Meteorological Sensitivity Analysis of Kangbao Economic Development Zone

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Abstract Kangbao County is located in the northwest of Bashang in Hebei Province, which is a sub-arid area in the middle temperate zone, with a cold and arid climate and frequent disastrous weather. The meteorological data of Kangbao County Meteorological Station from 1994 to 2023 were selected, and the meteorological elements such as air pressure, temperature, precipitation, wind, relative humidity, sunshine, thunderstorm, hail, gale, rainstorm, fog, and snow cover were counted. The climate background analysis and high-impact weather analysis were carried out in combination with the topographic characteristics, geographical location, and climate characteristics. The results of meteorological sensitivity survey in the park showed that industries such as food, agriculture and new energy are very sensitive to temperature. During the visit to the enterprises in the park, it was found that heavy precipitation, snow, strong winds and hail had a great impact on many industries, and it was recommended to carry out long-term planning and reasonable design of buildings. It should pay close attention to forecasts and early warnings, formulate emergency plans for high-impact weather defense, and actively take preventive measures.

Key words Climatic background analysis; High-impact weather; Sensitivity survey analysis; Kangbao County

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With the economic and social development, global warming intensifies, and extreme weather events occur frequently. Meteorological disasters and their secondary and derivative disasters have a certain impact on people's lives and property and economic and social development. The planning and construction of development zones and industrial parks are more sensitive and vulnerable to weather and climate (especially disastrous weather)[1-2].

Kangbao County has established and cultivated six leading industries including wind power, coal, non coal minerals, animal husbandry processing, characteristic agricultural products and ecotourism. They have become the main support for the economic development in Kangbao County, and have effectively promoted the transformation of the county's economy from focusing on agriculture to focusing on industry. The new industrialization development framework of strengthening the county with industry, feeding agriculture with industry and driving the three industries has been initially formed. Kangbao County is located in the northwest of Bashang, Hebei Province, with an average altitude of 1 450 m. It is a sub arid area in the middle temperate zone, with an obvious continental climate, which is cold and arid. Spring drought is easy to form due to strong wind, less rain, strong evaporation and rapid warming, which has a great impact on agricultural production. In summer, temperature and humidity are high, and precipitation is concentrated. Rainstorm, hail, thunderstorm and gale, high temperature, dry hot wind, continuous cloudy rain and other disastrous weather frequently occur, which often causes crops to suffer meteorological disasters and reduce production. The number of sunny days in autumn is more, the autumn is clear and crisp, and the daily temperature range increases. As the warm and humid air in early autumn still has a certain influence, it can also cause rainstorm, hail or continuous rainy weather. The weather is dry and cold in winter. Due to the rapid invasion of strong cold air, cold wave weather is often formed, accompanied by strong wind and snow. When the cold air force is weak, foggy and haze weather is more[3]. Therefore, it can avoid or mitigate the adverse effects of meteorological disasters to the greatest extent by carrying out climate suitability and risk assessment of the park, conducting meteorological sensitivity investigation and analysis, and giving scientific guidance[4-5].

1 Data

The observation data of Kangbao National Weather Station used in this paper were from Hebei Meteorological Information Center. Ground observation data involved meteorological elements and weather phenomena such as air pressure, temperature, precipitation, wind, relative humidity, sunshine, thunderstorm, hail, gale, rainstorm, fog, snow and so on[6].

The data period was from 1994 to 2023, and the data for statistical analysis of extreme value and high-impact weather were from observation records to 2023. Kangbao Meteorological Station was converted to automatic observation station in 2005[7], so the hourly data period was from 2005 to 2023; the extreme wind speed data period was from 2005 to 2023. Among them, the variation of statistical observation instrument for wind speed changed its statistics. Using the manual and automatic observation data of the same period in 2004 and 2005[8-9], the wind speed was corrected by fitting method, and the manual observation data from 1994 to 2004

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were corrected to automatic observation[10].

2 Meteorological sensitivity survey

A questionnaire survey was conducted among 21 key enterprises in the park and the park management committee, mainly involving leather, food, animal husbandry, agriculture, mining, service industry, power production, heat supply, new energy, building materials and other industries.

The survey results of meteorological element sensitivity (Fig. 1) showed that 33.3% of enterprises considered precipitation as high impact, 14.3% of enterprises considered temperature as high impact, and 4.8% of enterprises considered relative humidity as high impact; 19.0% of enterprises considered precipitation as moderate impact; all enterprises believed that the wind direction, wind speed and air pressure were low impact.

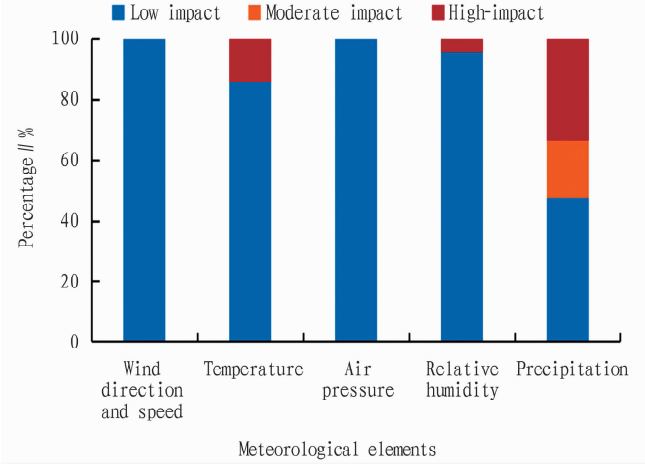

Fig. 1 Statistical results of sensitivity survey of meteorological elements

The survey results of high-impact weather sensitivity were shown in Fig. 2. 71.4% of enterprises thought rainstorm as high impact, 47.6% of enterprises thought gale as high impact, 42.9% of enterprises thought snow as high impact, 52.4% of enterprises thought low temperature and hail as high impact, and 23.8% of enterprises thought thunderstorm as high impact; 14.3% and 19.0% of enterprises considered rainstorm and snow as moderate impact respectively.

3 Meteorological sensitivity analysis

The fitting results of wind speed between manual observation and automatic observation of Kangbao Meteorological Station in 2004 and 2005, and the correlation of wind speed between manual observation and automatic observation (Table 1) have passed the significance test of $\alpha = 0.01$[11-14].

Only the meteorological elements that the enterprises believed having high impact and high-impact weather were analyzed. The statistical values of other elements and high-impact weather were shown in Table 2 and Table 3.

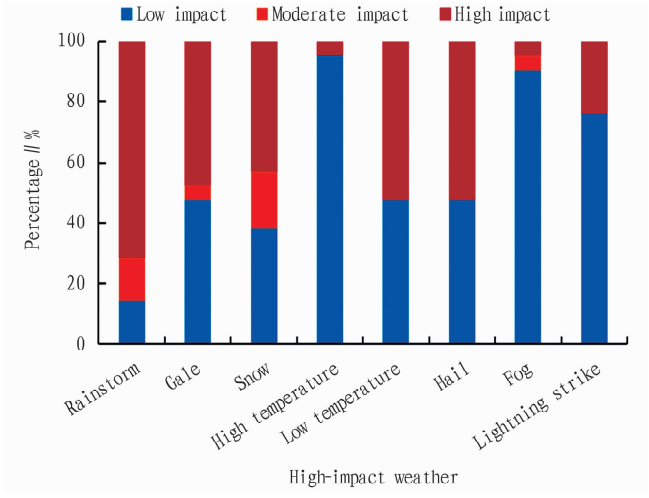

Fig. 2 Statistical results of high-impact weather sensitivity survey

Table 1 Correlation analysis of wind speed between manual and automatic stations of Kangbao Meteorological Station in 2005

Month	Fitting equation	Correlation coefficient	Significant level
January	$y = 0.942\,6x + 0.471\,6$	0.96	$\alpha = 0.01$
February	$y = 0.893\,7x + 0.611\,9$	0.97	$\alpha = 0.01$
March	$y = 0.879\,3x + 0.639\,2$	0.97	$\alpha = 0.01$
April	$y = 0.952\,3x + 0.311\,6$	0.97	$\alpha = 0.01$
May	$y = 0.896\,6x + 0.488\,1$	0.98	$\alpha = 0.01$
June	$y = 0.866\,9x + 0.449\,4$	0.95	$\alpha = 0.01$
July	$y = 0.867\,1x + 0.398\,0$	0.95	$\alpha = 0.01$
August	$y = 0.824\,3x + 0.503\,9$	0.94	$\alpha = 0.01$
September	$y = 0.863\,4x + 0.477\,3$	0.95	$\alpha = 0.01$
October	$y = 0.938\,7x + 0.329\,5$	0.97	$\alpha = 0.01$
November	$y = 0.910\,2x + 0.482\,3$	0.98	$\alpha = 0.01$
December	$y = 0.925\,7x + 0.432\,0$	0.98	$\alpha = 0.01$

The following analysis can be obtained from the data in Table 2:

The annual average temperature of Kangbao Meteorological Station from 1994 to 2023 was 2.7 ℃, the highest was 9.4 ℃, and the lowest was −4.9 ℃. The highest annual average temperature was 3.7 ℃ (2014), and the lowest was 1.6 ℃ (2012). The average temperature was the highest in July (19.5 ℃) and the lowest in January (−16.8 ℃). The extremely maximum temperature was 36.7 ℃ (July 2010), while the extremely minimum temperature was −37.4 ℃ (January 2021).

The annual average precipitation was 345.1 mm. The maximum annual precipitation was 570.1 mm (2012), and the minimum was 212.9 mm (1997). The average precipitation in July was the largest (91.6 mm).

The annual average wind speed from 1994 to 2023 was 3.1 m/s, with the maximum in May (4.1 m/s) and the minimum in August (2.4 m/s). The maximum wind speed in 10 min was 28.3 m/s, and the wind direction was WNW (January 3, 1986). The extreme wind speed was 31.0 m/s, and the wind direction was WNW (May 19, 2019).

Rainstorm, gale, extreme temperature, snow and hail were selected from various high-impact weather in Table 3 for analysis.

The annual average rainstorm days from 1960 to 2023 was 0.2 d, and the maximum was up to 2d (2008). The rainstorm mainly occurred from June to July. The rainstorm first occurred on June 25 (1972) and ended on August 18 (2016) at the latest. The maximum daily precipitation was 69.4 mm (June 30, 2004), the maximum continuous precipitation was 114.1 mm (August 21 – 31, 1983), and the longest continuous precipitation days were 11 d (July 6 – 16, 1976, August 21 – 31, 1983, and June 26 – July 6, 1998). There was no heavy rainstorm day.

The annual average gale days from 1960 to 2023 was 50.7 d, with a maximum of 91 d (1972) and a minimum of 12 d (2011). The gale days in spring was the most (47%), the most in April and the least in August.

The average high temperature days from 1960 to 2023 was 0.1 d, and the maximum was 3 d (2010). The extremely maximum temperature was 36.7 ℃ (July 2010), while the extremely minimum temperature was −37.4 ℃ (January 2021).

Table 2 Statistical values of meteorological elements at Kangbao Meteorological Station in each month over the years

Meteorological element		January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average temperature//℃		−16.8	−12.5	−3.8	4.9	12.0	17.2	19.5	17.6	11.8	3.3	−6.6	−14.7	2.7
Average maximum temperature//℃		−9.4	−5.0	2.8	11.8	19.1	23.3	25.1	23.5	18.5	10.8	0.5	−7.5	9.4
Average minimum temperature//℃		−23.7	−20.5	−12.1	−3.5	3.3	8.9	12.4	10.4	3.9	−3.9	−13.1	−20.8	−4.9
Average precipitation//mm		2.3	3.6	5.1	17.6	34.2	59.0	91.6	63.0	40.5	16.8	8.1	3.3	345.1
Average wind speed//m/s	Before revision	2.8	2.8	3.5	4.0	4.1	3.1	2.6	2.3	2.4	2.9	3.1	2.8	2.8
	After revision	2.9	2.9	3.6	4.0	4.1	3.1	2.6	2.4	2.5	2.9	3.1	3.1	3.1
Maximum wind speed//m/s		28.3	22.0	25.0	25.3	24.7	23.0	19.0	19.0	18.7	20.0	21.7	23.0	28.3
Extreme wind speed//m/s		21.1	21.5	26.1	29.5	31.0	26.4	23.7	22.7	22.3	23.6	25.4	21.1	31.0
Maximum wind speed of extreme wind speed corresponding day//m/s		15.2	14.9	17.0	19.1	20.5	18.2	13.5	16.8	13.1	17.2	17.3	15.5	20.5
Average relative humidity//%		67.0	62.0	49.0	44.0	44.0	56.0	68.0	69.0	64.0	60.0	64.0	67.0	60.0
Minimum relative humidity//%		5.0	0	0	0	2.0	5.0	10.0	7.0	8.0	3.0	0	9.0	0
Average air pressure//hPa		858.5	857.6	855.7	854.4	853.1	851.5	851.9	854.8	858.4	860.4	859.2	859.3	856.2
Extreme maximum air pressure//hPa		875.0	872.5	871.4	869.7	866.4	864.4	860.5	863.4	868.9	873.8	878.1	874.6	878.1
Extreme minimum air pressure//hPa		838.9	836.7	835.8	832.3	837.0	837.6	838.7	843.4	845.1	844.5	841.9	837.5	832.3
Average sunshine hours//h		213.7	216.8	258.9	265.1	291.5	268.8	265.3	262.5	240.0	238.6	205.7	198.0	2 924.9
Average sunshine percentage//%		72.0	72.0	69.0	66.0	65.0	59.0	58.0	62.0	65.0	71.0	71.0	70.0	66.0

Note: The statistical period for mean was from 1994 to 2023; the extremum was the value since the meteorological record; the statistical period of "extreme wind speed" was from 2005 to 2023; the statistical period of "maximum wind speed" was from 1971 to 2023.

Table 3 Statistics of extremely meteorological parameters and various meteorological disasters of Kangbao Meteorological Station in each month over the years

Meteorological elements	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Extremely maximum temperature//℃	7.6	12.7	20.8	29.3	32.4	35.7	36.7	32.9	31.7	24.7	17.6	11.3	36.7
Extremely minimum temperature//℃	−37.4	−35.0	−31.5	−17.5	−10.5	−3.8	1.2	−3.6	−8.8	−18.2	−32.0	−36.4	−37.4
Maximum daily precipitation//mm	4.9	7.7	10.8	24.8	40.8	69.4	59.5	65.5	42.6	22.3	14.4	4.0	69.4
Maximum continuous precipitation//mm	5.2	13.7	13.1	41.8	55.7	78.5	79.8	114.1	60.5	45.1	20.6	6.2	114.1
Longest continuous precipitation days//d	5.0	5.0	5.0	6.0	7.0	9.0	11.0	11.0	7.0	7.0	8.0	5.0	11.0
Average rainstorm days//d	0	0	0	0	0	0.1	0.1	0	0	0	0	0	0.2
Maximum frozen soil depth//cm	0	0	13.0	36.0	94.0	161.0	218.0	257.0	281.0	276.0	248.0	237.0	281.0
Maximum snow depth//cm	9.0	13.0	13.0	14.0	8.0	4.0	0	0	0	7.0	11.0	10.0	14.0
Accumulated hail days//d	0	0	0	8.0	29.0	70.0	49.0	46.0	37.0	10.0	0	0	249.0
Average hail days//d	0	0	0	0.1	0.4	1.1	0.8	0.7	0.6	0.2	0	0	3.9
Average gale days//d	3.5	3.5	6.0	9.1	8.9	4.8	1.3	1.1	2.1	3.1	4.0	3.3	50.7
Average snow days//d	17.7	12.4	8.0	2.8	0.4	0	0	0	0.1	1.6	9.9	15.5	68.4
Average fog days//d	0.5	0.6	0.6	0.6	0.3	0.6	1.7	2.5	1.6	1.3	0.9	0.6	11.8
Accumulated floating dust days//d	12.0	14.0	19.0	43.0	25.0	1.0	0	1.0	0	1.0	9.0	9.0	134.0
Average floating dust days//d	0.2	0.2	0.3	0.7	0.4	0	0	0	0	0.1	0.1	0.1	2.1
Accumulated sand lifting days//d	42.0	40.0	106.0	220.0	172.0	41.0	0	1.0	6.0	10.0	33.0	37.0	708.0
Average sand lifting days//d	0.7	0.6	1.7	3.4	2.7	0.6	0	0	0.1	0.2	0.5	0.6	11.1
Accumulated sandstorm days//d	15.0	15.0	64.0	122.0	96.0	17.0	1.0	0	0	0	2.0	14.0	346.0
Average sandstorm days//d	0.2	0.2	1.0	1.9	1.5	0.3	0	0	0	0	0	0.3	5.4
Average thunderstorm days//d	0	0	0.1	0.7	3.4	9.5	11.3	8.3	4.6	0.9	0	0	38.8

The annual average snow days was 68.4 d, with a minimum of 6 d (1967) and a maximum of 138 d (2009). Snow mainly occurred from October to April of the next year, the most in January, and there was no snow in July and August.

A total of 249 hail days were observed and recorded from 1960 to 2023. The average hail days was 3.9 d, and the annual maximum hail days was 13 d (1986). Hail weather mainly occurred from May to September.

The survey results of meteorological sensitivity show that food, agriculture, new energy and other industries are very sensitive to temperature. The storage temperature range of food industry is between 18 and 20 ℃; agriculture requires the production temperature to be controlled at 10 – 25 ℃; the low temperature affects the welding quality in the new energy industry. When the temperature is below −15 ℃, the machine is easy to freeze.

Seen from Fig. 3, the average temperature of Kangbao Meteorological Station in a day from 2005 to 2023 was the highest (14.6 ℃) at 15:00 and the lowest (4.6 ℃) at 06:00.

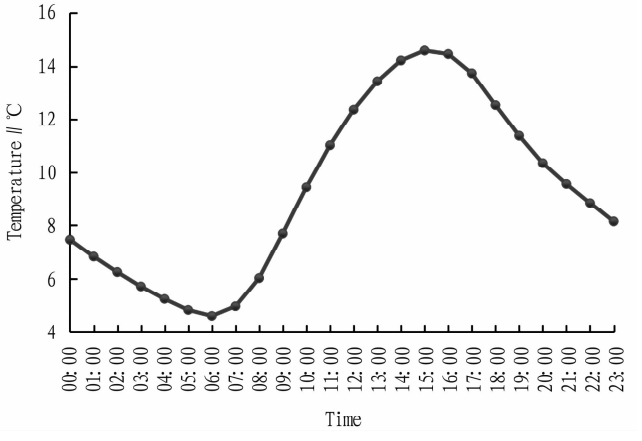

Fig. 3 Daily variation of average temperature at Kangbao Meteorological Station from 2005 to 2023

4 Applicability analysis and countermeasures

Kangbao Meteorological Station is only 1.7 km away from the park, which can better represent the climate characteristics of the park, but there are still some differences in local wind and heavy rainfall. Therefore, it is recommended to carry out on-site meteorological station observation in the park for no less than one year to analyze and assess the interaction between construction, operation and climate environment in the area.

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Food, building materials, agriculture, mining and other industries are sensitive to strong winds. In order to prevent and reduce the disasters and losses that may be caused by strong winds, when there is a strong wind in the park and surrounding areas, the hazardous power supply should be cut off in time, and outdoor operations should be stopped, especially in the plant area with high-rise buildings or outdoor equipment, so as to prevent damage and collapse of tower cranes, high-rise buildings and other facilities, and avoid casualties caused by strong winds. At the same time, it is recommended to pay close attention to the early warning and forecast of strong winds, and actively take defensive measures before the impact of strong winds, so as to prepare for the response.

According to the survey of enterprises in the park, food, building materials, leather, mining, power production, heat supply, animal husbandry, new energy and other industries are sensitive to heavy rainfall, which affects transportation and staff travel, outdoor construction in mining and building materials industries, and causes water accumulation. The annual average heavy rain days ($\geqslant$ 25.0 mm) at Kangbao Meteorological Station was 1.9 d, and the rainstorm mainly occurred from June to July. Since the establishment of the station, the maximum daily precipitation was 69.4 mm. It is suggested that the development zone should pay close attention to the rainstorm and flood warning in the region, and set up an emergency plan in advance. In the flood season, it is necessary to increase the publicity and education of flood control and waterlogging prevention, adopt long-term planning, reasonably design the drainage pipe network, strengthen disaster prevention measures for the areas where there have been floods in the park, and timely prompt the enterprises in the park, especially those with low-lying terrain, to prepare in advance to prevent the occurrence of secondary disasters[15].

Snow affects transportation, personnel travel, and the construction of the building materials industry, and the greenhouse needs to be cleaned in time to prevent collapse. Snow mainly occurs from October to April of the next year, with the largest snow days in January. The maximum snow depth at Kangbao Meteorological Station was 14 cm. It is recommended to pay close attention to the blizzard warning, prompt the enterprises in the park to plan transportation arrangements in advance, and pay attention to the safety of outdoor construction.

In the building materials industry and mining industry, low temperature affects the construction, and it needs to be stopped from late October to April. The operation of machinery in the agricultural products processing workshop will be affected, and pigs in animal husbandry will have a stress response when temperature is low. It is suggested to pay attention to the early warning and prediction of temperature drop and cold wave in time, reasonably arrange the construction, and do a good job in the prevention and control of cold stress in pig farms.

Hail affects the growth of crops and outdoor construction in construction, mining and other industries. It is suggested to pay close attention to the short-term and impending weather forecast and formulate the response measures to hail disasters, to avoid personnel and property damage. In case of hail weather, it is necessary to timely transfer the materials that are easy to be damaged

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salinity, as well as a better ability to resist TN impact.

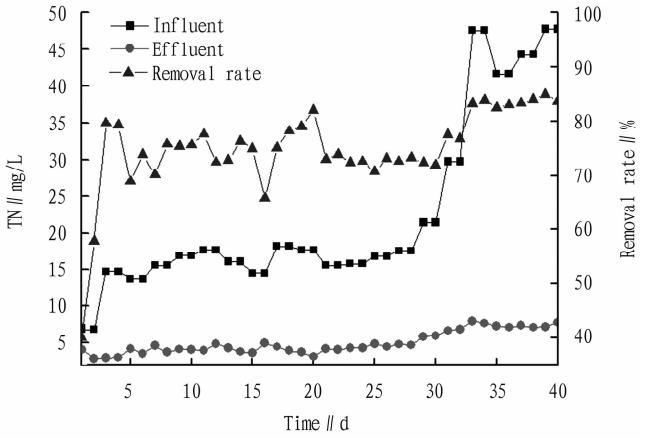

Fig. 6 Effect of TN removal during the continuous operation of the biological fluidized bed

4 Conclusions

(1) For the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed process, the most suitable temperature was 25 – 35 ℃, and the optimal hydraulic retention time was about 10 h.

(2) After the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed process, effluent COD concentration was lower than 60 mg/L, and the average removal rate reached 75%; NH_4^+-N concentration was lower than 1 mg/L, and the average removal rate was up to 97%; TN concentration was lower than 5 mg/L, the average removal rate was 72%. It is indicated that the biological fluidized bed process had a good effect on the treatment of flue gas desulfurization wastewater with high salinity.

(3) During the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed, when influent quality was impacted, the maximum of COD and TN concentration reached 710 and 47 mg/L, respectively. However, the effluent quality was relatively stable, and effluent COD and TN concentration were below 80 and 8 mg/L, respectively. The removal rate of COD and TN exceeded 85% and 75%, respectively. The results show that the biological fluidized bed process had a better ability to resist water quality impact during the treatment of the mixed flue gas desulfurization wastewater with high salinity.

(4) Meanwhile, the biological fluidized bed process provides a reference for the treatment of high-salinity wastewater that is difficult to be biologically treated.

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and collapse, and suspend the construction. Outdoor pedestrians should immediately take shelter in a safe place, and the vehicles and other outdoor objects or equipment that are vulnerable to hail attack should be properly protected.

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