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COLD AND HEAT IMPACT ON HUMAN COMFORT IN THE BAHÍA BLANCA ESTUARY HARBOURS (ARGENTINA)

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RESUMEN. *El objetivo del presente trabajo fue estudiar el confort humano en horas de trabajo en relación con el número de personas que fueron atendidas en las principales guardias hospitalarias de dos puertos localizados en la costa norte del estuario de Bahía Blanca. Para ello se calcularon y compararon los índices de sensación térmica de frío y de calor (humidex). Puerto Ingeniero White se sitúa en la cabecera del estuario mientras que Puerto Rosales se ubica en la boca. Los datos meteorológicos de ambos puertos se midieron durante el período 1999-2001. Los resultados muestran que la sensación térmica es en promedio 2,9ºC menor que la temperatura media real de invierno (9,5ºC). La sensación térmica en verano es 3ºC más alta que la temperatura media real estival (23,9ºC) y el mayor disconfort se experimenta entre el mediodía y la noche. No se observaron diferencias térmicas significativas entre el sector interno y externo del estuario de Bahía Blanca. Sin embargo, se encontró suficiente evidencia para probar que los índices correspondientes al invierno y al verano pueden estar relacionados con la salud de los trabajadores.*

ABSTRACT. *The aim of the present work was to study the human comfort at working hours related to the number of persons attended in the main hospital wards in two harbours located on the north coast of the Bahía Blanca estuary. For this purpose, the wind chill and humidex indexes were calculated and compared. Ingeniero White harbour is situated at the head of the estuary while Rosales port is located at its mouth. Meteorological data from both harbours was measured during the period 1999-2001. The results show that wind chill index is an average 2.9º C below the actual mean temperature in winter (9.5ºC). The humidex is 3º C above the actual mean temperature in summer (23.9ºC). The greatest discomfort is experienced from noon to night during this season. No sig-*

nificant thermal differences were observed between the inner and outer region of the Bahía Blanca estuary. However, enough evidence has been found to prove that the winter and summer indexes may be related to workers' health.

Palabras clave: sensación térmica de frío, sensación térmica de calor, confort humano.
Key words: Wind chill, Humidex, Human comfort

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1. Introduction

The importance of humidity and wind in both the perception of temperature and the definition of weather comfort is widely known. Indexes that express equivalent temperature (ie, wind chill or humidex) are employed in meteorology to express the temperature perceived by people, and they are often different from the registered ambient temperature. The wind chill factor and humidex are extremely useful parameters to prevent health problems, particularly among the old and the sick. The wind chill factor is used in winter both to define the temperature perceived by someone exposed to cold and wind and to assess possible risks to people's health in case precautions are not taken. Unlike the wind chill factor, humidex is applied in summer and it determines the temperature felt by an individual exposed to heat and humidity.

The original wind chill formula was developed by Paul Siple and Charles Passel in 1939. Later studies brought significant scientific breakthroughs, which modified their equation (ie, Kessler, 1993; Horstmeyer, 1994; Driscoll, 1981, 1994; Quayle and Steadman, 1999, Weather Service of Environment Canada, 2001). Humidex is a Canadian innovation first used in 1965. The humidex formula is based on Masterton and Richardson (1979). Although the use and analysis of these indexes are widespread in many countries, there are few works on the subject in Argentina. While the importance of wind in the perception of temperature in Patagonia was quantified by Coronato (1995), its role in defining the urban climate of Bahía Blanca, located in the SE of Buenos Aires province, was pointed out by Capelli de Steffens and Campo de Ferreras (1994) and Piccolo *et al*. (1989, 1994). However, only one attempt to quantify the effect of wind on the perception of temperature in Bahía Blanca have been presented (Diez *et al*., 2001).

The Bahía Blanca estuary is located in a temperate climate zone in the south-east of Buenos Aires province, Argentina (Fig. 1). The mean annual temperature varies from 14 to 20ºC. Clearly defined seasons are present. The area is windy with prevailing winds from the N and NW with an average speed of 24 km/h (Capelli de Steffens and Campo de Ferreras, 1994). However, gusts often reach values of 120 km/h. The coast of the estuary presents two sections, a northern one with a NW-SE orientation and a western one with a N-S direction (Melo *et al*., 2000). The northern section presents Argentina's largest deepwater port system as well as a major petrochemical complex. Bahía Blanca

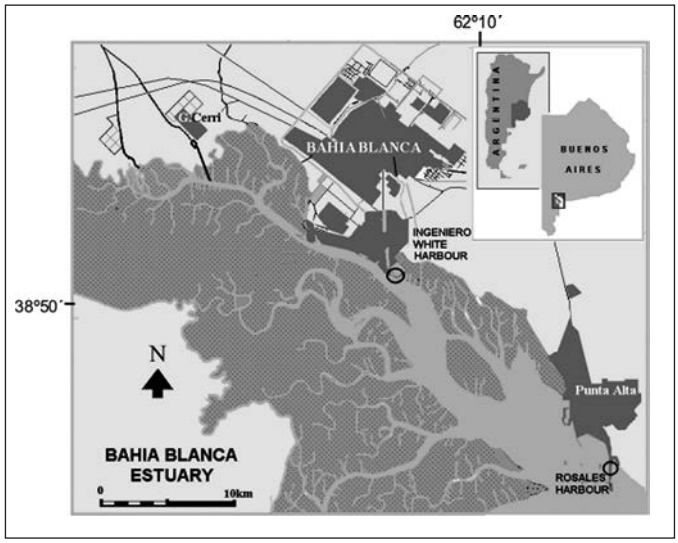

Figure 1. The Bahía Blanca estuary

harbour is composed by a series of premises scattered over 25 km. On the estuary coast lie hydrocarbon buoys, the trading dock of Rosales harbour and the Argentinian Navy Base Puerto Belgrano. Meanwhile, the inner estuary holds the port of Ingeniero White, which presents two separate areas: one devoted to the loading of grain and by-products and the other to merchandise in general. The recent enlargement of the harbours together with the development of new industries have brought about an increase in the number of people involved in port and industrial work. Owing to the nature of such activities, workers are usually in the open during most of their working day, and are therefore exposed to the conditions of the local climate.

Up to the present, no studies have been made to determine the degree of human comfort experienced by the workers and a possible relationship with their health. Therefore, the main objective of the present work is to evaluate the discomfort hours that characterize the summer and winter seasons of two locations along the estuary where the activities of the workers in the open air are predominant and also to estimate the influence that summer and winter weather conditions have on the health of both workers and inhabitants.

2. Methodology

Two stations located on the north coast of the Bahía Blanca estuary, one close to the head of the estuary (Ingeniero White harbour), and the other at its mouth (Rosales harbour) were considered in order to calculate and compare the human comfort using the

wind chill and humidex indexes. The wind chill index was calculated for the winter months (June, July and August) of 1999, 2000 and 2001; the humidex was calculated for the summer months (December, January and February) of 1998-1999, 1999-2000 and 2000-2001.

Meteorological data was obtained by automatic weather stations. The following equation was used to calculate the wind chill index (Weather Service of Environment Canada, 2001),

$$T(w) = 13.12 + 0.6215 * T_{air} - 11.37 * V^{0.16} + 0.3965 * T_{air} * V^{0.16} \quad (1)$$

Where *w* is the wind chill index, based on the Celsius temperature scale, T_{air} is the air temperature (ºC), and *V* is the wind speed at 10 metres.

The humidex (Weather Service of Environment Canada, 2001) was calculated by the following formula:

$$T(h) = T_{air} + 5/9 * (e - 10) \quad (2)$$

Where *e* is the vapour pressure (6.112 * 101 (7.5 * T/ (237.7 + T)) * H/100), T_{air} is the air temperature (ºC), and *h* is the humidity (%).

The Humidex Range Degree of Discomfort (Weather Service of Environment Canada, 2001) is:

20-29º C	comfortable
30-39º C	some discomfort
40-45º C	great discomfort; avoid exertion
above 45º C	dangerous
above 54º C	heatstroke imminent

Following the method proposed by Coronato (1995), the hourly mean equivalent temperature was used to draw a diagram of isopleths for both winter and summer. This type of graph is useful for the analysis of diurnal comfort. The data was placed on a matrix (hour per month) with a 1ºC isolines interval.

An average seasonal variation factor was defined and expressed as:

$$\text{Winter variation factor } (VF_w) = T(w) - T_{air} \quad (3)$$

$$\text{Summer variation factor } (VF_s) = T(h) - T_{air} \quad (4)$$

The seasonal behaviour of this factor was analysed for both winter and summer. Surgery hours in hospital wards for the study period were obtained from the Navy Hospital near Rosales harbour and from the Hospital Menor at Ingeniero White.

3. Results

3.1. Winter Season

The **analyses** of winter data show equal mean temperatures for both stations (9.5ºC). However, the average VF_w revealed that temperature is perceived to be 3ºC and 2.3ºC below the actual temperature in Rosales and Ingeniero White, respectively (Table 1). For the three winters Rosales shows a mean VF_w of -3ºC. But Ingeniero White presented more variable weather conditions with the highest mean VF_w in the year 2000 (-3.2ºC) and the minimum in 2001 (-1.5ºC).

Table 1. Mean seasonal parameters for Ingeniero White and Rosales harbours

Mean Seasonal Parameters	**1999**		**2000**		**2001**	
	Ing. White Harbour	**Rosales Harbour**	**Ing. White Harbour**	**Rosales Harbour**	**Ing. White Harbour**	**Rosales Harbour**
a) Winter mean air temperature	9.6	9	9	9.7	10	9.7
WindChill index	7.6	6	5.8	6.7	8.5	6.8
Winter variation factor	-2	-3	-3.2	-3	-1.5	-2.9
b) Summer mean air temperature	26	22.6	25.7	24	21.4	23.6
Humidex	28.3	26.9	28.7	29.6	20.4	27.8
Summer variation factor	2.3	4.3	3	5.6	-1.0	4.2

Despite the lack of information concerning June 2000 at Ingeniero White, the diagram of thermal isopleths drawn for both stations presented similar curve patterns for the three years (Fig. 2). This diagram shows the daily variation of the wind chill index during the three winter months at each station. July is the coldest month for both sta-

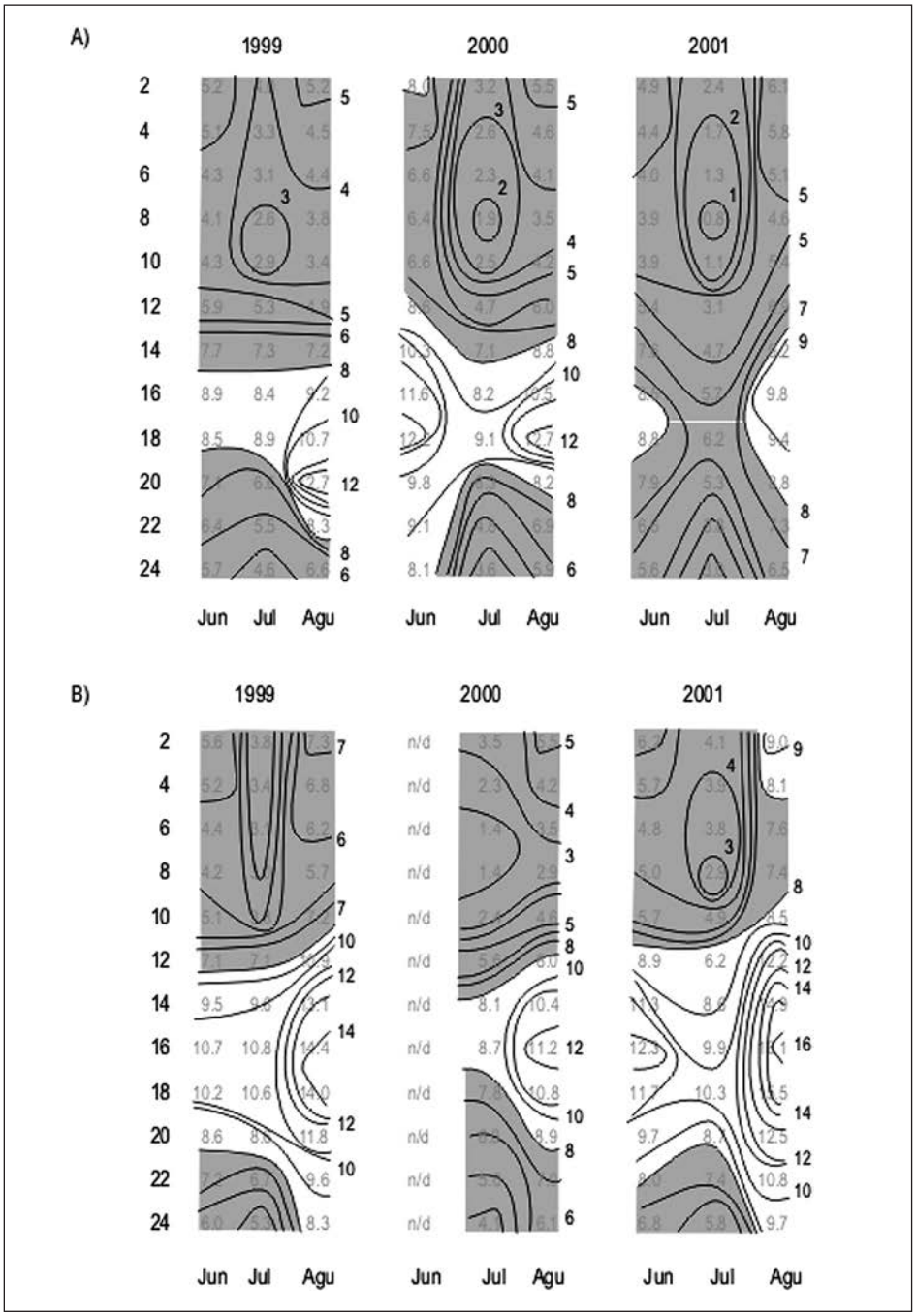

Figure 2. Isopleths showing the mean hourly wind chill index in A) Rosales harbour B) Ingeniero White harbour.

tions. Rosales presented lower wind chill index than Ingeniero White. Whereas Rosales showed an average wind chill of 4, 8 and 6.8ºC in the morning, afternoon and evening, respectively; Ingeniero White presented 4.8, 11.3 and 8.5ºC, at the same time of the day. In other words, mean wind chill is lower at Rosales harbour. As expected, the minimum index is found during early morning and at night in winter months. According to Olgyay's diagram (Servicio Meteorológico Nacional, 1984), when temperature is below 8ºC, even on a bright clear day with no wind, there is weather discomfort. The areas shaded in grey on the diagram of thermal isopleths (Fig. 2) show the hours of the day when the wind chill index was below 8ºC, i.e. those moments when the combined action of temperature and wind endangers workers' health. In July 2001 Rosales harbour presented discomfort conditions for the inhabitants all day long.

When comparing the wind chill index of the winters at Ingeniero White, it was observed that the winter of 2001 was the mildest one with values between 10 and 16ºC during the noon and the afternoon hours, whereas the winter of 2000 presented the lowest values of the three years. These results are related to the number of surgery hours in the hospital wards (Fig. 3). The lowest number of medical visits to the hospital was registered in 2001, while the highest number of visits was registered in 2000, especially in the months of July and August.

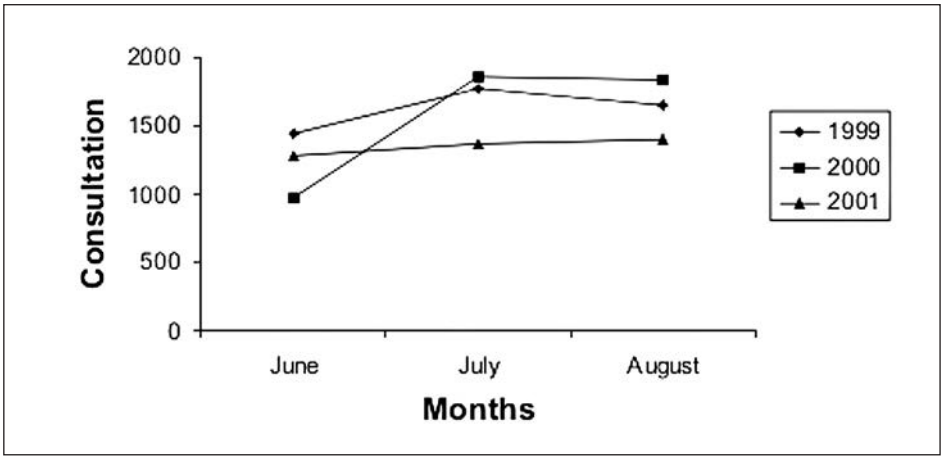

Figure 3. Monthly surgery hours at the Minor Hospital ward of Ingeniero White for the winter season

The minimum wind chill index was 0.8ºC and corresponds to the Rosales harbour in July, 2001. The drawing of the aforementioned diagrams was based on hourly mean values, and the extreme values registered during that period were analysed as well: 35 days at the Rosales station and 28 at the Ingeniero White station featured wind chill below 0ºC which often remained unchanged throughout the day. For instance, the wind chill index between noon and 4 p.m. on August 13th, 1999, exceeded 0ºC without reach-

ing the comfort threshold (Fig. 4), whereas the Rosales harbour registered the lowest wind chill (-6ºC) at 4 a.m.

As it was mentioned before, the wind chill index and the number of medical visits to the hospital were related. An example of the relationship between the occurrence of low wind chill index and the daily number of visits to the hospital ward, is shown in Figure 5 for the days 16-19 of July, 2000 at Ingeniero White hospital. On July 16th the wind chill index was below zero during most of the day reaching –4ºC at 6 a.m. and reached a maximum below 7ºC. On July 18th the wind chill index was again below zero or just above it. The number of visits to the hospital wards increased significantly, from 23 to 69 on July 17th and from 26 to 43 on July 19th.

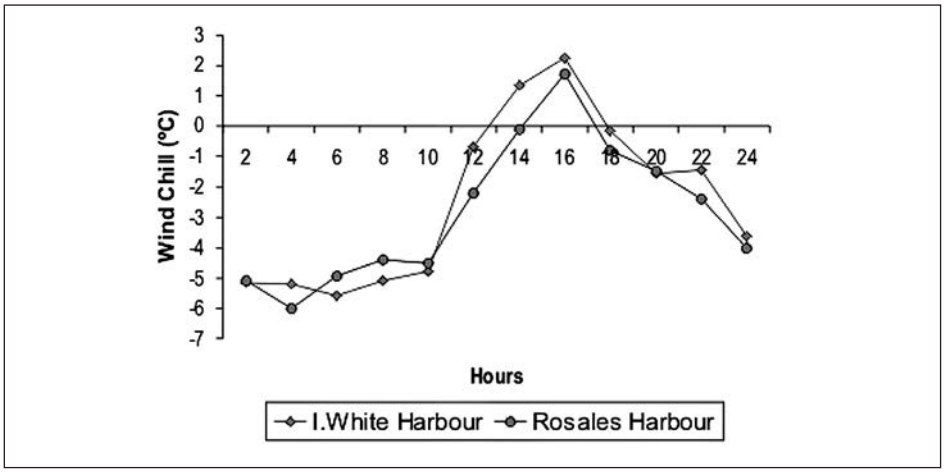

Figure 4. Hourly wind chill index on 08/13/1999

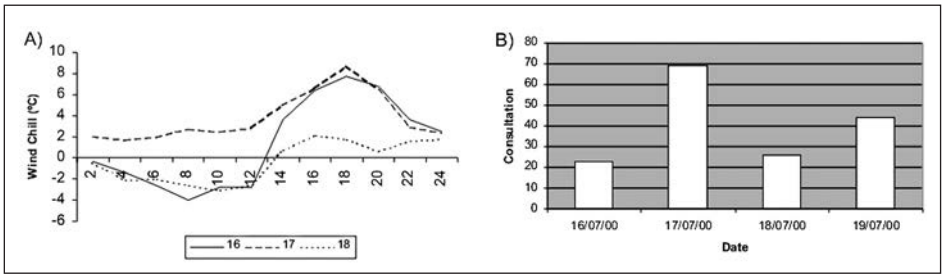

Figure 5. A) Hourly wind chill index during 16-18 July, 2000. B) Daily surgery hours at the Minor Hospital ward of Ingeniero White during 16- 19 July, 2000

3.2. Summer Season

In this season, the VF_S shows a difference of 3.2ºC between the stations, 4.7ºC and 1.5ºC in Rosales and Ingeniero White harbours respectively (Table 1). Ingeniero White harbour presents a mean humidex of 25.8ºC, while Rosales harbour shows the highest mean humidex (28.1ºC).

The humidex isoplets (Fig. 6) were similar for both stations. The hourly mean humidex values were higher in Rosales than in Ingeniero White. As shown in Figure 6a, Rosales presents high values of humidex during the afternoon and early night. The 1999-2000 summer was an extremely hot one. The hourly analysis of the humidex for both stations revealed that it reaches its maximum values between 2 and 22 p.m. in January and February, decreasing in the early hours of the day. Mornings are scarcely cooler than nights. In this case, the areas shaded in grey show the hours of the day when there is a certain degree of discomfort.

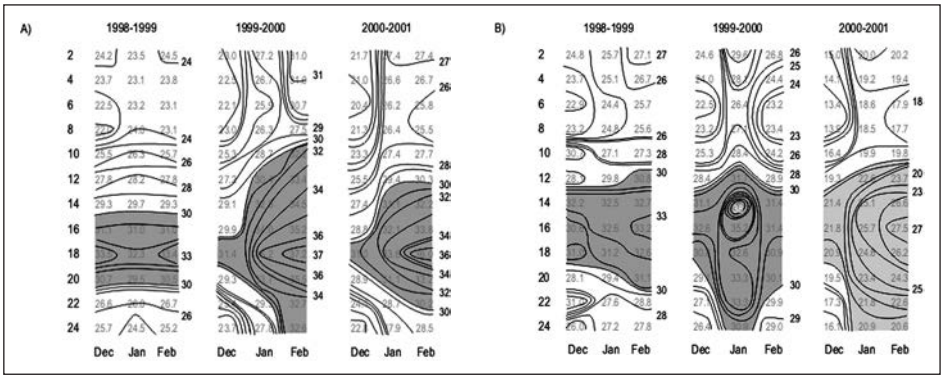

Figure 6. Isopleths showing the mean hourly humidex in A) Rosales harbour B) Ingeniero White harbour.

The 2000-2001 summer was the mildest one with humidex values below 28ºC which explains the lowest number of medical consultations at the Ingeniero White hospital that summer, compared to the other ones. The remaining years presented humidex values above 30ºC, reaching a maximum of 38ºC in Ingeniero White. January 2000 presents the highest humidex values of the study period and therefore the number of visits to the hospital wards increased significantly (Fig. 7).

During the summer, humidex values above 40ºC were registered between 2 and 6 p.m. in 30 and 12 days in Rosales and Ingeniero White, respectively. For instance, Rosales presented humidex values below 29ºC on the morning of February 19th, 1999, increasing progressively up to 40ºC at 8 p.m. Ingeniero White was hotter than Rosales since the humidex was over 40ºC between 12 and 8 p.m. (Fig. 8a) . On February 25th, 1999 the humidex was above 30ºC throughout the day, reaching 42ºC at 4 p.m. in

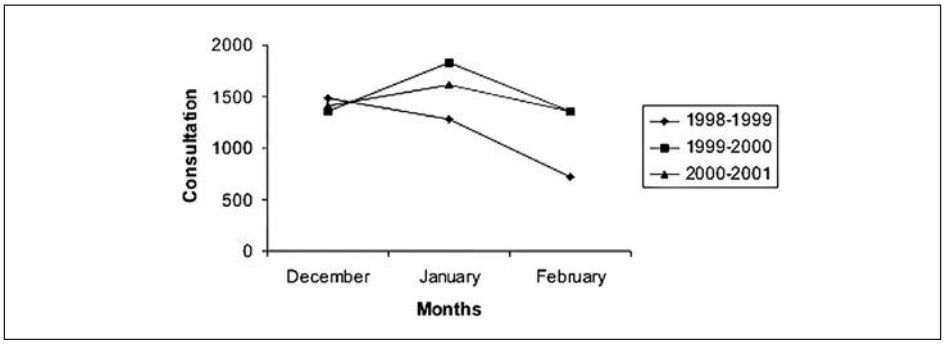

Figure 7. Monthly surgery hours at the Minor Hospital ward of Ingeniero White for the summer season

Ingeniero White and 43ºC at 6 p.m. in Rosales (Fig. 8b). The maximum humidex (54ºC) corresponds to January 22nd, 1999, when the actual temperature was 32.5ºC with a relative humidity of 100 %.

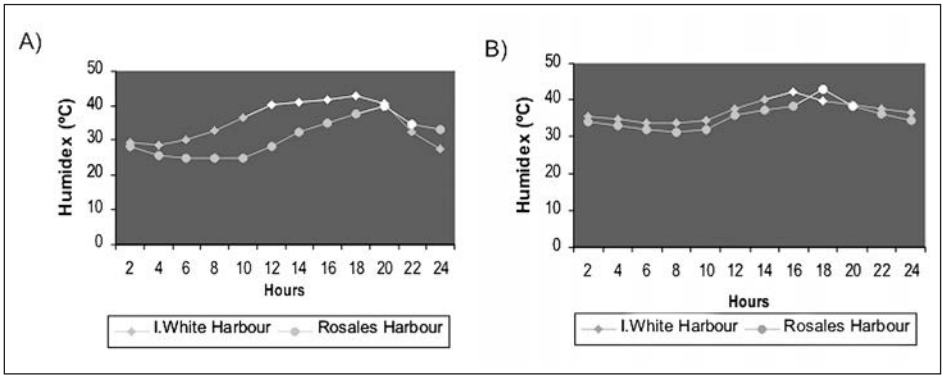

Figure 8. Hourly humidex on A) 02/19/1999 and B) 02/25/1999

To show an example of the discomfort conditions that the workers suffer in summer, a detail of the humidex index is presented between February 20 and 28, 1999. In that week the actual temperature was above 30ºC. In Rosales harbour the humidex reached values of 42ºC between 4 and 8 p.m. on February 24th. The following day a significant increase of the number of visits to the hospital was registered (Fig. 9a). The number increased from 152 to 228 visits to the Navy Hospital. Similar results were observed at the Hospital Menor in Ingeniero White (Fig. 9b). Thus, the analysis shows a clear relationship between the degree of discomfort and the number of visits to the hospital wards at each location.

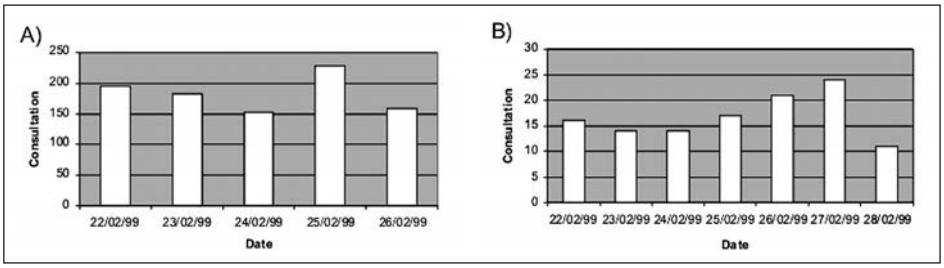

Figure 9. Daily surgery hours at the: A) Navy Hospital ward of Rosales harbour, B) Minor Hospital of Ingeniero White

4. Conclusion

Considering the climatic characteristics of the two locations, it can be stated that the temperature perceived by the industrial and harbour workers differs from the actual temperature due to the combined action of temperature and wind as well as of temperature and humidity. Wind chill index is perceived to be an average of 2.9ºC below the actual mean temperature (9.5ºC) in winter. Moreover, the index seems to be 3.6ºC lower in the outer zone of the estuary (Rosales station) and 2.2ºC in the inner one (Ingeniero White station). In several **occasions,** extreme discomfort conditions, which are classified as dangerous for human health when people are exposed to the exterior, were found in the area. Despite the relatively small distance between the two locations a difference in the wind chill index was found for the winter of 2001. Workers in this sector are exposed to the open during most of their working day and suffer discomfort mainly in the morning and at night.

Conditions change in summer when humidex is perceived to be an average of 3ºC above the actual mean temperature (23.9ºC). During summer, the greatest feeling of discomfort is experienced at noon and may extend up to the night. There have been cases in which humidex reached 54ºC, a value that could lead to an imminent heatstroke. Heatstroke is the severest heat-related illness and requires immediate medical attention. A strong relationship was found between those (summer and winter) days when the inhabitants suffer discomfort and the number of patients that visit the hospitals of the study locations the same or the following day.

Enough evidence was found to prove that there is a risk for the health of the people that must work outdoors. Therefore, further research should be undertaken over a longer period of time in order to determine the kind of illnesses caused by those extreme climatic conditions.

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