about 9 times that of activated carbon. PHU et al. modified the open metal site of MIL-101 with ethylenediamine and obtained a modified MIL-101 MOFs material with adsorption capacity of 5.49 mmol/g for formaldehyde. In addition, the modification also improves the material's recyclability and water resistance, revealing the potential use of amine-modified MOFs in indoor air purification [22]. Although the physical adsorption method is simple and economical, the adsorption capacity of the adsorbent is limited, and the adsorbent needs to be updated and maintained regularly. This shows that the physical adsorption method only transfers formaldehyde from indoor air to the adsorbent, and the subsequent steps are still needed to completely decompose and eliminate the adsorption of formaldehyde.

Catalytic technology

Catalytic technology is also known as cold catalyst technology, while adsorption decomposition, improve the adsorption of pollution particles, adsorption efficiency and saturation capacity, no secondary pollution, and the life of the adsorption material is more than 20 times that of ordinary materials, more targeted, can catalyze the decomposition of indoor formaldehyde and other harmful gases.

Cold catalyst is a kind of high-tech catalyst, it can be adsorbed on formaldehyde at room temperature edge decomposition, effective decomposition of formaldehyde and other toxic gases in the air into pollution-free carbon dioxide (CO_2) and water (H_2O) [23], so that indoor air more green and healthy. It can not only catalyze the reaction of formaldehyde with oxygen in the air, but also catalyze the reaction of ammonia, toluene, xylene, hydrogen sulfide and a variety of harmful gases in TVOC with oxygen at room temperature to produce water and carbon dioxide. At room temperature and pressure to decompose a variety of harmful odor gases into harmless odorless substances, from simple physical adsorption into chemical adsorption, adsorption edge decomposition, removing formaldehyde, benzene, xylene, toluene, TVOC and other harmful gases, water and carbon dioxide generation. In the process of catalytic reaction, the cold catalyst itself does not directly participate in the reaction. After the reaction, the cold catalyst does not change or lose, and plays a long-term role.

Cold catalyst itself is non-toxic, non-corrosive, non-combustion, reaction products for water and carbon dioxide, no secondary pollution. Is facing the future, the most suitable for healthy home safety, environmental protection products.

Several characteristics of cold catalyst:

(1) Natural catalytic cold catalyst: the catalytic decomposition reaction of cold catalyst does not require ultraviolet light, high temperature and high pressure. In the normal living environment can play a catalytic effect to control pollution.

(2) Can decompose a variety of harmful gases: cold catalyst can catalyze formaldehyde, ammonia, benzene, TVOC, hydrogen sulfide and other harmful gases to react with oxygen in the air, catalyze, generate water and carbon dioxide.

(3) Long-term effect: in the process of catalytic reaction, the cold catalyst product itself does not directly participate in the reaction, the cold catalyst does not change or lose after the reaction, so once used without external damage, the period of validity is more than five years, basically synchronized with the formaldehyde release period, long-term effect of formaldehyde treatment is good.

(4) Safety and environmental protection: the main ingredients of cold catalyst are food and drug additives, and the products are non-toxic, non-corrosive and non-flammable; It can catalyze the reaction at room temperature and remove formaldehyde, benzene, xylene, toluene, TVOV and other harmful gases. The reaction product is water and carbon dioxide, and does not produce secondary pollution. Is facing the future, the most suitable for healthy home safety, environmental protection products.

(5) Wide use: cold catalyst can be used to deal with artificial board, furniture, wall wallpaper, chemical fiber carpet, curtain, bedspread and free formaldehyde, ammonia, TVOC, hydrogen sulfide and other harmful gases in the indoor air.

The traditional catalytic decomposition needs to be completed at a certain temperature (generally above 200ºC), and the operation cost is high. Plasma catalysis technology is the combination of plasma technology and catalytic decomposition, the use of high frequency, high voltage current to produce ion fragments, can decompose harmful gases at normal temperature and pressure, its advantage is that almost all harmful gases have a high purification efficiency, the disadvantage is easy to produce carbon monoxide, ozone and nitrogen oxides, need to increase further oxidation and alkali absorption of the post-treatment process, And the equipment that produces the plasma is expensive. Photocatalysis technology is a method to purify pollutants based on the REDOX ability of photocatalyst under ultraviolet irradiation. Photocatalysts belong to semiconductor materials, including TiO_2, ZnO_2, Fe_2O_3, CdS and WO_3, etc.

The advantages of photocatalysis technology are as follows: (1) it can occur under ultraviolet irradiation or solar irradiation; (2) The reaction occurs quickly and takes a few minutes or hours; (3) The reaction products are CO_2, H_2O and inorganic salts, which will not cause secondary pollution; (4) photocatalytic oxidation has no

selectivity; (5) The temperature required by the reaction is low, room temperature can be; (6) the catalyst is non-toxic; (7) Simple equipment and low cost. Therefore, more and more attention has been paid to photocatalysis technology for air pollution control, and it has become a hot topic in the research and development of air pollution control technology.

Air negative ion technology

In 1889, German scientists Elster and Geitel first discovered the existence of negative air ions (NAI). In the late 19th century, German physicist Dr. Philippe Leonard proved the effect of negative oxygen ions on the human body for the first time. Aschkinass and Caspari further confirmed NAI's biological significance in 1902. The world's first medical NAI generator was born in the United States in 1932.

In July 2020, Dr. Zhang Xiaohao, director of the Advanced Manufacturing Research and Development Center of Tianjin High-end Equipment Research Institute of Tsinghua University, and his team successfully developed a healthcare grade high concentration negative oxygen ion generator, which can form a uniform and dense nanoparticle layer on the wall just by spraying on the wall of the room, so that the indoor wall can release high concentration small particle size negative oxygen ions in a stable and long-term. At present, the achievement has obtained the national patent. Maximizing the effect of nanoscale tourmaline powder by sticking it uniformly and compactly on the surface of an object is a key point of the technology. Seven papers on the results have been published in SCI journals such as Acta Physica and Microfluidics and Nanofluidics. This technology is the first of its kind in China, and fills the gap of efficient anion generation materials which are colorless and transparent. Compared with the current widely used high voltage ionization technology, the process of producing negative oxygen ions by this technology does not require energy consumption, and the small particle size of negative oxygen ions account for a higher proportion, and effectively avoids the problem of ozone associated with high voltage power technology.

Air ion refers to the charged fine particles floating in the air. Its formation is due to the effect of external forces on the electrically neutral gas molecules, which

lose or gain electrons. Those who lose electrons are positive ions and those who get electrons are negative ions. Air negative ion technology is to decompose water molecules into positive and negative ions by ion generator high voltage discharge. Since water molecules are wrapped to form positive and negative ion groups, the positive and negative ion groups floating around in the air with water molecules as the carrier can immediately surround and isolate bacteria, mold, viruses and other harmful substances. Then the most active hydroxide ion in the positive and negative ion group carries out a violent chemical reaction with these harmful substances, and finally they are completely decomposed into harmless substances such as water molecules.

Air negative ion technology mainly selects rare mineral stone with obvious thermoelectric effect as raw material to be added to the wall material in contact with the air, ionized air and water in the air to produce negative ions can be polarized, and discharge outward-play the role of purifying indoor air. Air negative ions can be attached to solid or liquid phase pollutant particles, form large ions and settle down, can reduce the concentration of air pollutants, play the role of purifying air; At the same time, the number of negative ions in the air is also lost. In the environment with high concentration of formaldehyde, if the negative ions lost by formaldehyde are not compensated in time, there will be imbalance of positive and negative ion concentration, high concentration of positive ions in the air, which makes people uncomfortable. Therefore, in this kind of environment, artificial negative ions to compensate for the continuous consumption of negative ions by pollutants, maintain the balance of positive and negative ions, and constantly remove pollutants.

Air negative ion technology mainly uses rare mineral stone with obvious thermoelectric and piezoelectric effect as raw material, added to the wall material, decoration after brushing, in the process of contact with the air, ionized air and water in the air, negative ions, materials can be polarized, and can discharge outwards, to purify the indoor air.

Non-equilibrium plasma technology

Plasma is an open flowing system in which external energy is applied to a molecular gas to continuously produce active non-molecular particles. The energy states of plasma electrons and ions in the plasma surface processor are generally divided into Te≈Ti and Te, and Te (electron temperature Te and ion temperature Ti). The former is called equilibrium plasma or high temperature plasma, the latter is called non-equilibrium plasma or low temperature plasma.

Non-equilibrium plasmas are generally generated at low atmospheric pressure, when the molecular spacing is large, electrons are accelerated over long distances in space, and the kinetic energy can easily reach a high energy of 10-20eV. This accelerated electron and gas molecules occur inelastic collision, so that the molecular orbital fracture, so that the molecular excitation, dissociation, ionization, generating a large number of ground state or excited state atoms and charged particles. In this case, the electrons have higher kinetic energy and the other heavy particles have lower temperatures, so the system is in a non-equilibrium state. The particles in non-equilibrium plasma have very high chemical activity in plasma surface processor. The use of plasma hydrogen to reduce metal oxides, especially the metal oxides with high melting point which are very difficult to reduce, provides a potential possible way.

Non-equilibrium plasma technology is a process in which electrons, atoms, molecules and free radicals with high reactivity generated by gas discharge react with various organic and inorganic pollutant molecules to decompose pollutant molecules into small molecular compounds. Non-equilibrium plasma can be produced by glow discharge, corona discharge, dielectric barrier discharge and radiofrequency discharge, among which pulsed corona plasma discharge and dielectric barrier discharge have achieved initial success in the treatment of formaldehyde gas due to their simple process, low energy consumption and high treatment efficiency.

3.3 Chemical technology

Chemical technology is mainly the use of oxidation, decomposition, complexation and other principles of air purifier, formaldehyde trapping agent to purify the air, including ozone oxidation method, chlorine dioxide oxidation method and metal oxide method.

Ozonation method

Ozone is a strong oxidant, its oxidation capacity is second only to fluorine, than oxygen, chlorine and permanganate and other commonly used oxidants are higher. Under ideal reaction conditions, ozone can oxidize most of the elements and compounds in aqueous solution to their highest oxidation state, has a strong oxidation degradation of organic matter in water, as well as strong disinfection and sterilization.

Ozone has strong oxidizing ability, decomposition of formaldehyde, benzene and other TVOC into non-toxic products CO_2 and O_2. Ozone oxidation method is very effective for formaldehyde in the new house, and ozone can be reduced to oxygen at room temperature for about 30 minutes, so there is no need to worry about secondary pollution and other problems. Ozone oxidation ability, decolorization, deodorization, sterilization, removal of organic matter and inorganic substances effect, no secondary pollution, preparation of ozone only air and electricity, easy operation and management;

Ozone reacts with polar organic compounds such as formaldehyde, resulting in the rupture of unsaturated organic molecules, so that ozone molecules combine with the double bond of organic molecules, generating ozonides, so as to achieve the purpose of decomposing formaldehyde molecules. Ozone has a certain effect on purifying formaldehyde pollution in indoor air, but the effect is not very ideal. The reasons may be: on the one hand, the chemical reaction rate of O_3 with formaldehyde is slow, and the rate constant is less than 2.l×10-24cm^3/(mol·s) at 25ºC; On the other hand, O_3 may reform formaldehyde when it reacts with other organic matter in indoor air. In addition, in the case of ozone decomposition and purification of indoor pollutants such as formaldehyde, there may be new indoor air pollution, stimulate people's respiratory system, serious harm to the human body, and ozone itself is a

kind of air pollutant, the national also has the corresponding limit standard. So if the amount is not well controlled, it will backfire [24].

Chlorine dioxide oxidation method

Chlorine dioxide disinfection refers to a method of adding chlorine dioxide into water to complete oxidation and disinfection. Chlorine dioxide has the functions of sterilization, bleaching, deodorization, disinfection and preservation.

Action mechanism of chlorine dioxide oxidation method: It is mainly dependent on the oxidation of chlorine dioxide. The electronic structure of chlorine dioxide molecules is unsaturated, with 19 electrons in the outer layer. It has a strong oxidation force. So as to achieve its purpose.

(1) bactericidal mechanism: chlorine dioxide has strong adsorption and penetration ability to cell wall, and releases atomic oxygen to oxidize sulfhydryl enzymes in cells to play a bactericidal role.

(2) Bleaching: The bleaching of chlorine dioxide achieves the purpose of decomposing pigment by releasing atomic oxygen and producing hypochlorite. Use it as bleach instead of chlorine gas, chlorate, etc., can prevent and avoid oxidation with fiber and reduce fiber strength, so the effect is more comprehensive.

(3) Deodorization: The deodorization of chlorine dioxide is because it can dehydrate with odor substances (such as H_2S, -SOH, -NH_2, etc.) and make odor substances rapidly oxidize and transform into other substances. And it prevents methionine from breaking down into ethylene, and it also destroys the ethylene that has been formed, thereby delaying decay and killing microorganisms without reacting with fatty acids and destroying the food structure.

(4) disinfection effect: the oxidation of chlorine dioxide can transform toxic substances into non-toxic substances.

The use of chlorine dioxide as oxidant to eliminate formaldehyde is rarely reported. However, many of the listed formaldehyde removers use chlorine dioxide as the main component. Theoretically speaking, the oxidation property of chlorine dioxide can oxidize and decompose formaldehyde molecules, but the effect is not obvious in practical application. At the moment of the occurrence of high

concentration of chlorine dioxide gas, the concentration of formaldehyde decreased significantly, but soon recovered, the concentration and persistence of chlorine dioxide is difficult to control, its effect of eliminating formaldehyde gas should be carefully studied experimentally.

Chlorine dioxide is a strong oxidant and a new type of highly efficient bactericidal disinfectant, which is listed as AI grade disinfectant by World Health Organization (WHO). Chlorine dioxide is highly oxidizing because it has an outer electron of 19 and an unpaired electron. Chlorine dioxide is superior to chlorine in the field of sterilization and disinfection because its reaction with organic matter is not carcinogenic. Teratogenic and mutagenic organic halogens have a wide range of applications. At present, it has been reported that chlorine dioxide is used to eliminate formaldehyde in the air and wood-based panels. Chlorine dioxide can also kill all microorganisms after disinfection, leaving no residual toxicity on the articles. However, due to its strong oxidation capacity, high concentration can stimulate, damage the skin and mucous membrane corrosion articles, so the concentration must be controlled when using.

Metal oxide method

Metal oxide is a binary compound composed of oxygen element and another metal chemical element, such as iron oxide (Fe_2O_3), sodium oxide (Na_2O) and so on. Oxides include basic oxides, acid oxides, peroxides, superoxides and amphoteric oxides.

Basic oxides are oxides that react with acids to form salts and water. Basic oxide must be metal oxide, calcium oxide, sodium oxide, magnesium oxide, barium oxide, iron oxide, copper oxide and other most metal oxide is alkaline oxide, alumina, zinc oxide and other exceptions, for amphoteric oxide, can not say that metal oxide must be alkaline oxide, such as Mn_2O_7 is metal oxide, but it is acidic oxide, the corresponding acid is permanganic acid.

Active metal oxides are ionic compounds that form ionic crystals and have high melting and boiling points.

Metal oxides are a kind of important catalysts, which have been widely used in the field of catalysis. After metal oxides are nano-sized, their catalytic performance is better. It can be predicted that nano-metal oxides will be an important direction of catalyst development.

Metal oxides are widely used in daily life. Quicklime is a commonly used desiccant and can also be used for disinfection; Iron oxide (Fe_2O_3) commonly known as iron red, can be used as red pigment; Catalysts used in some industrial processes are also metal oxides. Metal oxides are compounds that combine metal elements with oxygen. All metals, including platinum and gold, have corresponding metal oxides. Variable metal generally has a variety of oxides, for example, iron has ferrous oxide (FeO), iron oxide (Fe_2O_3) and ferric oxide (Fe_3O_4) (can be approximated as $FeO \cdot Fe_2O_3$).

Metallic oxide (metallic oxide, except for a few metallic oxides which are liquid, such as Mn_2O_7) is generally solid at room temperature. Metallic oxides dissolve in water to form bases, for example:

$$Na_2O + H_2O = 2NaOH$$

Less reactive metal oxides are insoluble in water, but most are soluble in acids:

$$CuO + H_2SO_4 = CuSO_4 + H_2O$$

Some metal oxide sources and minerals, for example, iron oxide is the main component of hematite, rare earth metal mineral composition is mainly their oxides; Other oxides can be prepared by decomposition reactions, for example, the preparation of quick lime (CaO), an oxide of calcium. Common ones are ionic crystals and atomic crystals, for specific substances. Most metal oxides are ionic crystals, with some exceptions. Alkaline earth metal oxides are typical ionic crystals. Beryllium oxide is an exception, close to atomic crystals. It can be roughly judged by electronegativity, but it also depends on the situation, for example, aluminum oxide has two different types of ionic crystals and atomic crystals.

Various modern physical and chemical experimental methods, such as scanning microscopy, X-ray photoelectron spectroscopy, temperature programmed desorption techniques, Mossbauer resonator X-ray diffraction, infrared or laser man

spectroscopy, nuclear magnetic resonance, paramagnetic resonance, etc., can be used to study the structure of catalysts. It includes surface structure, composition, type of active center, valence state and chemical environment of active component, configuration of adsorption state and so on. Selective oxidation of catalysts composed of various metal oxides is the main content of metal oxide catalysis [25].

The surface of metal oxide generally has surface hydroxyl and other adsorbent. In the atmosphere at room temperature, water is usually adsorbed on the surface of metal oxides, and in most cases, hydroxyl is eventually dissociated. Surface hydroxyl groups play an important role as acids or bases in adsorption and catalytic reactions. In addition, various surface reactions can occur. There are two types of bond in metal oxides: M-O-M and M=O. Compounds without M=O chain such as manganese dioxide (MnO_2) are catalysts for deep oxidation. Some data show that MnO_2 has the strongest oxidation ability under acidic conditions.

In current reports, only Sekine et al. in Japan used a mixture of activated carbon and metal oxides (mainly transition metal oxides) of a certain proportion to treat indoor formaldehyde under normal temperature, atmospheric pressure and no light conditions. In his study, he found that the removal rate of formaldehyde by cobalt oxide (CoO), MnO_2 and TiO_2 was more than 50%. And zinc oxide (ZnO), vanadium pentoxide (V_2O_5) and formaldehyde did not react. In the study, it was also found that MnO_2 and formaldehyde had the highest reactivity among all metal oxides, and could reduce the indoor formaldehyde concentration from 0.33 mg/m^3 to 0.049 mg/m^3. The main product is CO_2, and no harmful side gases CO and formic acid (HCOOH) are generated during the reaction. The metal oxide method has mild reaction conditions, simple operation and good removal effect, which has a promising development prospect. However, the method has not been thoroughly studied and the reaction mechanism is not clear yet.

Chemical neutralization technology

Chemical neutralization technology is also known as polymer polymerization reaction is at room temperature under the conditions of products in the water penetration driven into the pollution sources such as plate and low boiling point of

free formaldehyde neutralization reaction generated stable irreversible resin solid reaction process no volatile matter does not produce secondary pollution to solve the problem of free formaldehyde pollution sources. The irreversible resin fixative produced by the reaction is retained in the fine pores of volatilization of free formaldehyde to prevent the outside moisture from entering to reduce or even eliminate the problem of the decomposition of urea-formaldehyde resin adhesive in the water. But the method can only be used before spraying paint on artificial plates and the amount is difficult to master the late continuous distribution of harmful gases powerless and walls, floors, sofas and other places can not be used is a limited range of use, simple emergency treatment means can not achieve the purpose of permanent removal of formaldehyde.

Chemical neutralization technology generally uses complex technology to destroy the molecular structure of harmful gases such as formaldehyde and benzene, neutralize harmful gases in the air, and then gradually eliminate them. At present, experts have developed a variety of deodorant and formaldehyde trapping agent, which belongs to the technical class of products. This technology is best combined with decoration engineering, can effectively reduce the free formaldehyde in the wood-based panel.

When the formaldehyde efficient scavenger is sprayed to the surface of the plate, the formaldehyde efficient scavenger and the adsorption of formaldehyde on the surface of the plate will be complex into salt reaction, the production of stable substances will not hair so as to achieve the purpose of removing formaldehyde; Second: formaldehyde efficient scavenger can constantly penetrate into the interior of the plate, the adsorption of free formaldehyde inside the plate, the reaction occurs, and the formation of an isolation layer, play a closed role. The advantage of this technology is that it really treats the source, but the disadvantage is that if the product quality is not up to standard, there may be secondary pollution.

Photocatalytic oxidation method

Photocatalytic oxidation technology is based on the REDOX ability of photocatalyst under light conditions. It uses photoexcited electrons and holes

generated by semiconductor photocatalytic materials to participate in a series of oxidation-reduction reactions. Under the irradiation of the sun or visible light, the photocatalyst absorbs visible light to produce electron transition, and the photogenerated electrons in the valence band (CB) will migrate to the conduction band (VB), producing electron-hole pairs. Subsequently, photogenerated electrons (e-) and holes (h +) are transferred to the surface of the catalyst. Electrons in CB are conducive to the formation of adsorbated oxygen O_2 – active substance. h+ on VB makes the surface of the catalyst adsorb water to generate hydroxyl radical (·OH). Then the generated ·O2 - and h + stimulate the generated ·OH to attack the HCHO molecule, gradually breaking it down into CO2 and H2O. Compared with other methods to remove formaldehyde, it has the advantages of non-toxic, stable, sustainable, no secondary pollution and reusable. Its catalytic principle is shown in Fig. 3.3.

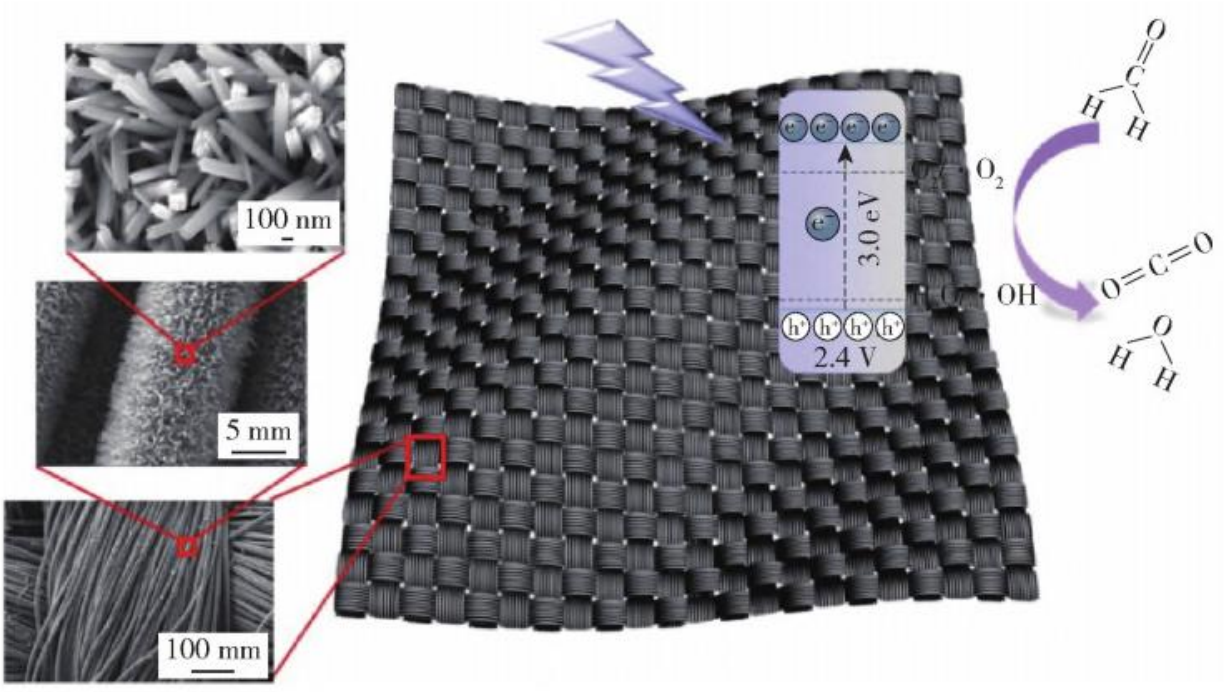

Figure 3.3 – Photocatalytic degradation of formaldehyde by fluorine-doped rutile TiO_2 nanorods arrays on carbon fiber cloth

Titanium series semiconductor photocatalytic materials

Titanium dioxide (TiO_2) is a kind of N-type semiconductor oxide. Because of its non-toxic, cheap and easy to obtain, good chemical stability and thermal stability, it has become a research hotspot in semiconductor photocatalytic materials. However, its high band gap energy (Eg anatase type = -3.2 eV) can only absorb ultraviolet light, which seriously restricts the practical application of photocatalytic oxidation technology in indoor air purification. Therefore, it is necessary to expand the optical response range of TiO_2 and improve its absorption capacity to visible light. Some researchers have found that the combination with precious metals (Pt, Au, Ag, Pd, Cu and Ru) can effectively improve the photocatalytic activity of TiO_2. For example, Bao et al. prepared a series of silver-doped Fe-TiO_2 catalysts (Ag@Fe-TiO_2) by ultrasonic hydrothermal method for catalytic oxidation of gaseous formaldehyde at room temperature. After repeated experiments, 0.6%Ag@0.3%Fe-TiO_2 showed good catalytic activity and stability, and the formaldehyde concentration could be reduced to 0.05 mg/m^3. After 4 repeated experiments, the formaldehyde concentration can still be reduced to 0.08 mg/m^3. Sun et al. synthesized a Rh /TiO_2 catalyst in which formaldehyde molecules could be adsorbed on the surface of TiO_2 through hydrogen bonding and quickly converted into methylenedioxy (DOM) and formate. O_2 is decomposed into O atoms on the Rh cluster surface, which can react with adsorbed formaldehyde molecules or H_2O adsorbed on the Rh surface to produce hydroxyl radicals (OH^-). The resulting OH^- can oxidize formate species into H_2O and CO_2. When the Rh loading capacity was 1.5%, the Rh /TiO_2 catalyst had high activity and could completely transform formaldehyde at room temperature. The transformation mechanism was shown in Fig. 3.4.

Photocatalytic technology is a general term for a photocatalytic photosemiconductor material represented by nano-scale titanium dioxide, namely photocatalytic technology, which is the most ideal material for air pollution control in the world.

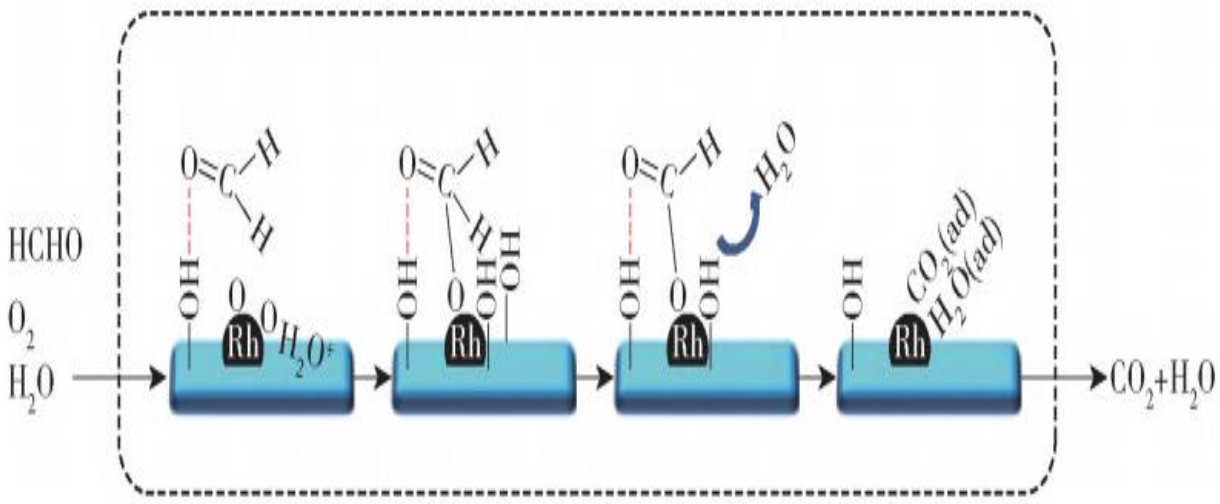

Figure 3.4 – The reaction mechanism for the HCHO oxidation under humidity condition over Rh/TiO_2

In the late 1960s, Akira Fujijima, a graduate student at the University of Tokyo in Japan, shone light on single crystals of titanium oxide placed in water and found that the water was broken down into oxygen and hydrogen. This is known as the "Hondo-Fujijima effect".

In the 1990s, the breakthrough development of nanotechnology made people pay more attention to this photocatalytic oxidation decomposition effect. All countries in the world have invested a lot of manpower and material resources in the preparation and application of various nanomaterials. After continuous research, it is found that titanium dioxide has high chemical stability and non-toxic properties among many photocatalytic materials. Nano titanium dioxide photocatalyst technology has gradually entered the market application out of the laboratory.

After nearly two decades of application test, titanium dioxide photocatalyst has been proved to be the most ideal material for air pollution control in the world, and has been widely used in Europe, the United States, Japan and other countries. It has the characteristics of safety, no secondary pollution, lasting action time, etc., the product of decomposition is water and carbon dioxide [26].

Photocatalytic technology function

(1) Purifying air: REDOX reduction can reduce most organic pollutants and some non-polar pollutants in the air, the product is water, carbon dioxide and some root ions.

(2) Odor removal: it can decompose and eliminate the odor produced by common organic matter in life.

(3) sterilization and disinfection: sterilization capacity is 99.99%, can kill the common bacteria and viruses in life, and can decompose the bacteria corpse and bacteria secrete toxins.

(4) Anti-mildew: in the plum rain season, photocatalyst spraying on fresh objects can prevent objects from mildew.

(5) Antifouling and self-regeneration: the use of photocatalyst superhydrophilicity, can prevent stains, dust adhesion.

Purification principle of photocatalytic technology

Photocatalyst is a kind of magic thing. When light (ultraviolet light, sunlight, light) is fired at the photocatalyst, its atoms will absorb the heat energy of light, and the ions inside the atoms will run faster. At this time, some ions will escape to the surface of the atom to form charged ions (e -) and holes (h+). Charged ions and holes combine with oxygen in the air to form superoxide anion radicals and active hydroxyl radicals. Both of these substances have strong REDOX capacity. They can seize and decompose organic matter on the surface of photocatalyst into carbon dioxide and water in an instant.

Photocatalytic oxidation method is to use photocatalyst to directly convert the absorbed light energy into chemical energy, which can oxidize indoor harmful organic pollution gas into CO and H_2O, so as to eliminate indoor air pollution. In the former market, various air purification products developed by photocatalytic technology generally include: a new generation of efficient green health products developed by adding photocatalytic purification function to the traditional air purifier; The photocatalyst is directly compounded on various structural materials to obtain new materials with photocatalytic function. A variety of clean luminaire made by directly compounding the photocatalyst to the outer wall of the lamp. The selection of

photocatalyst can be considered from the cost, chemical stability, photocorrosion resistance, photomatching and many other factors. Nano has the advantages of high activity, good thermal stability, cheap price and harmless to human body. The photocatalytic treatment of formaldehyde has the characteristics of mild reaction conditions, low energy consumption and less secondary pollution, so it has become a hot topic in the research and development of air pollution control technology. But its disadvantage is that it can only work under ultraviolet light. For this reason, people are studying photocatalytic materials which can use visible light as excitation source, but the removal efficiency obtained by current research is not ideal.

Since the 21st century, photocatalyst has been widely used in the fields of space, water resources, air purification and space sterilization in developed countries. However, due to the relatively high cost, the purification characteristics require very professional testing instruments for identification, and China's photocatalyst market lacks effective supervision. Since the 21st century, the application scope of photocatalyst in China is relatively narrow, limited to the field of household decoration pollution purification. Many people think that photocatalysts can only be used to remove formaldehyde. With the gradual standardization of domestic market supervision and people's increasing attention to environmental pollution, it is believed that photocatalyst will gradually be accepted by the public in the near future and become the backbone of air pollution purification [27].

Bismuth semiconductor photocatalytic materials

Bismuth photocatalytic material is a new type of photocatalytic material with narrow band gap, wide light absorption range and good visible light catalytic activity. It is because of this advantage that more and more researchers have applied it to the degradation of indoor organic pollutants and other fields. Common bismuth photocatalysts can be divided into bismuth dioxides (BiO_3), bismuth oxates ($BiVO_4$, Bi_2WO_6, Bi_2MoO_6), bismuth halide oxides (BiOCl, BiOBr, BiOI), etc. Yang et al. successfully synthesized a bismuth vanadate quantum tube (BVO-QTs) and loaded it on the reduced GO to obtain a composite aerogel, which can degrade formaldehyde from 1.0×10^{-6} to 4.0×10^{-5} in 15 min. Zhu et al. prepared a series of Ag /$BiVO_4$

photocatalytic agents loaded with silver nanoparticles of different morphology, and found that the 0.0003 wt.% silver doped triangular nano samples showed superior photocatalytic degradation of formaldehyde, and maintained more than 95% of the initial photocatalytic activity after five test cycles. Yu et al. prepared Bi_2WO_6 photocatalyst using $Bi(NO_3)_3$ and Na_2WO_4 as raw materials, after hydrothermal reaction at 150ºC for 24 h and calcination at different temperatures for 2 h respectively. The results show that the powder photocatalyst obtained by calcination at 500ºC crystallizes well, and the degradation efficiency of formaldehyde is 68.8% within 20 h. Sun et al. prepared two-dimensional ultra-thin Bi_2WO_6 nanosheets by hydrothermal method. After adding well-dispersed Pt nanoparticles, Pt-Bwo-Ns catalyst which could provide abundant surface active sites for formaldehyde adsorption was obtained, and the formaldehyde removal rate was 93% within 1 h [28].

Heterojunction semiconductor photocatalytic materials

The key of photocatalytic oxidation technology is to improve the visible light absorption and photogenic charge separation efficiency of photocatalytic material system. For one component semiconductor photocatalyst, its limited visible light absorption will limit its application in the degradation of indoor formaldehyde. Fortunately, in recent years, many researchers have proved that heterojunction photocatalytic system can be composed of two or more semiconductors with appropriate band gaps, and this method has become an effective strategy to improve the efficiency of photocatalysis. Graphene-like carbon nitride (g-C_3N_4) is a good candidate material for constructing heterojunction photocatalytic systems. Because it can provide a large number of reaction sites, modification of other semiconductors with g-C_3N_4 can effectively improve the visible light response and charge separation/transport performance, thus enhancing the photocatalytic performance. For example, Zhu et al. used hydrothermal co-assembly technology to construct TiO_2 / g-C_3N_4 heterojunctions by in-situ growing TiO_2 nanosheets on the surface of g-C_3N_4 nanosheets. This unique 2D/2D heterojunction has an ultra-thin thickness and a larger interfacial contact area, resulting in a shorter migration distance of photogenerated carriers to the surface and a faster rate of participation in photocatalytic

decomposition. RAN et al. synthesized a series of Ag_3PO_4 / g-C_3N_4 nanocomposites by combining g-C_3N_4 with Ag_3PO_4 with visible light response. The results show that Ag_3PO_4 / g-C_3N_4 nanocomposites can degrade continuous flow of gaseous formaldehyde for 600 h under visible light irradiation, and maintain stable photocatalytic activity after four consecutive cycles. Wu et al. successfully constructed a Z-type heterojunction photocatalyst of Bi_2MoO_6 /Bi /g-C_3N_4 by in-situ reduction method, and this heterojunction can effectively degrade gaseous formaldehyde with a concentration of 5.0×10^{-5} – 10×10^{-3}. And when the concentration of formaldehyde is higher than 2.0×10^{-4}, it shows good activity. In addition, in order to promote the effective separation of catalyst photocarriers, researchers tried to combine different kinds of titanium series, bismuth series, silver series and zinc series semiconductor photocatalysts to prepare a series of new photocatalysts with heterojunction structure. Hu et al. synthesized a new type of amorphous TiO2-Biobr-sepiolite composites rich in oxygen vacancies by hydrothermal method. Under visible light, the adsorption and photocatalytic removal ability of the composite to gaseous formaldehyde is enhanced, and the reaction rate constants are 11.75 times, 3.44 times, 1.69 times and 6.27 times of TiO_2, BiOBr, TiO_2-Biobr and P_2O_5, respectively.

Although photocatalytic oxidation technology has the advantages of high efficiency, non-toxic and low carbon, due to the current photocatalytic degradation of gaseous formaldehyde catalysts are mostly nano-powders, there is a risk of human inhalation, and is not conducive to the integration of air filter materials, Therefore, the immobilization and integration of nano-powder photocatalyst is one of the important research directions in the removal of indoor formaldehyde by photocatalytic oxidation.

3.4 Ecological purification and degradation method

Ecological purification and degradation method, also known as biological method, is a kind of environmental protection method using ecological plants to remove formaldehyde. Its principle is to absorb indoor 112 pollution gas through

potted green plants, and decompose formaldehyde into harmless substances by various reactions of green plants themselves. This method can continuously and effectively absorb indoor formaldehyde gas and keep a good indoor environment for a long time. Ecological purification degradation method is an effective method of daily formaldehyde protection. It not only decorates and beautifies the indoor environment, but also achieves the purpose of removing part of formaldehyde. Although the cycle is longer and the effect is slower, it is still an economic and practical method of prevention and control. Studies show that the common plants with strong ability to remove formaldehyde are mainly ivy, goosewood palm, rubber tree, Clivia, aloe vera, green plants, etc. Wolverton et al. found in their investigation on formaldehyde removal in green potted plants that hanging basket plants had the strongest purifying capacity for formaldehyde pollutants. Hanging basket plants could not only purify formaldehyde pollutants in the air, but also transform formaldehyde absorbed in the soil. In addition, the peel of some common fruits in life also has the ability to remove formaldehyde, such as grapefruit peel, orange peel, tea stalk, because of the porous structure on the surface of these skins, all have adsorption effect on formaldehyde.

Green plants have a good air purification effect, is a simple and effective long-term ecological management method. Some plants can absorb - metabolize formaldehyde gas. After more than 20 years of research, NASA scientists have found that in addition to regularly opening doors and Windows to improve ventilation, indoor planting of green plants is a simple and effective way to eliminate chemical pollution. German scientists have labeled formaldehyde gas with carbon-14 and carried out absorption experiments with spider plants. Traces of carbon-14 were found in the cell tissues of spider plants, proving that spider plants convert formaldehyde into organic acids, sugars and amino acids through their own metabolic reactions. Giese M et al. found that a pot of chlorophytum could absorb 88% formaldehyde within 24 h when exposed to an environment with a formaldehyde concentration of 815 mg/m^3. It is also reported that a pot of duck plantgrass can absorb half of the formaldehyde gas within 6 hours. Under the condition of 24 hours

of illumination, aloe vera can absorb 90% of the formaldehyde contained in 1 m^3 of air. Bai Yanbin et al. observed the absorption of formaldehyde by hanging chlorophylla in an indoor room without ventilation after 1 week of decoration, and showed that formaldehyde concentration changed significantly after 2 weeks. Aloe, agave and hanging orchid had better removal efficiency of formaldehyde. The leaf-viewing plants with large leaves, such as turtleback bamboo, tigertail orchid and one-leaf orchid, also have certain absorption and accumulation capacity of formaldehyde.

Green plants become the air purifier that ordinary families can bear, and provide an excellent method and means for the control and elimination of air pollution in the living room. It is expected that formaldehyde is the primary pollutant in indoor air, with a wide range of pollution sources, which is not easy to remove and seriously endangers human health. The formaldehyde pollution control or purification technology mentioned in this paper has different purification efficiency of formaldehyde due to different working principles, and all have certain effects and limitations. In the existing formaldehyde treatment measures, physical and chemical methods need to constantly update drugs and reagents, and need as large as possible contact area, the effect is not very good and more trouble in life. Photocatalytic technology used in the home environment cost is relatively high, harmful gas can not achieve the effect of fundamental governance. The method of using green plants to absorb indoor harmful gases has been accepted by more and more people because of its economic efficiency. Therefore, how to introduce plants into the room more scientifically, so that they can form indoor elements with both ecological and decorative functions, so as to realize the control of toxic volatile substances of ornamental plants in the room as well as greening and beautifying, is an important subject at present.

3.5 Control indoor temperature and air humidity

The results show that the rate of formaldehyde release is accelerated with the increase of indoor temperature, and the amount of formaldehyde release increases with the increase of indoor air humidity. When the indoor temperature dropped from

30ºC to 25ºC, the indoor formaldehyde emission was reduced by 50%. When indoor air humidity decreases from 70% to 30%, indoor formaldehyde emission can be reduced by 40%. Therefore, indoor formaldehyde concentration can be controlled within a certain safe range by increasing indoor temperature and humidity in daily life. Other control methods are catalytic oxidation degradation method, physical and chemical adsorption method, such as activated carbon adsorption method. The most effective way to solve the problem of indoor formaldehyde pollution is to control the source. Surveys show that more than 80% of indoor formaldehyde pollution is mainly caused by the use of excessive formaldehyde content in the decoration of building materials and furniture floors. Therefore, in order to quickly solve the problem of indoor formaldehyde pollution, we should increase the research and development of indoor formaldehyde pollution control technology and green decoration building materials.

By controlling the temperature and humidity to reduce the content of formaldehyde, it is found that the release of formaldehyde increases with the increase of humidity and temperature. When the temperature drops from 30 degrees to 20 degrees, the amount of formaldehyde can be reduced by 50%. When the relative humidity drops from 70% to 30%, the amount of formaldehyde can be reduced by 40%. The effect of temperature and humidity to reduce the amount of indoor formaldehyde is mainly to reduce the expansion of pollution source to make the formaldehyde in indoor materials released as soon as possible And in the cleaning process at the same time to achieve the role of disinfection and sterilization safely remove bacteria, mites, microorganisms and other pathogens to remove dust to prevent allergies. Due to the use of no chemical substances in the process of use does not produce odor ideal green products.

3.6 Microbial degradation method

Microbial degradation method is a new method to remove indoor formaldehyde in the past 20 years. Depending on the strong adaptability of microorganisms to pollutants, they can take pollutants (organic pollutants such as formaldehyde) as

"food" and convert pollutants into simple and harmless substances such as H_2O and CO_2. The treatment of formaldehyde pollution has the advantages of good effect, low cost and no secondary pollution. The alkali-producing pseudomonas isolated by Mirdamadil et al. had a 100% degradation concentration of 3700 mg /L within 24 h. The performance of the biodegradation system for formaldehyde removal under typical indoor conditions was studied. The Pseudomonas malodus strain was embedded in sodium alginate gel by microbial immobilization method. A new packaging material, microbial particles, was formed, and the initial formaldehyde concentration was controlled at 0.222-1.339 mg/m^3. The corresponding formaldehyde removal efficiency of the system could reach 68.6%-93.5%. Microbial degradation method is still in the stage of imperfect development, first of all, the selection of bacteria is not easy, the environmental requirements are very high, the same degradation of formaldehyde pollutants is relatively low efficiency, but it still has low processing cost, no equipment requirements, no secondary pollution and other green environmental characteristics.

Microorganisms are small, numerous and invisible to the naked eye, which exist widely in nature (mushrooms are an exception, essentially belonging to large fungi). They need to be magnified hundreds, thousands or even tens of thousands of times by optical microscopy to observe tiny organisms. Microorganisms can be divided into prokaryotic microorganisms eukaryotic microorganisms and acellular microorganisms according to their evolutionary level and character differences. Prokaryotic microorganisms mainly include bacteria, cyanobacteria, actinomyces, mycoplasma, Rickettsia and chlamydia. Eukaryotes include fungi, protozoa and microalgae. Non-cellular microorganisms are those without cellular structure, including viruses, viroids and prions. Microbial species on Earth are roughly estimated to be on the order of one million, and they are the most abundant and diverse biological resources on Earth. Without them, the material and energy cycle of the biosphere will be interrupted, and life on Earth will be difficult to reproduce. Therefore, microbes and microbial technology are closely related to human life.

In fact, people have accumulated a lot of empirical rules about microbial action in production and daily life, and apply these rules to create wealth, reduce and eliminate diseases. People have long been widely used in wine making, vinegar making, noodles, pickled pickled cabbage pickles, salting, preserves and so on, these are the typical examples of human control and application of microbial activity rules in food technology. Compost, compost manure, compost dirt, diaerated cultivation of legumes and other crops are among the production techniques that humans have used to control and apply the biological activity law of microorganisms in agricultural production practice. Vaccination against smallpox is a valuable practice for human to control and apply the rules of microbial life activities in preventing diseases and protecting health. Although these did not rise to the early microbial theories, they were all practical activities to control and apply the rules of microbial life activities.

Nowadays, microbial technology is an indispensable part of modern biotechnology. Industrial microorganisms involve food, pharmaceutical, metallurgy, mining, petroleum, leather, light chemical industry and other industries. Single-cell protein, cell protein or microbial fermented feed prepared by microbial fermentation engineering are widely used in animal husbandry and crop production. With the progress of technology, great changes have taken place in microbial fermentation technology, engineering equipment, detection and control, and the industrial production of antibiotics has reached an unprecedented level. Microbial technology is also widely used in the treatment of water environment. Specific microbial treatment technology can be used to separate nitrogen elements from water bodies, which can not only obtain additional abundant crop fertilizer in an environmentally friendly and energy-saving way, but also reduce the economic and environmental costs caused by chemical pollution control.

Microbial technology is to put beneficial strains and enzymes into the polluted environment so that it can adapt to survive to reach a certain concentration of bacteria in a short time to form a micro-ecosystem relying on the biological oxidation of strains and enzymes in the environment of formaldehyde, benzene, ammonia and other harmful substances quickly hydrolysis into harmless CO and H_2O.

Microorganisms live in the environment for a long time to play a role in lasting effect, no secondary pollution. However, because the biological active temperature is generally 10-40 degrees, the indoor temperature must be maintained within the range of the active temperature of specific microorganisms.

3.7 Material sealing technology

Formaldehyde sealing technology is to use the characteristics of the product coated into a film, covered in the board containing formaldehyde, closed the formaldehyde volatilization channel, blocked not to let formaldehyde volatilization out.

For a variety of formaldehyde in wood-based panels, many companies develop sealing liquid in addition to formaldehyde, called formaldehyde sealing agent, mainly used in furniture and artificial board formaldehyde gas sealing, can be painted in furniture without paint treatment and wood-based panels, in order to reduce the amount of formaldehyde released in a variety of wood-based panels. But this is only to seal the formaldehyde inside the material. If the sealing material is aged or damaged, there will still be formaldehyde released. So this method treats the symptoms rather than the root cause.

Real life harmful air pollution source is more than one plate. Other release sources can not necessarily use sealer, such as fabric sofa, textile products, etc. This kind of sealing agent is only effective for the plate construction is not long-term effective, but temporarily closed formaldehyde release channel.

New house decoration is the high release period of formaldehyde, formaldehyde is a kind of protoplasmic poison that destroys biological cell protein, can cause damage to human skin, respiratory tract and internal organs, anesthesia human central nervous system, can cause pulmonary edema, liver coma, kidney failure and so on. The World Health Organization has confirmed that formaldehyde is a teratogenic and carcinogenic substance and a source of allergy. Long-term exposure will lead to genetic mutations.

The principle of formaldehyde sealing agent is to use the film characteristics of the product to partially or completely block the formaldehyde from volatilizing. However, the practical effect of such products is very limited. We cannot block the pollution sources in the real life and working environment. Formaldehyde release is long-term, can maintain 8 to 15 years of active period! Unless the material you use is real natural wood without any processing (after the trunk is cut and dried), no you can not avoid the existence of formaldehyde pollution, and more importantly, these indoor pollution in our decoration use of latex paint will also be released in large quantities!

Another closed method is the film, furniture film after the formaldehyde can not volatilize into the air, a period of time in the room formaldehyde content is very low, but with the passage of time, furniture surface film wear, formaldehyde in the furniture will continue to volatilize into the air, and because there is no measurement of formaldehyde exceed the standard, people will neglect to prevent this, Formaldehyde levels get higher over time, causing great health hazards for unsuspecting family members. So the use of film method to prevent formaldehyde is completely unreliable.

Formaldehyde release time is very long, with the passage of time, the material formaldehyde and other harmful gases continue to release, the membrane will be broken, and usually cleaning will destroy it, so many owners in addition to formaldehyde a few months later, found that the formaldehyde in the home again exceeded the standard.

However, this method has a good short-term effect. Aldehyde removal companies use it to complete the current effect is very good, the customer can pay the bill, so there are also some companies in use, because it can solve serious excessive, but for the customer, this is not a good way.

So formaldehyde treatment can not be opportunistic, otherwise the gains outweigh the losses, the treatment of formaldehyde so far still need to rely on scientific methods, the first treatment of formaldehyde is the most effective or

frequent ventilation, only adhere to ventilation to make indoor and outdoor air effective circulation.

3.8 Composite governance technology

Compound formaldehyde treatment is one of the new hotspots of indoor formaldehyde treatment technology. The most studied method is the combination of physical adsorption and photocatalytic oxidation, followed by the combination of physical adsorption and chemical treatment. However, the combination of photocatalytic oxidation and chemical treatment has not been reported in the literature.

The supported photocatalyst can be prepared by combining physical adsorption method with photocatalytic oxidation method, which can increase the effective surface area of the photocatalyst, improve the photocatalytic activity and facilitate its recovery. Can be used as the carrier adsorbent are: activated carbon, silica gel, Buddha stone, glass, mesoporous molecular sieve. TiO is generally selected for photocatalyst. Preparation methods include: chemical vapor deposition, sol-gel method, ion exchange method, coupling method, powder sintering method, hydrolysis precipitation method, doping method, among which sol-gel method and coupling method are more commonly used. V. Gun'Ko et al. Miguel Holgado and others. The preparation of uniform TiO creep layer on monodisperse silica gel spheres by sol-gel method was studied. The experimental results show that the specific surface of catalyst decreases with the increase of NagSiO mass fraction. TiO photocatalyst is an environmentally friendly catalyst with wide application prospects. The preparation of TiO photocatalyst with high activity and uniform load and solid support is the future research direction.

Physical adsorption and chemical treatment method, adsorbent indoor formaldehyde adsorption, and then with aldehyde elimination agent reaction, formaldehyde into non-toxic, odorless substances. For example, after a certain amount of raw activated carbon was activated and dried at 100 degrees, it was soaked for 1h in the reaction agent solution with molar ratio of NHCl and NgSO at 111

degrees and 1mol/L, and then the adsorption reaction type formaldehyde eliminator product was obtained by drying, and the formaldehyde elimination effect experiment was conducted. The results show that the elimination rate of solid eliminators for Li is about 70% within 24h. There are few researches on this composite treatment technology, but it can be predicted that the combination of physical adsorption and chemical treatment has obvious advantages and has a good development prospect.

3.9 Fresh air system

Fresh air system is a set of independent air treatment system composed of air supply system and exhaust system. It is divided into pipe type fresh air system and no pipe fresh air system. The pipe type fresh air system is composed of a new fan and pipe fittings. The outdoor air is purified by the new fan into the room, and the indoor air is discharged by the pipe. The ductless fresh air system consists of new fans, which also purify the outdoor air into the indoor air. Relatively speaking, the pipeline type fresh air system is more suitable for industrial or large office area because of the large amount of engineering, and the pipeline type fresh air system is more suitable for family use because of the convenient installation. Chun in 1935, after many attempts to invent and manufacture the world's first can filter air pollution heat exchange equipment, also known as the fresh air system.

The release cycle of formaldehyde is as long as several years, and it is not possible to completely eradicate it at once. Even if you live in it, you should maintain air circulation. For winter or haze weather, or some can not open the window ventilation situation, fresh air system is a good choice.

Due to haze and other reasons, fresh air system gradually becomes popular among people. As an air treatment system, outdoor air can be purified and introduced into the room, and indoor air can be discharged, which is equivalent to ventilation and formaldehyde emission, as shown in Fig. 3.5.

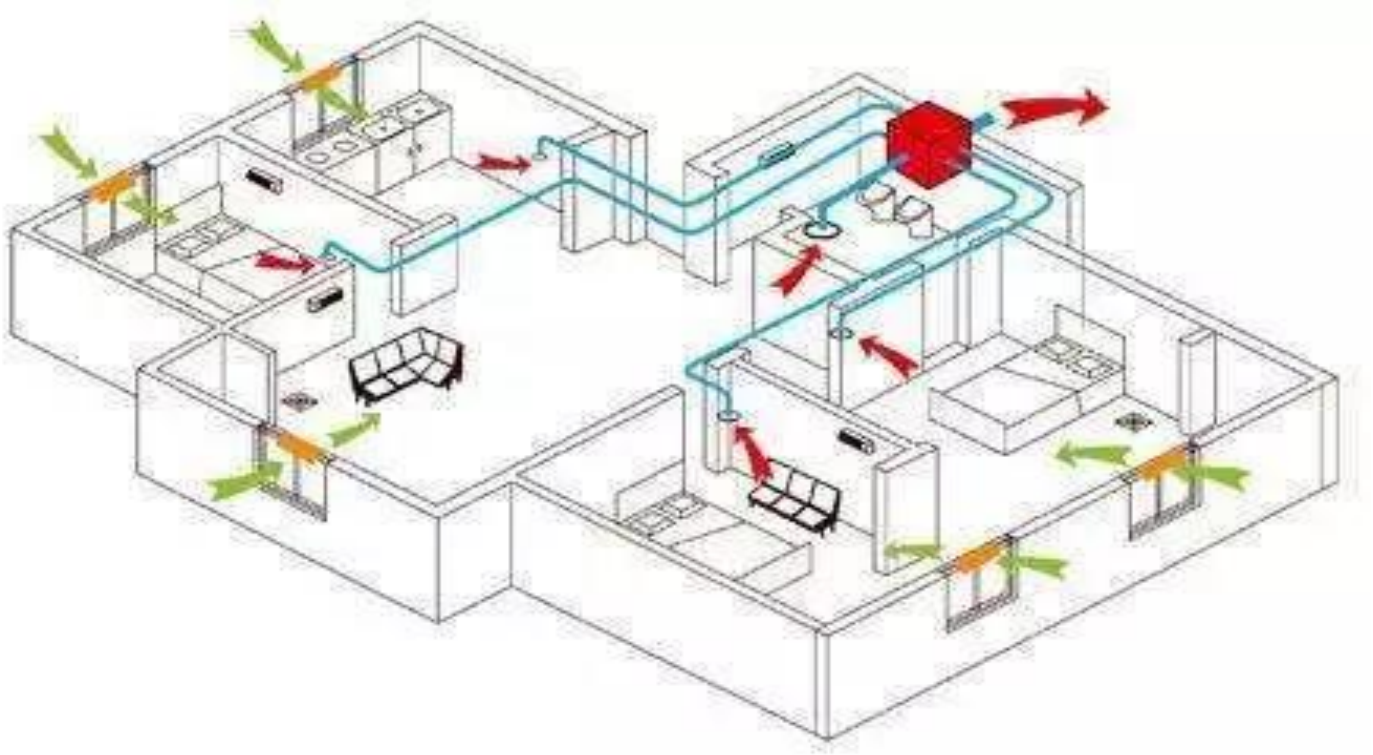

Figure 3.5 – Schematic diagram of fresh air system

The fresh air system is based on sending fresh air indoors with special equipment on one side of the closed room, and then discharging it outdoors from the other side by special equipment. The "fresh air flow field" will be formed indoors, so as to meet the needs of indoor fresh air ventilation. The implementation scheme is: using high air pressure, large flow fan, relying on mechanical force from one side to the indoor air, from the other side with specially designed exhaust fan to the outdoor forced in the system to form a fresh air flow field. At the same time of air supply, the air entering the room is filtered, disinfected, sterilized, oxygenated and preheated (winter).

The fresh air system has three main functions. First, the outdoor fresh air is used to renew the indoor air polluted by living and living process, so as to keep the indoor air cleanliness to a certain minimum standard level. Second, it increases internal heat dissipation and prevents discomfort caused by moist skin. This kind of ventilation can be called thermal comfort ventilation. Thirdly, when the indoor

temperature is higher than the outdoor temperature, the building components are cooled. This kind of ventilation is called the cooling ventilation of the building.

Advantages of fresh air system:

(1) Enjoy the fresh air of nature without opening the Windows;

(2) Avoid "air conditioning disease";

(3) Avoid moldy indoor furniture and clothing;

(4) Remove harmful gas released slowly for a long time after indoor decoration, which is good for human health;

(5) Recycle indoor temperature and humidity to save heating costs;

(6) effectively eliminate indoor bacteria and viruses;

(7) super quiet;

(8) Reduce indoor carbon dioxide concentration;

(9) Dust prevention;

4 FOMALDEHYDE POLLUTION CONTROL

In recent years, indoor pollution caused by indoor decoration has led to disputes between residents and owners. The investigation results show that most of them are related to indoor formaldehyde concentration exceeding the standard. In July 2001, a household in Yinchuan City reported a strong irritating odor after interior decoration. The investigation showed that the concentration of formaldehyde gas was 3.44 mg/m^3 in the north living room, 3.66 mg/m^3 in the southeast room and 3.74 mg/m^3 in the southwest room. They are 43 times, 45.7 times and 46.75 times higher than the formaldehyde concentration limit of 0.08 mg/m^3 in the room. The results showed that the concentration of formaldehyde gas was 0.48 mg/m^3 in the north living room, 0.52 mg/m^3 in the southeast room and 0.54 mg/m^3 in the southwest room. The formaldehyde concentration in the room exceeded the limit of 0.08 mg/m^3 by 6 times, 6.5 times and 6.75 times.

It is understood that since April 2003, Qingdao City Disease Control Center officially carried out indoor pollution detection, for residents to provide doorknocking services. In half a year, inspectors conducted field tests on the air in the living rooms of nearly 100 households entrusted with testing. The results showed that the formaldehyde content in 100 percent of the living rooms exceeded the national health standard, with the highest being 30 times the standard, and individual families still exceeded the standard after 10 years of decoration.

Shenyang's technical supervision department began testing in November and has conducted more than 40 tests so far, inspecting nearly 100 homes. The results were alarming, with some homes exceeding the national standard by 200%. According to reports, one household indoor formaldehyde concentration reached 1.8mg/m3, and the national standard is 0.08mg/m3.

Indoor air sampling monitoring in Beijing and Shanghai showed that the concentration of formaldehyde exceeded the standard by 73.3% and 79.1% respectively, and the highest concentration of formaldehyde was more than 10 times the standard. According to the pollution index formula: Pi=Ci/Si, where Pi is the

indoor formaldehyde pollution index of different types of buildings, Ci is the measured indoor formaldehyde value of different types of buildings mg/m3,Si=0.08mg/m3 -- the national standard limit.

Through calculation, the pollution batch number of newly decorated indoor is 3.025 (the average concentration of formaldehyde in the air of newly decorated indoor is 0.242 mg/m^3), and the indoor pollution index of new residential is 1.575 (the average concentration of formaldehyde in the air of new residential is 0.126 mg/m^3). The indoor pollution index of ordinary residential buildings was 0.3 (the average concentration of formaldehyde in indoor air of ordinary residential buildings was 0.028 mg/m^3).

According to the data provided by the World Health Organization, in five developed European countries, the average indoor formaldehyde concentration is between 9-70 μg/m^3, and high concentrations occur from time to time, especially in homes where urine aldehyde foam products are used. In less developed countries, the high concentration is more serious, the formaldehyde concentration in the living room is even higher than the concentration in the occupational place. In developed countries, a study conducted in Canada also found similar results, 10% to 20% of the population in the United States was exposed to formaldehyde, and 14% of households in eastern Germany had indoor air concentrations of formaldehyde that exceeded the German national standard.

It can be seen that the harm of formaldehyde is worldwide. Through the above groups of specific survey data can be seen that the concentration of formaldehyde in our living room exceeds the standard seriously, so it is urgent to find a series of effective prevention and control of indoor formaldehyde pollution methods and measures.

As early as 2004, the World Health Organization issued a press release stating that formaldehyde is a human carcinogen that causes cancers of the nasal cavity, nasopharynx and sinuses. A 2013 study by the American Chemical Toxicology Council found that formaldehyde is also a major cause of leukemia.

In indoor air environment, when the concentration of formaldehyde reaches 0.08-0.09 mg/m^3, children will have mild asthma; When the formaldehyde content is 0.1 mg/m^3, there is bad smell and discomfort; When the concentration of formaldehyde reached 0.5 mg/m^3 can stimulate the eyes cause tears; When the concentration of formaldehyde reaches 0.6mg/m can cause throat discomfort or pain. When the concentration of formaldehyde is higher, it can cause nausea, vomiting, cough, chest tightness, asthma and even pulmonary edema. Formaldehyde kills instantly at concentrations of 30 mg/m^3.

Long-term exposure to low doses of formaldehyde can cause chronic respiratory diseases, but also can cause nasopharyngeal cancer, colon cancer, brain tumors, women's menstrual disorder, gene mutations in the nucleus of the DNA single strand cross-linking and DNA and protein cross-linking and inhibit DNA damage repair, pregnancy syndrome, newborn chromosome abnormalities, leukemia adolescents memory and intelligence decline and other diseases.

Among all the contacts, children and pregnant women are particularly sensitive to formaldehyde and more harmful. According to the latest statistics, 40% of the death toll in the world every year died from diseases caused by environmental pollution, more than 90% of human cancer is caused by environmental factors in China every year 111,000 people die from indoor pollution more than 90% of our children leukemia are living in the newly decorated room within one year of the disease.

With the continuous improvement of people's living standards, indoor environmental pollution began to become a serious social problem in the late 1990s. According to the survey of Beijing, Shanghai and other places, up to 80% of the decoration of two years of residential buildings, office indoor environmental pollution indicators seriously exceed the standard. Formaldehyde, benzene and xylene, which have been identified as carcinogens by the United Nations Health Organization, seriously harm people's health. In particular, children suffer from leukemia, which has been confirmed to be related to decoration pollution.

Since the beginning of the new century, China has paid special attention to the increasingly serious indoor environmental pollution. It has issued a series of laws, regulations and technical specifications, requiring that the indoor environmental quality of new, expanded and reconstructed civil buildings must meet the corresponding standards. The indoor environmental treatment industry has developed rapidly. Shanghai alone, for example, is estimated to have at least 5,000 employees. However, the technical level of employees in this industry is uneven, in urgent need of industry management and norms.

Nowadays, residents' demand for housing has changed from survival type to comfort type, health has become the first element of people's home, and the endless indoor environmental pollution caused by decoration has been widely concerned by the society. According to a survey, 90% of the indoor environmental pollution in the newly renovated rooms exceeds the standard, and the highest pollution value exceeds 50 times the standard value. In early 2003, a sudden "SARS" greatly promoted the improvement of people's awareness of indoor environment quality, and promoted the indoor environment purification and treatment industry into a new round of rapid development stage.

According to statistics, there are more than 200 enterprises producing and acting for indoor air purification products in mainland China at present, and the average annual turnover of each enterprise is about 38 million yuan. It can be estimated that the total market size of domestic indoor environment purification products production and acting industry is about 8 billion yuan in 2003.

According to the different uses of the products, the main market segments of the current air purification products have the following types of market size: one is ordinary air purifier. This kind of products mainly include air humidifier, air purifier, fresh air exchanger, its main use for home, office, indoor public places and other places. This kind of product occupies a leading position in the current production industry of air purification products, with annual sales of about 7 billion yuan. The second is the portable air purification device. Such products mainly include portable oxygen bars, vehicle purifiers, etc., which are mainly used to improve the air quality

of small indoor Spaces. This kind of product occupies a small share in the current air purification product production industry, with annual sales of about 300 million yuan. Three is to purify the material. The products mainly include all kinds of air fresheners, formaldehyde capture agent, benzene scavenger, all kinds of filter materials, photocatalyst materials, etc. The development speed of this kind of products is very fast in recent years, the current annual sales of about 700 million yuan.

Indoor environmental pollution has long been recognized by the United Nations Health Organization as the "third generation of environmental pollution", indoor environmental governance in foreign countries started earlier, and formed a certain scale, industry management standards, the development is more mature, its indoor environmental governance more pay attention to living, comfortable use.

According to the estimates of experts, with the continuous improvement of people's environmental awareness and the continuous improvement of indoor environment quality standards, the market of indoor environment governance will continue to rise. It is expected that in 5 years, the indoor environment governance market in Shanghai alone will need about 60,000 employees. If some large and medium-sized cities can strengthen the attention and support to the development of this industry, the development prospect of this industry will be more considerable.

In the production and agent industry of indoor environmental purification and treatment products, the number of small and medium-sized enterprises is large, accounting for about 64% of the total number of enterprises in the industry, and the annual turnover of these enterprises is generally less than 10 million yuan. Another 5 per cent, or about 10, have an annual turnover of more than Rmb100m, with Beijing Yadu Technology Development, the industry leader, recording an annual turnover of more than Rmb1bn in the past two years. Most of the enterprises with a turnover of more than 10 million yuan mainly produce air purifiers, fresh air exchangers and air humidifiers. In this field, the industry concentration is relatively high, among which Beijing Yadu Technology Co., LTD's main products share more than 70% of the market.

At present, the number of domestic enterprises producing air purification materials is also relatively large. The turnover of these enterprises is not high, and the annual output value is mainly concentrated in 5-10 million yuan, or no more than 20 million yuan at most. At present, there are no strong enterprises, and the industry concentration is relatively low. With the acceleration of urbanization, the gradual improvement of consumers' awareness of environmental protection and the continuous improvement of living standards, the demand for indoor environment purification and treatment products in China will steadily increase, especially in the next 3-5 years, the product demand will continue to grow rapidly. In terms of product supply, the wide application of emerging technologies such as nanotechnology will greatly improve the efficacy of air purification products to meet the needs of consumers.

With the improvement of people's living standards and the environmental protection requirements for the living environment, the control of indoor pollutants, including formaldehyde, has become increasingly important and urgent, and countries are constantly improving the relevant standards. Pollution has become the focus of attention in China. Premier Li Keqiang said "we will do everything we can to fight pollution as it destroys people's lives". "Decoration pollution is fiercer than tiger". Formaldehyde release is a long process of decoration with some pollution-free materials: before the house is moved in to maintain good ventilation at the same time put some plants or put some activated carbon or formaldehyde scavengers so as to stay away from the harm of formaldehyde to the human body, indoor formaldehyde treatment technology and related industries are very broad, but at the same time we also want to see the shortcomings of the current situation, cause enough attention.

With the increasing strictness of national environmental laws and regulations and the popularity of environmental awareness, more and more attention has been paid to the control and treatment of indoor formaldehyde pollution. Foreign air purification technology of formaldehyde pollution has been more used in practice, at the same time, a variety of new methods and new technologies are constantly being studied, among which nano photocatalytic technology makes the development trend

of air purification technology research, at the same time, because each method has its own advantages and disadvantages, appropriate technology is selected for the actual situation, In particular, the combination of various technologies can effectively control and treat formaldehyde pollution in the laboratory.

The most effective way to solve the problem of indoor formaldehyde pollution is to control the source. Surveys show that more than 80% of indoor formaldehyde pollution is mainly caused by the use of excessive formaldehyde content in the decoration of building materials and furniture floors. Therefore, in order to quickly solve the problem of indoor formaldehyde pollution, we should increase the research and development of indoor formaldehyde pollution control technology and green decoration building materials.

In order to create a healthy, comfortable and green indoor air environment, not only need effective formaldehyde detection methods, timely take targeted prevention and control measures, but also need to nip in the bud, understand the possible sources of formaldehyde pollution, the use of green decoration materials and clothing, reduce the content of formaldehyde in indoor air.

In summary, according to the comprehensive analysis and research of formaldehyde pollution of indoor environment, layer by layer in-depth, from a practical point of view, deep and detailed to the human body harm caused by a awakening, and as a starting point, for the indoor environment in the comprehensive treatment of formaldehyde pollution technology, research, indoor ventilation, plant purification, air purification technology, etc., Have carried on a comprehensive discussion, carry out a deep analysis, and strive to make more progress for the related work, make a positive contribution, and to reduce the indoor environment for the harm to the human body, reduce the content of formaldehyde, indoor purification effect, laid a solid theoretical foundation.

5 ECONOMIC EFFECTIVENESS OF ENVIRONMENTAL MEASURES

5.1 Economics and environmental protection

Economic effectiveness is a means of measuring the efficacy and purposefulness of a given business activity given by the comparison (ratio) of the value of the obtained effects to the factors invested in order to achieve them [29].

Economics explains how people survive. It concerns the ways in which individuals and groups act to attain what they want in terms of income, subsistence and other goods and services which they feel will provide them with an adequate quality of life. Economics basically addresses the problem of scarcity – how to fulfil people's unlimited needs and aspirations from a scarce resource base in a way which is both equitable and efficient.

Incorporating environmental concerns into economics involves introducing concepts of sustainability into scarcity. It deals with the issue of how to meet people's current needs in a way which is both equitable and efficient and does not diminish the supply or quality of environmental goods and services available for future generations.

If the environmental resource base is conserved it will continue to provide these economic benefits and support human production and consumption in the future. If it is destroyed or environmental quality declines, such goods and services will decrease and human economies will suffer as a result, at global, national and local levels.

Economics is also linked to the environment because economic forces contribute to environmental degradation. While environmental resources support economic production and consumption opportunities, the same economic activities impact back on the environment through using up non-renewable environmental goods and services, by converting environmental resources to other uses and by adding waste and effluent to the environment. A decline in environmental quality and resources impacts on economic activities by diminishing the amount of goods and services available for future production and consumption, and by progressively

precluding economic activities. Economic opportunities spiral downwards as the environment becomes more and more degraded.

This downward spiral has implications for both economic efficiency – the sound use and management of scarce resources to generate output, and equity – the access of different groups and individuals to secure livelihoods and economic opportunities. The people who bear the costs of environmental degradation are not necessarily those who are causing degradation, spatially or temporally. For example, many of the indirect or knock-on effects of environmental degradation such as bad health, loss of productive opportunities and ecological disaster are felt by poorer people who lack the resources to cope with these costs, or will be felt by future generations as a result of activities carried out today. Environmental degradation also incurs substantial costs to governments, who bear the overall responsibility for maintaining the basic quality of life in a country [30].

It is clear that production and consumption activities can lead to a downward spiral of environmental degradation, economic costs and loss of productive opportunities. Conversely, environmental conservation can lead to an upward spiral of economic growth and benefits. A major challenge is to ensure that sound environmental management systems are set in place which will enhance current opportunities for production and consumption at the same time as sustaining economic growth in the future.

A range of policy factors, as well as broader socio-economic conditions such as poverty and land pressure, put people in a situation where it makes more economic sense to them to degrade the environment in the course of their day-to-day economic activities than to conserve it. There is often little immediate or tangible economic gain to conserving the environment, and many gains and profits from mining, depleting, polluting or converting it. People are often unwilling − or economically unable − to conserve the environment, because there is no personal benefit to them in doing so.

Economic analysis provides a useful set of tools understanding the forces which lead to environmental degradation. Economic measures can encourage people

to conserve the environment by setting in place the conditions which result in their being economically better off by doing so. They aim to make sure that producers and consumers take into account the real value of the environment and the real cost of environmental damage when they make decisions.

Basic tools for the use of economics for environmental planning and management are as follows [31]:

Identifying environmental economic benefits and costs: ensures that the economic impacts of environmental activities, and the environmental impact of economic actvities, are understood and made explicit in both conservation and development planning and management.

Valuing environmental economic benefits and costs: provides important information which can be integrated into both development and conservation planning and management. Making monetary estimates of environmental values means that they can be considered, and given equal weight, alongside other sectors of the economy, benefits and costs.

Analysing the profitability of economic activities in terms of their environmental effects: provides a framework within which to use information about environmental costs and benefits and their values for decision-making. It provides basic measures of whether a policy, programme or activity can be judged desirable in environmental and economic terms.

Highlighting the economic causes of environmental degradation and the need for economic measures for environmental conservation: points to areas and groups where there is a need for the use of economic measures to provide incentives and finance for environmental conservation. It forms the basis of identifying and planning conservation activities.

Setting in place economic incentives for environmental conservation: forms a cross-cutting component of environmental planning and management. Unless people are provided with positive incentives to conserve the environment in the course of their economic activities, and the perverse incentives which encourage environmental

degradation are overcome, environmental programmes and projects are unlikely to succeed.

Financing mechanisms for environmental conservation: form an important part of environmental planning and management because they provide the basic funding which enables environmental projects, programmes and activities to be carried out.

Ensuring that economic measures for conservation are appropriate and sustainable: means that they are practically implementable in different social, cultural, institutional and ecological situations.

5.2 Calculation of the financial profit of resource saving

Net financial result due to the implementation of resource-saving measures in company is calculated by the equation:

$$FP = t \cdot (C_f + p_e + p_h) - I_t \quad (5.1)$$

where:

t is time of implementation of resource saving measures, years;

C_f is the cost of fuel saved, USD/year;

p_e is the payment for emissions of pollutants into the environment, USD/year;

p_h is the payment for damage to public health, USD/year. We accept equal to 0 USD;

I_t is the investment in resource-saving measures, USD.

Cost of fuel saved:

$$C_f = Pr \cdot N_f \quad (5.2)$$

where:

Pr is the price for fuel (1 m^3 of natural gas - 0.38 USD, 1 ton of coal – 125 USD);

N_f is the amount of fuel saved or the amount of fuel that would need to be burned to obtain energy produced by alternative sources. In fact, N_f is the total amount of fuel used by company (then we suggest that we completely replace it with alternative energy).

Payment for emissions of pollutants into the environment:

$$p_e = (M_1 \cdot r_1) + (M_2 \cdot r_2) + ... + (M_n \cdot r_n) \quad (5.3)$$

where M is the amount of pollutant emission, ton:

$$M = q \cdot N_f \quad (5.4)$$

where q is specific emission of pollutant:

for coal: SO_2 – 30 kg/t, NO_x – 9 kg/t, CO – 55 kg/t

for natural gas: SO_2 – 0.0037 kg/m^3, NO_x – 0.0031 kg/m^3, CO – 0.0051 kg/m^3.

r is fee rate per ton of pollutant, USD/t (see Table 5.1).

Table 5.1. Fee rate for pollutants [32]

Pollutant	**rate, USD/t**
Nitrogen oxides	75
Ammonia	15
Sulfur dioxide	75
Carbon monoxide	3
Hydrocarbons	5

Investments (e.g., in wind or solar energy) are calculated as follows:

$$I_t = k \cdot N_f \cdot T / 8760 \quad (5.5)$$

where:

k is the specific investment in the production of 1 kWh of energy (for wind turbines k = 500 USD/kWh, for solar panels k = 900 USD/kWh);

T is the heat capacity of the fuel to be replaced (7.5 kW/t for coal and 8.8 kW/m^3 for natural gas).

Calculate the net result from the implementation of resource saving measures in formaldehyde production company. The company consumes 4000 ton of coal per year and is going to replace it with wind turbines). The project implementation period is 5 years.

1. Time of implementation: t = 5 years

2. Amount of fuel used (= amount of fuel saved): Nf = 4000 t/year

3. Cost of fuel saved: Cf = Pr · Nf (Eq. 5.2).

The price for coal Pr = 125 USD/t.

Then, Cf = 125 USD/t · 4000 t/year = 500000 USD/year

4. To calculate the payment for emissions of pollutants (p_e), we need to know amount of pollutant emission (M) for each pollutant (see Eq. 5.4):

Pollutant 1. Nitrogen oxides. q1 = 9 kg/t (see specific emission of NOx for coal). Then, M1 = q1 · Nf = 9 kg/t · 4000 t/year = 36000 kg/year = 36 t/year.

Pollutant 2. Sulfur dioxide. q_2 = 30 kg/t (see specific emission of SO_2 for coal). Then, $M_2 = q_2 \cdot Nf$ = 30 kg/t · 4000 t/year = 120000 kg/year = 120 t/year.

Pollutant 3. Carbon monoxide. q_3 = 55 kg/t (see specific emission of CO for coal). Then, M3 = q3 · Nf = 55 kg/t · 4000 t/year = 220000 kg/year = 220 t/year.

5. From Table 5.1:

for NOx r_1 = 75 USD/t

for SO_2 r_2 = 75 USD/t

for CO r_3 = 3 USD/t

According to Eq. 5.3:

$p_e = (M_1 \cdot r_1) + (M_2 \cdot r_2) + (M_3 \cdot r_3)$ = (36 t/y·75 USD/t) + (120 t/y·75 USD/t) + (220 t/y ·3USD/t) = 12360 USD/year

6. Specific investments for wind turbines k = 500 USD/kWh, heat capacity for coal T = 7.5 kW/t.

Then investments:

It = k·Nf·T / 8760 = 500 USD/kWh · 4000 t/year · 7.5 kW/t / 8760 h/year = 1712 USD

7. Financial result (Eq. 5.1):

FP = t (Cf + p_e + p_h) – It = 5 y · (500000 USD/y + 12360 USD/y + 0) – 1712 USD = 2560000 USD.

Therefore, implementation of resource-saving measures in company (use of wind turbines for energy production) would lead to income 2.56 million USD during 10 years.

CONCLUSIONS

In this work, the latest progress of indoor formaldehyde removal was summarized from the harm of formaldehyde, the principle of formaldehyde removal, the detection of formaldehyde, and the way of formaldehyde removal. In formaldehyde detection, portable formaldehyde detector is fast and efficient when measuring indoor formaldehyde, which is suitable for ordinary people, but not suitable for accurate detection of formaldehyde concentration in indoor environment. Formaldehyde removal methods include physical, chemical and biological methods, etc. Physical adsorption and photocatalysis are the main methods used in air purifiers. In addition to a single removal path, more is the combination of the above removal methods, which is also reflected in formaldehyde scavenger and formaldehyde removal activated carbon and other products, which shows that the rational use of the advantages of various methods, effective combination, comprehensive treatment, is the direction of formaldehyde treatment.

For efficient indoor formaldehyde removal technology, this paper has the following prospects: (1) to find the best raw materials, explore the optimal synthesis method, while reducing the cost of adsorbent, improve the adsorption and degradation of formaldehyde; (2) Focus on exploring the material design problems that formaldehyde adsorbent is easy to fill and pores are easy to plug; (3) Through the combination of biological method and other methods, design more ideal indoor air formaldehyde removal system, such as plant-microbial formaldehyde removal system, air conditioning system connected with biological filter, etc.; (4) Explore photocatalytic materials that can efficiently remove formaldehyde and are environmentally friendly, so as to improve the removal efficiency of indoor volatile organic compounds in real environment; (5) Future air purifiers can be improved in terms of material composition and structure optimization to achieve safe, pollution-free, long-term and efficient removal of indoor formaldehyde.

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Appendix A

Technical task

Ministry of education and science of Ukraine
Vinnytsia National Technical University
Faculty of Construction, Civil and Environmental Engineering

APPROVED
Head of the Department ECEPT
Prof. V. Petruk
27.09 2022

TECHNICAL TASK

for master thesis

"Environmental impact assessment of pollution with formaldehyde"
specialty 183 – Environmentla protection technologies

08-12.МКР.103.01.01 ТЗ

Supervisor: PhD, Dr.
_____ V. Ishchenko
(signature)
«27.09» 2022

Student: group 2ТЗД-21м
Xiu Pei Xiu
(signature)
«27.09» 2022

Vinnytsia VNTU 2022

1. Basis.

The basis for master thesis preparing is the order of VNTU No. 203 on "14" 09 2022, and individual task approved by protocol of Department ECEPT No. 3 on "21" 09 2022.

2. Goal.

The goal is to analyze pollution with formaldehyde in indoor environments.

3. Input data.

Maximum allowable concentration of formaldehyde – 0.08 mg/m^3

4. Research methods

Analysis, mathematical modelling, environmental impact assessment, statistical methods.

5. Stages and deadlines

No.	Stages of master thesis	Deadline
1.	Technical task	
2.	Indoor air quality evaluation	
3.	Pollution with formaldehyde	
4.	Formaldehyde treatment technologies	
5.	Formaldehyde pollution control	
6.	Conclusions, literature list	

6. Area of use

The results can be used by industrial companies to reduce environmental impact of formaldehyde generation.

7. Requirements

Main part and illustrative part.

8. Procedures

Public defense «27» 06. 2024

Beginning of writing «27» 06. 2024

Finish due to «27» 06. 2024

Student Xiu Pei Xiu

Appendix B

PROTOCOL
OF CHECK FOR PLAGIARISM

Title of work: Environmental impact assessment of pollution with formaldehyde

Type of work: master thesis

Department Ecology, Chemistry and Environmental Protection Technologies

Similarity report by Unicheck

Originality 84,8% Similarity 15,2%

Analysis of similarity report (mark the relevant)

1. Similarities found in the work are correctly formatted and may not be considered as plagiarism.
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Appendix C

ILLUSTRATIVE PART

ENVIRONMENTAL IMPACT ASSESSMENT OF POLLUTION WITH FORMALDEHYDE

Figure C.1 – Activated Carbon

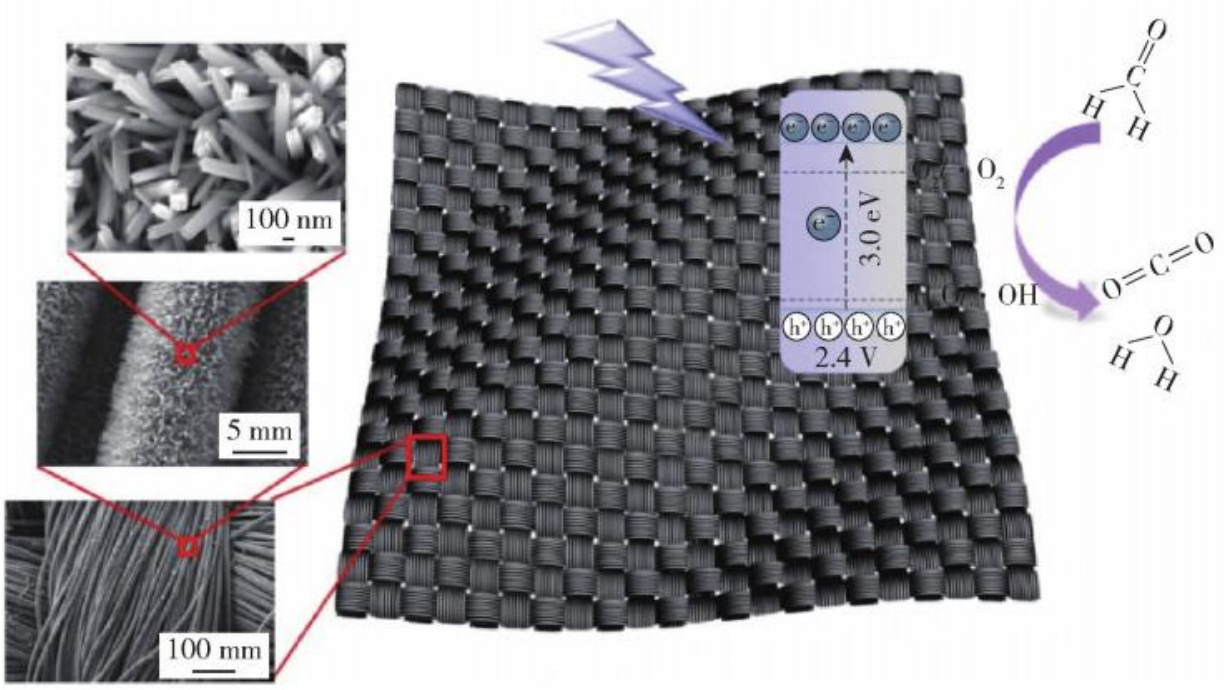

Figure C.2 – Photocatalytic degradation of formaldehyde by fluorine-doped rutile TiO_2 nanorods arrays on carbon fiber cloth

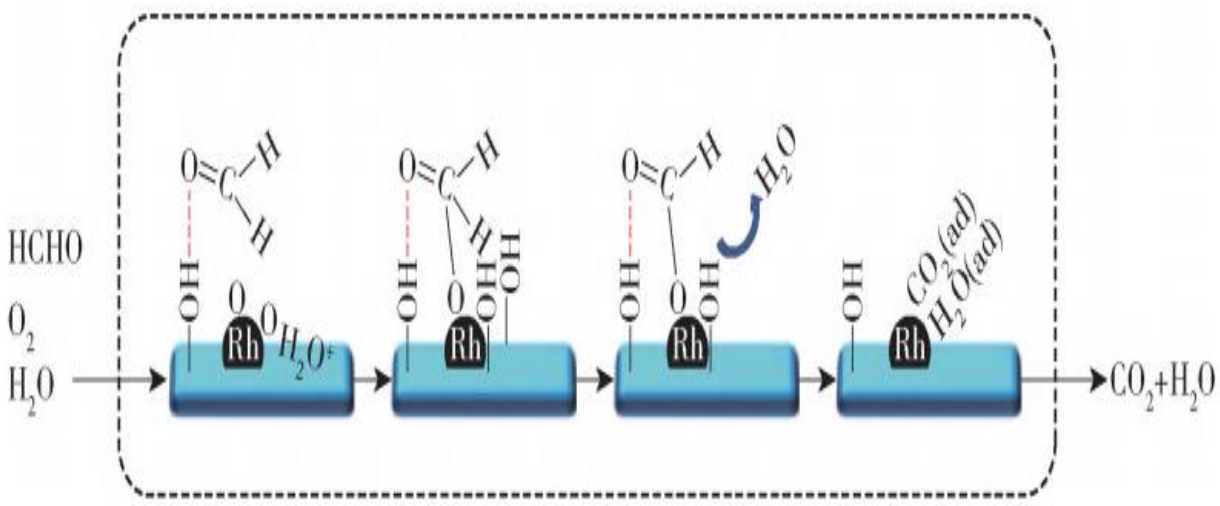

Figure C.3 – Reaction mechanism of HCHO oxidation by Rh/TiO_2 under humidity condition

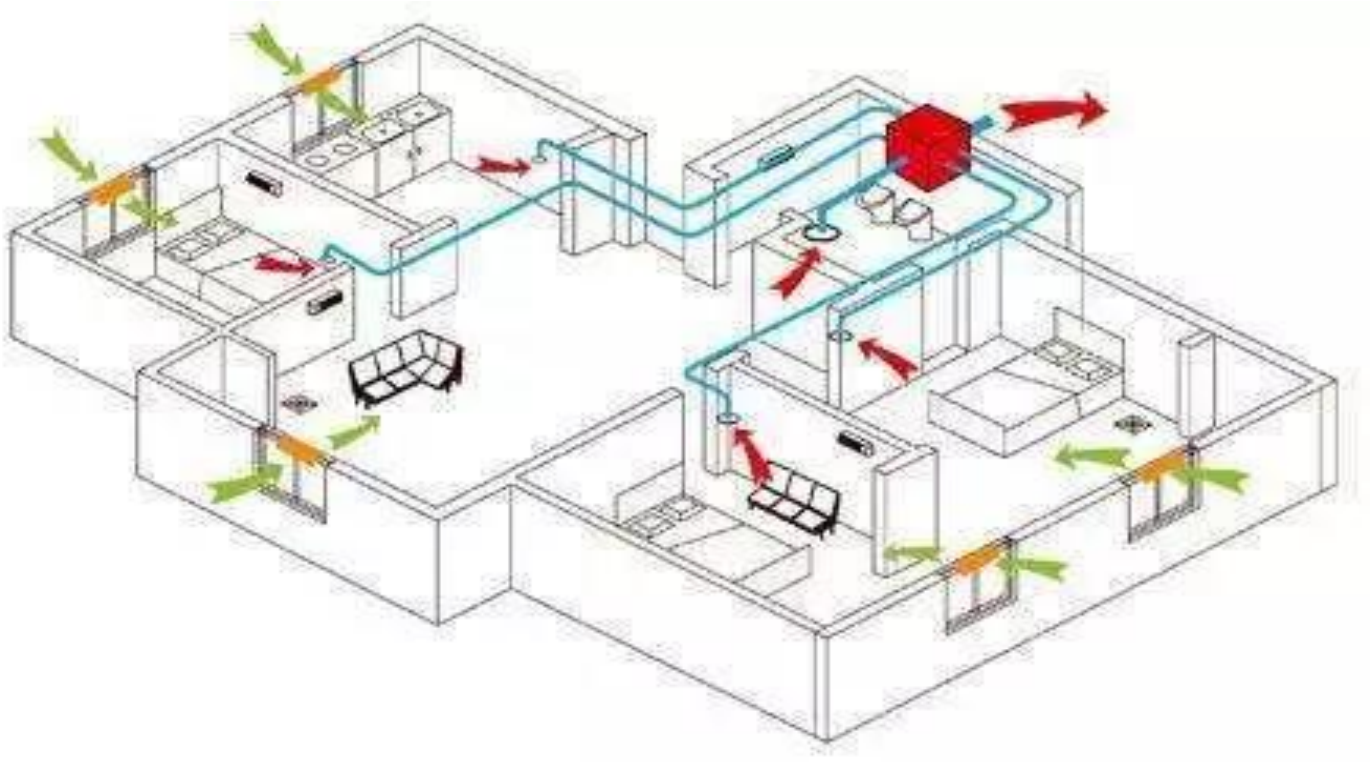

Figure C.4 – Schematic diagram of fresh air system