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## ASSESSMENT OF ENVIRONMENTAL RISKS FROM THE AIR POLLUTION OF CHINA CITIES

The problem of air pollution in the cities of China is known far beyond its borders. It even jeopardized the holding of the XXIX Olympic Games in 2008. **Purpose.** o determine environmental risks for the population based on the assessment of air pollution in the cities of Beijing, Chengdu and Sanya (PRC). The work was carried out on the basis of data from the Chinese online platform «PM2.5 lishishuju» on the condition of air pollution in China's cities. A comparative assessment of pollutants content in the air has been carried out and the environmental risk for the population of these cities has been calculated. This calculation has been made in accordance with the methodology used in assessing the risk to public health exposed to chemicals that pollute the environment by inhaling substances into the human body. The risk is calculated by comparing the actual exposure level with the safe exposure level and determining the hazard coefficient of exposure to the substance. According to the calculations results, the ranking of substances polluting the air by the magnitude of the hazard coefficient was carried out to determine the highest priority pollutants. The results of the study have showed that the overall risk level for Beijing is 11.6; for the city of Chengdu − 26.4; for the city of Sanya − 4.5. In all studied cities, the overall level of non-carcinogenic risk exceeds the permissible limit value. The greatest contribution to the overall risk of non-carcinogenicity is made by the following elements: in Beijing − suspended solids (PM 2.5) − 40%, in Chengdu − suspended solids (PM 2.5) − 73%, in Sanya − ozone ($O_3$) - 52%. These substances determine the likelihood of negative effects in various organs and systems of the human body. Therefore, in addition to the overall level of risk, the effects on critical organs and systems must also be considered. The results of the study have showed that the respiratory organs are most vulnerable to air pollution in the cities under study. The most dangerous excess is observed in Chengdu − 26.11. A negative effect on the cardiovascular system occurs in two cities: Chengdu − 2.35, and Beijing − 2.30; impact on human development is from 2.30 to 2.35 (respectively, in Beijing and Chengdu). In Sanya, risk indicators do not exceed the permissible level.

***Keywords***: air, pollution, online monitoring, suspended substances, ozone, environmental risk, Beijing, Chengdu, Sanya, China

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**ОЦІНКА ЕКОЛОГІЧНИХ РИЗИКІВ ВІД ЗАБРУДНЕННЯ ПОВІТРЯ МІСТ КИТАЮ**

Проблема забруднення атмосферного повітря міст Китаю відома далеко за його межами. Вона, навіть, поставила під загрозу проведення XXIX Олімпійських ігор у 2008 році. Мета роботи: на основі оцінки забруднення атмосферного повітря міст Пекін, Ченду і Санья (КНР) визначити екологічні ризики для населення. Робота виконувалась на основі даних китайської он-лайн платформи «PM2.5 lishishuju» щодо стану забруднення атмосферного повітря міст Китаю. Проведено порівняльну оцінку вмісту забруднюючих речовин у повітрі та розраховано екологічний ризик для населення цих міст. Розрахунок екологічного ризику зроблено у відповідності до методики, яка використовується для оцінки ризику для здоров'я населення, що зазнає впливу хімічних речовин, забруднюючих довкілля при інгаляційному надходженні речовин до організму людини. Обраховано ризик шляхом порівняння фактичного рівня експозиції з безпечним рівнем впливу та визначення коефіцієнту небезпеки впливу речовини. За результатами розрахунків здійснено ранжування речовини, що забруднюють повітря за величиною коефіцієнту небезпеки для визначення найбільш пріоритетних забруднювачів. Результати дослідження показали, що рівень загального ризику для м. Пекін складає 11,6; для м. Ченду – 26,4; для м. Санья – 4,5. В усіх досліджуваних містах загальний рівень неканцерогенного ризику перевищує граничну прийнятну величину – 1. Найбільший внесок у сумарний неканцерогенний ризик вносять такі елементи: у м. Пекін − завислі речовини (PM 2,5) – 40%, у м. Ченду − завислі речовини (PM 2,5) – 73%, у м. Санья - озон ($O_3$) – 52%. Зазначені речовини обумовлюють імовірність розвитку негативних ефектів у різних органах і системах організму людини. Тому необхідно розглядати окрім загального рівня ризику, ще й вплив на критичні органи і системи. Результати дослідження показали, що найбільш уразливими в умовах забруднення атмосферного повітря досліджуваних міст є органи дихання. Найнебезпечніше перевищення спостерігається в м. Ченду – 26,11. Негативний вплив на серцево-судинну систему відбувається в двох містах: Ченду – 2,35 та Пекіні – 2,30; на розвиток людини діапазон значення ризику розвитку неканцерогенних ефектів складає від 2,30 до 2,35 у м. Пекін та м. Ченду, в м.Санья значення ризику не перевищують допустимий рівень.

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***Ключові слова:*** атмосферне повітря, забруднення, он-лайн моніторинг, завислі речовини, озон, екологічний ризик, Пекін, Ченду, Санья, Китай

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**ОЦЕНКА ЭКОЛОГИЧЕСКИХ РИСКОВ ОТ ЗАГРЯЗНЕНИЯ ВОЗДУХА ГОРОДОВ КИТАЯ**

Проблема загрязнения атмосферного воздуха городов Китая известна далеко за его пределами. Она даже поставила под угрозу проведение XXIX Олимпийских игр в 2008 году. Цель работы: на основе оценки загрязнения атмосферного воздуха городов Пекин, Чэнду и Санья (КНР) определить экологические риски для населения. Работа выполнялась на основе данных китайской онлайн платформы «PM2.5 lishishuju» о состоянии загрязнения атмосферного воздуха городов Китая. Проведена сравнительная оценка содержания загрязняющих веществ в воздухе и рассчитан экологический риск для населения этих городов. Расчет экологического риска сделано в соответствии с методикой, которая используется в оценке риска для здоровья населения, подвергающегося воздействию химических веществ, загрязняющих окружающую среду при ингаляционном поступлении веществ в организм человека. Рассчитан риск путем сравнения фактического уровня экспозиции с безопасным уровнем воздействия и определения коэффициента опасности воздействия вещества. По результатам расчетов осуществлено ранжирование веществ, загрязняющие воздух по величине коэффициента опасности для определения наиболее приоритетных загрязнителей. Результаты исследования показали, что уровень общего риска для г. Пекин составляет 11,6; для г.. Чэнду − 26,4; для г.. Санья − 4,5. Во всех исследуемых городах общий уровень не канцерогенного риска превышает предельную приемлемую величину. Наибольший вклад в суммарный не канцерогенных риск вносят такие элементы: в г.. Пекин - взвешенные вещества (PM 2,5) − 40%, в г. Чэнду − взвешенные вещества (PM 2,5) − 73%, в г. Санья - озон ($O_3$) - 52%. Указанные вещества обусловливают вероятность развития негативных эффектов в различных органах и системах организма человека. Поэтому необходимо рассматривать кроме общего уровня риска, еще и влияние на критические органы и системы. Результаты исследования показали, что наиболее уязвимыми в условиях загрязнения атмосферного воздуха исследуемых городов являются органы дыхания. Самое опасное превышение наблюдается в г. Чэнду − 26,11. Негативное влияние на сердечно-сосудистую систему происходит в двух городах Чэнду − 2,35 и Пекине − 2,30; влияние на развитие человека составляет от 2,30 до 2,35 (соответственно, в г. Пекин и г. Чэнду. В г. Санья показатели риска не превышают допустимый уровень.

***Ключевые слова:*** атмосферный воздух, загрязнение, он-лайн мониторинг, взвешенные вещества, озон, экологический риск, Пекин, Чэнду, Санья, Китай

## *Introduction*

The problem of air pollution is one of the global problems of mankind. Growing emissions of pollutants into the atmosphere are the focus of attention not only of residents of large cities, but also of the scientific community and the government. In this regard, a large number of regional and international summits were held to address this problem. International agreements were signed and governmental (at the level of individual countries) programs to limit and reduce emissions to the atmosphere [19–20] were adopted, giving positive results.

International attention to the problem of air pollution has led scientists to develop a system for monitoring the ecological state of the atmosphere in all regions of the world. There are now more than 20,000 known air quality monitoring stations in the world, monitoring data of more than 10,000 of which is published in the World Air Quality Index (AQI) project. The map below (Fig. 1) shows the location of known monitoring stations (Fig. 1). The AQI standard for each published station is based on the US EPA Instant-Cast standard.

From the outset, the World Air Quality Index project team (WAQI) has always strived for transparency in delivering Air Quality Information to citizens of the world. In order to make common information about air quality more relevant, the World Air Quality Index team has organized studies with the most well-known international institutions on the possibility of creating an open database. The project involved:

- UNEP (United Nation Environmental Program);
- WMO (World Meteorological Organization);
- WHO (World Health Organization);
- GEO (Group on Earth Observations);
- CCA (Climate & Clean Air Coalition);
- UNIDO (United Nation Industrial Development Organization);
- WRI (World Resource Institute) [7].


**Fig. 1** – Network of stations for automatic monitoring of air quality [6]

In September 2018, thanks to the great efforts of the world the EPA (Environmental Protection Agency), information on air quality is now available in real time for more than 10 000 stations in 1000 large cities from 80 countries [6].

Data published in AQI in real time cannot be corrected at the time of publication, which ensures the objectivity of the information. However, to provide a high level of accuracy for each digit of the AQI, several levels of computer processing are used. For example, the consistency of the data is checked in real time with neighboring stations, which allows you to automatically identify the faulty monitoring stations and delete them, if necessary, from the map.

As the World Environment Agency is constantly evolving and increasing the list of air quality monitoring stations, this page is regularly updated on the Internet.

**Formulation of the problem**

The system of atmospheric air condition observation in China now covers almost the entire country. At present, 24 organizations conduct real-time observations in all major cities of China. In March 2015, a meeting was held in Beijing with many environmental specialists from the US State Department, as well as with the China Mission (a well-known organization working in PM2.5 monitoring time at the embassy in Beijing). Among all the questions that were considered, it is worth mentioning the «now» system. This system is used by the US EPA to convert raw pollutant, expressed in µg / m3 or ppb, to AQI (scale from 0 to 500) [6]. It is used for all AQI values reported at airnow.gov.

The problem is to compensate for the «24-hour averaging» that should be used when converting the concentration to AQI. The reason for this averaging is that the AQI scale indicates that each of the levels of health problems (i.e, Good, Moderate ... Unhealthy ...) is valid for 24 hours of exposure [1]. For example, when you see 188 AQI (unhealthy), you should read it as «if I stay in place for 24 hours, and AQI - 188 during these 24 hours, then the effect on health is negative». This is very different from the fact that «if AQI reported that now it is 188, then the effect on health is negative».

The problem is that 24-hour averaging is a very bad idea and should be reversed [3] for at least two reasons:

Firstly, the dynamics of air pollution is such that the wind is able to completely clean the air in less than 30 minutes! This phenomenon is often observed in Beijing with strong northern winds that can reduce PM2.5 AQI from more than 300 to less than 50 in less than an hour [2]. When this happens, no one wants to wait 24 hours before knowing that the air quality is good (and go for a walk to enjoy the fresh air!);

The second reason is that the air quality suddenly deteriorates. One of the known cases is the Indonesian forest fire, which caused the Singapore smog. When the winds move north, in these circumstances, the AQI can grow from 50 to 150 in just one hour. Indeed, there were a lot of requests from asthmatics / sensitive people, when the average for the previous 24 hours was still applied in Singapore.

For these reasons, the US EPA introduced the NowCast system: it is an alternative conversion formula that is used to counteract the balance of averaging needs as air quality conditions change.

To emphasize the importance of substances selected for monitoring, we will explain where these pollutants originate from and how they affect our health and the environment.

$NO_2$ is a reddish-brown gas that is released from all internal combustion engines. There are two main nitrogen-based compounds that are produced from internal combustion engines: $NO_2$ and nitrogen oxide (NO). At the point of emission (i.e. exhaust pipe), the proportion of $NO_x$ is about 90% NO and 10% $NO_2$ [1].

After a few hours in the atmosphere and in the presence of volatile organic compounds (VOC), NO is converted to $NO_2$. This reaction can take from a couple of seconds to several hours [2]. $NO_2$ then reacts with other substances in the air to form nitric acid, particulate matter, and substances called PANs (peroxyacyl nitrates).

Also, with the help of sunlight, $NO_2$ can turn back to NO and produce ozone ($O_3$) as a strange pollutant. Through the potential of $NO_2$ for the production of these «secondary» pollutants, it is important to control and regulate $NO_2$.

Short-term and long-term exposure to $NO_2$ is associated with an increased risk of developing respiratory disfunctions. People with asthma, young children and adults have an increased sensitivity to its effects [1].

Secondary pollutants caused by the presence of $NO_2$ in the atmosphere also have their adverse effects. PAN is an irritant, nitric acid causes acid rain and particles, and $O_3$ causes breathing problems.

Suspended particles (PM - particulate matter) are a widespread air pollutant, including a mixture of solid and liquid particles in the air in suspension.

Indicators that are commonly used to characterize PM and are important for health include mass concentration of particles with a diameter of less than 10 microns ($PM_{10}$) and particles with a diameter of less than 2.5 microns ($PM_{2.5}$). $PM_{2.5}$, which is often referred to as fine suspended particles, also contains ultra-fine-dispersed particles with a diameter of less than 0.1 microns. In most of Europe, $PM_{2.5}$ is 50-70% $PM_{10}$ [9]. RM with a diameter of 0.1 μm to 1 μm can be in the air for many days and weeks and, accordingly, undergo transboundary air transport over long distances. 2PM is a mixture with physical and chemical characteristics, varying with location. The most common chemical components of the PM include sulfates, nitrates, ammonia, other inorganic ions, such as sodium, potassium, calcium, magnesium and chloride ions, organic and elemental carbon, minerals of the earth's crust, water bound particles, metals (including vanadium, cadmium, copper, nickel and zinc) and polycyclic aromatic hydrocarbons (PAHs). In the composition of the RM biological components, such as allergens and microorganisms, [9] are also found.

Currently, there are new studies, showing that $PM_{2.5}$ is more harmful than $PM_{10}$. Physically, it makes sense - less than a fraction, a greater likelihood that it will be absorbed deeper into the lungs and harm us. This is also one of the important reasons for WHO to push all countries to have standards for $PM_{2.5}$.

Ozone $O_3$. It is worth considering ozone pollution as a global problem. In general, ozone is distributed from the surface to an altitude of 20 km and thus contains both "good ozone", the ozone layer in the upper stratosphere, and "bad" ozone in the troposphere. Ozone pollution is tropospheric ozone, and in particular, surface concentration, which is important for quantifying health effects. In addition, tropospheric ozone has a daily cycle, with pollution exceeding during the day when the temperature reaches its maximum, and almost no pollution during the night. In China, ozone actually becomes a major pollutant, exceeding $PM_{2.5}$ pollution.

### *Research methods*

The purpose of the study is to assess the degree of air pollution in the cities of Beijing, Chengdu and Sanya (PRC) and to determine the environmental health risk.

The work was carried out on the basis of the collected statistical reporting on the condition of air pollution in the cities of China - Beijing, Chengdu and Sanya. A comparative assessment of pollutants content in the air of cities was carried out and the environmental risk from this pollution was calculated.

Modern monitoring in the world is carried out with the help of GAIA Air Quality Monitoring Stations. It is a specially optimized, highly accurate and easy-to-use monitoring station, developed by Earth Sensing laboratories. Gaia A13: Gasification [8]. The Chinese online air monitoring and analysis platform is a software platform and contains information on the air composition of 367 cities.

The platform records such indicators as AQI, $PM_{2.5}$, $PM_{10}$, $SO_2$, $NO_2$, $O_3$, CO, temperature, humidity, wind speed, wind direction, satellite images of clouds and other monitoring elements. All data is automatically updated every hour. The platform provides a historical analysis of data requests from December 2013, including real-time monitoring, statistical data, urban analysis, satellite imagery of clouds and equipped with other functions.

The results of on-line monitoring are posted on the Internet and on demonstration screens in certain places of cities. The color coding of the level of pollution of the atmosphere is used; it makes it possible, without reading the numbers, to understand the degree of threat to health (Fig. 2).

The color coding of the air pollution level is used; it allows one to understand the degree of threat to health without reading the numbers (Table 1).

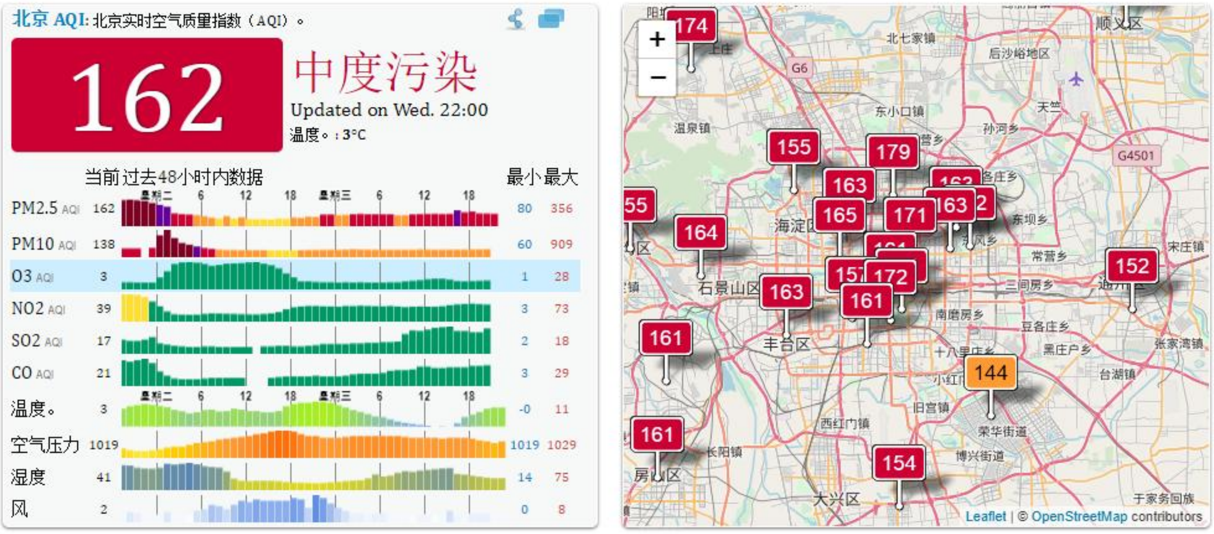


**Fig. 2** − An example of a comprehensive description of the environmental condition of atmospheric air in Beijing [2]

**Table 1**

**Scale of pollution level relative to calculated AQI index and health risk**

| Category | Index Value | Level of Health Concern | How Does This Affect Me? |
|---|---|---|---|
| Green Good | 0-50 | **Good.** Air quality is considered satisfactory and air pollution poses little or no risk. | The air quality is good. No precautions necessary. Breathe deeply and enjoy! |
| Yellow | 51-100 | **Moderate.** Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of individuals. For example, people who are unusually sensitive to ozone may experience respiratory symptoms if ozone levels fall into this range. | Sensitive people* should plan strenuous outside activities when air quality is better. |
| Orange | 101-150 | **Unhealthy for Sensitive Groups.** Members of sensitive groups may experience health effects. | Sensitive people* should cut back or reschedule strenuous outside activities. Everyone else should consider limiting strenuous outdoor activities. |
| Red | 151-200 | **Unhealthy.** Everyone may begin to experience health effects. Members of sensitive groups may experience more serious health effects. | Sensitive people* should avoid strenuous outside activities. Everyone else should cut back or reschedule strenuous outside activities. |
| Purple | 201-300 | **Very Unhealthy.** This will trigger a health alert, meaning everyone may experience serious health effects. | Sensitive people* should avoid all outside physical activities. Everyone else should significantly cut back on outside physical activities. |
| Maroon | 301-500 | **Hazardous.** This triggers health warnings of emergency conditions. The entire population is likely to be affected. | Everyone should avoid all outside physical activities. |

The calculation of the environmental risk in the work is done in accordance with the methodology described in [10], which is used to assess the risk to public health exposed to chemical substances that pollute the environment.

Characterization of the risk of non-carcinogenic effects is carried out either by comparing the actual level of exposure with a safe level of exposure (index / hazard ratio), or based on the concentration-response parameters obtained in epidemiological studies [10].

Since our study determined the concentration of pollutants in the ambient air, from a large set of methods for calculating environmental risk contained in [10], we use the one that is used during inhalation of substances in the human body. Environmental risk is calculated by the formula:

$$HQ_i = C_i / RfC, \qquad (1)$$

where: HQ − the hazard coefficient of exposure to a substance and; RfC − the safe level of the substance exposure, mg / m$^3$ (Table 2); $C_i$ − level of exposure, mg / m$^3$.

**Table 2**

**Reference concentrations for chronic inhalation exposure [10]**

| CAS | | Substance | RFC, мг/м$^3$ | Critical organs/ systems |
|---|---|---|---|---|
| | PM2,5 | Suspended particles <2,5 mm | 0,015 | Respiratory system, mortality |
| | PM10 | Suspended particles <10 mm | 0,05 | Respiratory system, mortality, cardiovascular system, development |
| 7446-09-5 | SO2 | Sulfur dioxide | 0,05 | Respiratory system, mortality |
| 630-08-0 | CO | Carbon monoxide | 3 | Blood, cardiovascular system, development, CNS |
| 10102-44-0 | $NO_2$ | Nitrogen dioxide | 0,04 | Respiratory system, blood, formation of MetHb |
| 10028-15-6 | $O_3$ | Ozone | 0,03 | Respiratory system |

If the calculated hazard coefficient (HQ) of a substance does not exceed one, then the probability of the development of harmful effects in a person with the daily intake of a substance during life is insignificant. Such an impact is characterized as acceptable.

If the hazard coefficient exceeds one, then the probability of occurrence of harmful effects in a person increases in proportion to the increase in HQ, but it is impossible to accurately name the multiplicity.

According to the results of calculations, it is advisable to rank the substances polluting the air by the magnitude of the hazard ratio to determine the highest priority for pollutants.

***Research results***

The ecological condition of atmospheric air in China is controlled by automated systems. Monitoring results are constantly updated on the website, where information is collected on all cities of the country, forecasts are analyzed and compiled [8].

Many indicators are used to assess the ecological state, including:

- Air temperature;
- Atmospheric pressure;
- Air humidity;
- Wind;
- Content in the air:
  - suspended particles up to 2.5 mm and up to 10 mm in size (PM2.5 and PM10)
  - carbon monoxide (CO)
  - nitrogen dioxide (NO2)
  - ozone (O3)
  - sulfur dioxide (SO2).

The network of tracking stations in China covers almost the entire country (Fig. 3). Therefore, the accuracy of the information provided on the monitoring site is quite high. It is ensured not only by the accuracy of the equipment and the quality of the software, but also by constant adjustments of the indicators by comparison with neighboring stations of observation.

The density of stations is especially high in the eastern part of the country, where the largest cities are located and the main sources of air pollution are concentrated. As can be seen from Fig. 3, the overwhelming majority of cities have threatening AQI indicators, the cause of which is the intense anthropogenic load on the atmospheric air in China.

To assess the diversity of the ecological status of cities in China, a study was conducted on the example of three fundamentally different settlements. For the study Beijing, Chengdu and Sanya were selected.

Beijing is the capital of the People’s Republic of China, a national political, cultural, scientific and technological innovation center. It should be noted that after the XXIX Olympic Games (2008), it is in Beijing where they are supported now, which is reflected in many low average atmospheric pollution indices (Fig. 4).

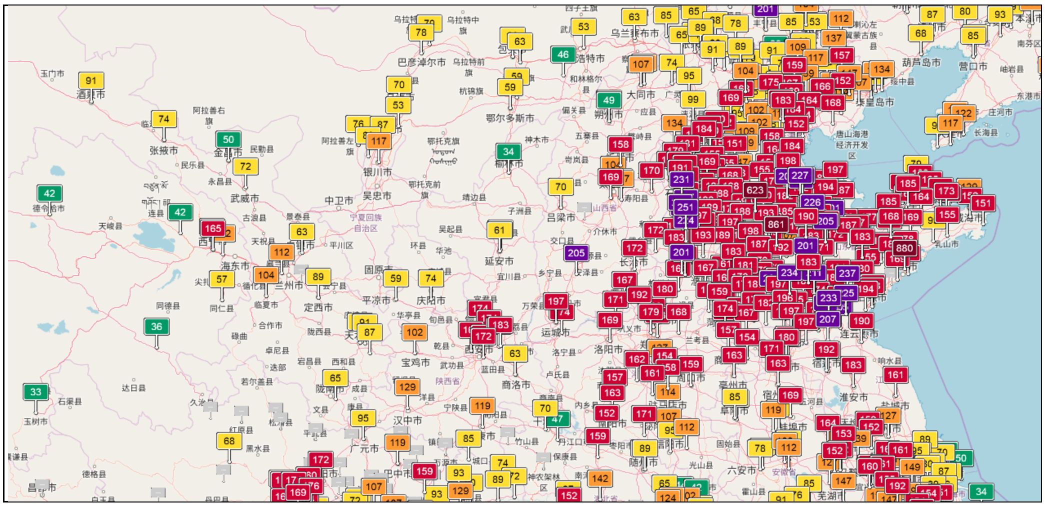

**Fig. 3** – Location of monitoring points in the People's Republic of China with the symbol of the pollution index (taken from on-line monitoring) [11]


**Fig. 4** – Air Pollution in Beijing (AQI) [14]

The city has a large number of observation posts that allow you to make appropriate calculations and plot the resulting value on the map, updated every hour.

Pollution distribution in the air is significantly influenced by the weather and, in general, the climate. Beijing is located in a monsoon-prone humid continental climate or a monsoon subtropical climate, characterized by hot, wet summers due to the influence of the eastern monsoons and cold, windy, dry winters, which are formed under the influence of Siberian anticyclones. The average annual temperature in a flat area is 11 ~ 13 ° C, 800 meters below the sea is 9 ~ 11 ° C, in a mountainous area is 3 ~ 5 ° C. The average annual maximum temperature ranges between 35 ~ 40 ° C. Extreme minimum temperatures, like typically between -14 ~ -20 ° C [12].

Spatial distribution of annual precipitation is uneven. In the northeast and southwest, the windward slope of the mountain front resists precipitation, so the amount of precipitation is between 600 ~ 700 mm. In the north and northwest, rainfall is less than 500 mm. Summer precipitation is about 3/4 of annual precipitation [12].

For a more detailed description of the air pollution in each area of the city, there are screens showing online change of the situation, which are duplicated on the Internet and sent to SMS on phones.

Chengdu is the capital of Sichuan province, one of the largest cities in China, is a political, economic, cultural and educational center. The climate is subtropical wet monsoon, four different seasons are clearly distinguished, summer without heat, winter without cold. The average annual temperature is 16.7 ° C. The solar temperature is 1071 hours, the average annual precipitation is 945.6 mm. Chengdu is located in the eastern part of the plain, with an average elevation of about 500 meters above sea level.

The climate feature of Chengdu is excessive cloudiness and short daylight hours. Also, the climate of Chengdu is described by air humidity, in summer the temperature is not high (the maximum temperature as a whole does not exceed 37 ° C), but the high humidity creates a feeling of dry temperatures. The average temperature in winter does not exceed 5 ° C, but due to cloudiness, the air seems very cold.

In total, the city has more than 500 different enterprises. They are mainly focused on the production of chemical raw materials and products (without flammable, explosive materials, easily accessible drugs and hazardous products), building materials, steel, detergents.

Monitoring of the ecological state of atmospheric air is carried out in the on-line system (Fig. 5).

Sanya is a city of the province and island of Hainan, located in the southern part of Hainan Island. Sanya is located in low latitudes, tropical sea monsoon climate zone. The island has a long summer, there is no winter, in the fall and spring it is immediately sunny, a large amount of evaporation. The climate is characterized by frequent typhoons and strong winds.

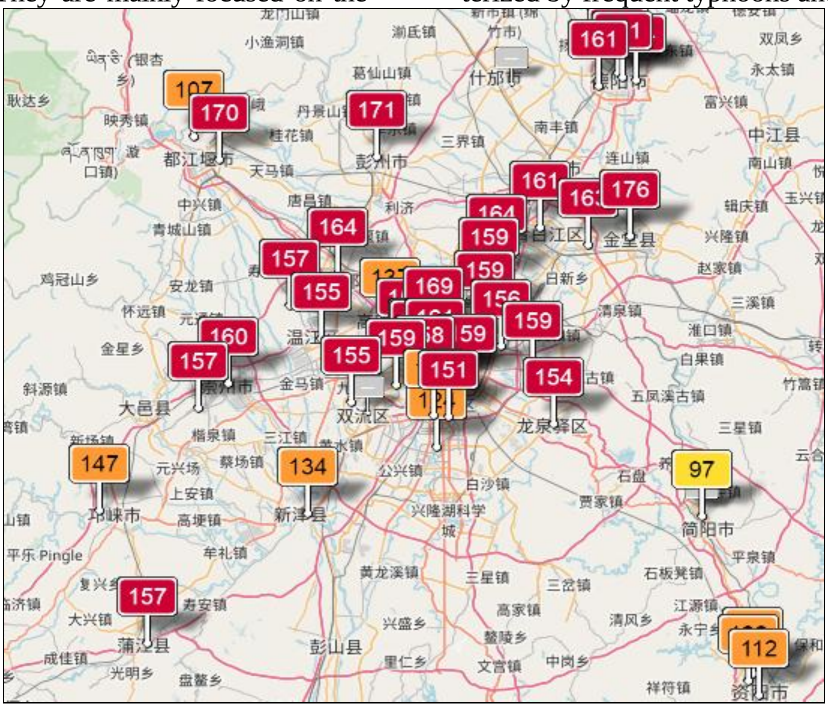


**Fig. 5** − Air pollution in Chengdu (AQI) [16]


**Fig. 6** − Air pollution in Sanya (AQI) [18]

The average annual temperature is 26.2 ° C. The average maximum temperature of the year is 34.4 ° C. The average minimum temperature is 15 ° C. The average annual rainfall is 1347.5 mm. There are 2226.1 hours of sunshine throughout the year [16].

On the territory of Hainan tourist and recreational activities are being actively developed, which is due to the warm mild climate most of the year.

Absence of industrial pollution sources does not eliminate the need for air quality control. Online monitoring records the air pollutant content, calculates AQI and displays on the corresponding map (Fig. 6). Air pollution indices are very low.

Based on the data of the Chinese online platform "PM2.5 lishishuju", we calculated the environmental risk, using formula (1) for the population of these cities (Tables 3–5).

**Table 3**

**Assessment of non-carcinogenic risk for the population of Beijing (PRC) due to atmospheric pollution**

| № | Chemical element | Ci, мг/м$^3$ | RFCi, мг/м$^3$ | HQ | Critical organs and systems |
|---|---|---|---|---|---|
| 1 | PM2,5 | 0,070389 | 0,015 | 4,692 | Respiratory system, mortality |
| 2 | PM10 | 0,095889 | 0,05 | 1,92 | Respiratory system, mortality, cardiovascular system, development |
| 3 | Sulfur dioxide | 0,010056 | 0,05 | 0,2011 | Respiratory system, mortality |
| 5 | Carbon monoxide | 1,157028 | 3 | 0,39 | Blood, cardiovascular system, development, CNS |
| 5 | Nitrogen dioxide | 0,047528 | 0,04 | 1,188 | Respiratory system, blood, formation of MetHb |
| 6 | Ozone | 0,097778 | 0,03 | 3,26 | Respiratory system |
| General HQ | | | | 11,644 | |
| Respiratory system | | | | 11,25893 | |
| Cardiovascular system | | | | 2,303449 | |
| Development | | | | 2,303449 | |
| Blood | | | | 1,573868 | |
| Formation of methemoglobin | | | | 1,188192 | |
| CNS | | | | 0,385676 | |
| Mortality | | | | 6,81 | |

**Table 4**

**Assessment of non-carcinogenic risk for the population of Chengdu (PRC) due to atmospheric pollution**

| № | Chemical element | Ci, мг/м$^3$ | RFCi, мг/м$^3$ | HQ | Critical organs and systems |
|---|---|---|---|---|---|
| 1 | PM2,5 | 0,291083333 | 0,015 | 19,405 | Respiratory system, mortality |
| 2 | PM10 | 0,099943333 | 0,05 | 2,00 | Respiratory system, mortality, cardiovascular system, development |
| 3 | Sulfur dioxide | 0,013806667 | 0,05 | 0,276 | Respiratory system, mortality |
| 5 | Carbon monoxide | 1,083333333 | 3 | 0,36 | Blood, cardiovascular system, development, CNS |
| 5 | Nitrogen dioxide | 0,052053333 | 0,04 | 1,301 | Respiratory system, blood, formation of MetHb |
| 6 | Ozone | 0,094083333 | 0,03 | 3,14 | Respiratory system |
| General HQ | | | | 26,479 | |
| Respiratory system | | | | 26,118 | |
| Cardiovascular system | | | | 2,360 | |
| Development | | | | 2,360 | |
| Blood | | | | 1,662 | |
| Formation of methemoglobin | | | | 1,301 | |
| CNS | | | | 0,361 | |
| Mortality | | | | 21,68 | |

**Table 5**

**Assessment of non-carcinogenic risk for the population of Sanya (PRC) due to atmospheric pollution**

| № | Chemical element | Ci, мг/м$^3$ | RFCi, мг/м$^3$ | HQ | Critical organs and systems |
|---|---|---|---|---|---|
| 1 | PM2,5 | 0,015222 | 0,015 | 1,015 | Respiratory system, mortality |
| 2 | PM10 | 0,029389 | 0,05 | 0,59 | Respiratory system, mortality, cardiovascular system, development |
| 3 | Sulfur dioxide | 0,002861 | 0,05 | 0,0572 | Respiratory system, mortality |
| 5 | Carbon monoxide | 0,625972 | 3 | 0,21 | Blood, cardiovascular system, development, CNS |
| 5 | Nitrogen dioxide | 0,012417 | 0,04 | 0,310 | Respiratory system, blood, formation of MetHb |
| 6 | Ozone | 0,070083 | 0,03 | 2,34 | Respiratory system |
| General HQ | | | | 4,515 | |
| Respiratory system | | | | 4,31 | |
| Cardiovascular system | | | | 0,80 | |
| Development | | | | 0,80 | |
| Blood | | | | 0,52 | |
| Formation of methemoglobin | | | | 0,31 | |
| CNS | | | | 0,21 | |
| Mortality | | | | 1,66 | |

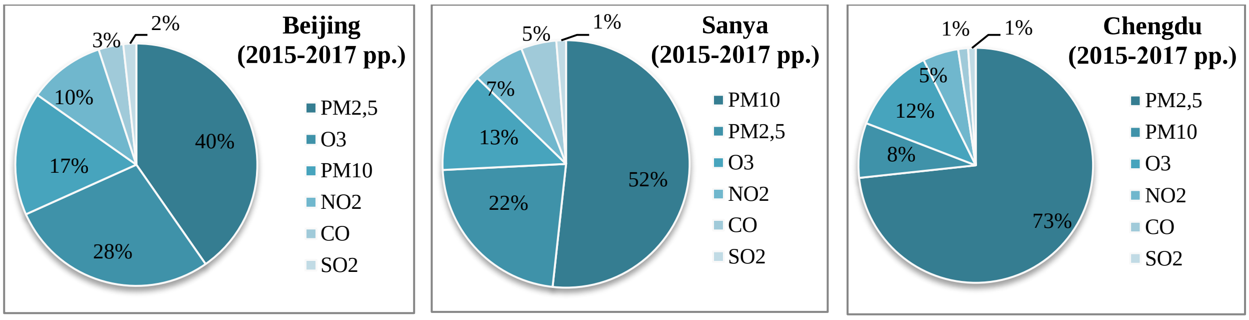


**Fig. 7** – The contribution of each pollutant to the overall environmental risk of the studied cities

The results of the study have showed that the following substances make the greatest contribution to the total non-carcinogenic risk: in Beijing – suspended particles PM 2.5 – 40%, in Chengdu - suspended particles PM 2.5 – 73%, in Sanya – O3 ozone – 52% (Fig. 7). These substances determine the likelihood of the development of harmful effects in the respiratory system.

The results of air pollution analysis for the period from 2015 to 2017 (Fig. 7 on the left) have showed that a significant excess of PM 2.5 is observed in the city of Beijing, in the city of Chengdu, this excess is particularly critical, especially in the village. In Sanya, harmful polutants exceeding the norm are not observed. Hazard ratio for PM10 is exceeded in Beijing and in Chengdu, equal to 1.91 and 1.99, respectively. Excess of NO2 pollutant is observed in the city of Beijing – 1.18 and in the city of Chengdu – 1.30. In all three cities, hazard coefficient of $O_3$ is exceeded (city of Beijing – 3.25, m. Sanya – 2.33), but in city of Chengdu the excess is the highest – 3.13. The three-year HQ averages with $SO_2$ and CO substances did not show excess in any of the cities.

The analysis and comparison of the seasons of the year (Fig. 3.8 right). It is established that in winter high rates are observed in the city of Chengdu; in spring, in summer and in autumn, the greatest atmospheric pollution is observed in Beijing, which is caused by the meteorological conditions of the atmospheric stratification.

Each pollutant has a special effect on the human body. This action is manifested in the occurrence of certain negative effects in various organs and systems of the human body. It is therefore necessary to consider, in addition to the general level of risk, also the effect on critical organs and systems in the event of exposure to pollutants.

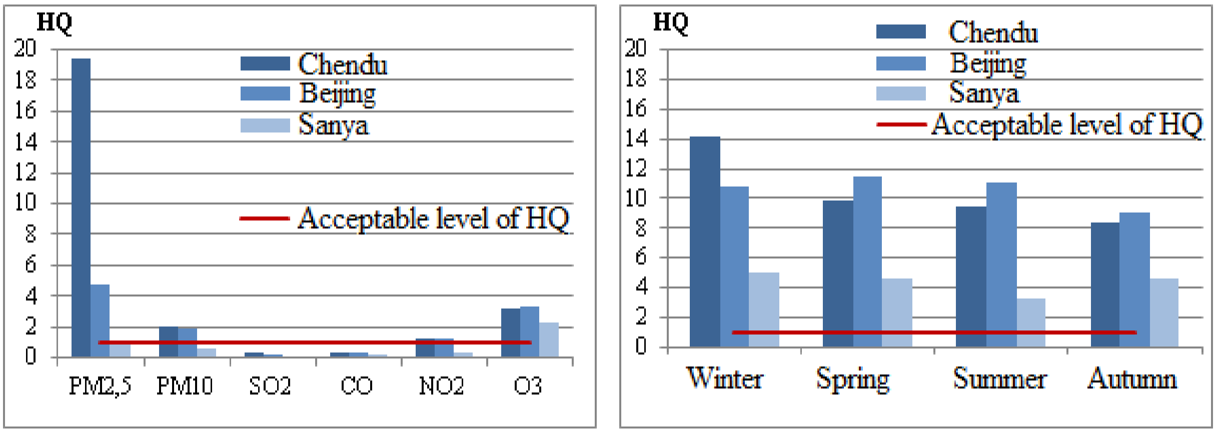


**Fig. 8** − Comparison of environmental risk due to atmospheric pollution in different seasons of the cities of Beijing, Chengdu and Sanya

The results of the study have showed that the respiratory organs are the most vulnerable in conditions of air pollution in the studied cities. The most dangerous excess is observed in Chengdu, 26.11 (Fig. 9).

Threatening effects on the cardiovascular system occur in two cities of Chengdu – 2.35 and Beijing – 2.30; on human development the risk value of the development of non-carcinogenic effects ranges from 2.30 to 2.35 in the city of Beijing and the city of Chengdu, in the city of Sanya the risk value does not exceed the permissible level. In blood and methemoglobin formation, the greatest risk is associated with the formation of methemoglobin – from 0.31 to 1.30. Risk of developing non-carcinogenic diseases of the CNS is in the range of 0.20 to 0.38.

Thanks to the work of online monitoring, in any city in China for any period of time there is a warning of the population against threats associated with air pollution. By following the recommendations that are provided there, you can prevent a negative impact on your health.

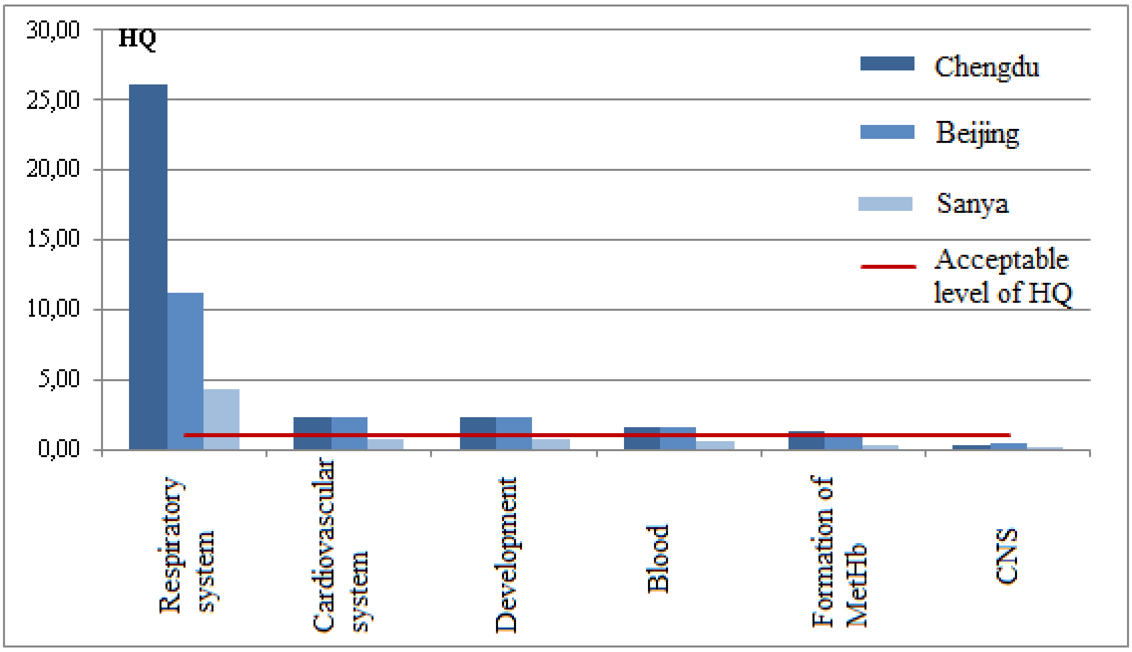


**Fig. 9** − Comparison of the risk of certain types of diseases in the cities of Beijing, Chengdu and Sanya as a result of atmospheric pollution

## *Conclusions*

The world air monitoring system covers almost all continents and has more than 20,000 known air quality monitoring stations, of which more than 10,000 are published in the World Air Quality Index (AQI) project. Interval of observations and updates in the system is different in different countries − from one day to 1:00. The work substantiates the expediency of an hourly update of information considering the use of its population as warnings about the occurrence of negative health effects.

On the selected territory − three cities of the PRC (Beijing, Chengdu, Sanya), atmospheric air pollution studies are conducted by the Chinese online monitoring platform and updated hourly. On the basis of statistics, for the three-year observation period (2015−2017), collected by the authors, an environmental risk assessment was made for indicators such as AQI, PM2.5, PM10, SO2, NO2, O3, CO. It has been established that the greatest contribution to the total non-carcinogenic risk in Beijing and Chengdu is made by suspended particles (PM 2), respectively − 40% and 73%, in the city Sanya − ozone − 52%.

Since the effect of pollutants on the human body is manifested in the occurrence of certain diseases, their risk has been assessed. The results of the study have showed that the respiratory organs are the most vulnerable in conditions of air pollution in the studied cities. The most dangerous excess is observed in the city of Chengdu - 26.11 (at a rate of HQ = 1).

It is advisable for the population to avoid the negative impact of pollution by following the recommendations developed in accordance with the calculated AQI index.

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