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Original Research

Contribution to the Assessment of Carbon Monoxide Poisoning in Algeria: Case Study

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Abstract

Despite the implementation of a national action plan and a deployed monitoring of intoxications, Algeria deplores each year more than 2000 victims, who require immediate medical care, and a hundred deaths. For this reason, the risk of carbon monoxide poisoning is not negligible in confined spaces. The gases used or generated by certain work processes or household appliances can impoverish the air. When the oxygen content in the air, is usually 21%, it decreases to less than 15%, which creates a risk of carbon monoxide poisoning. Under-oxygenation leads to the physical and mental capacities' reduction, with the victim's unawareness of it. At 10% of oxygen in the air, the victim faints. Below 10% the victim dies within minutes, unless immediately rescued. Through this research, we are trying to highlight the dangers associated with faulty domestic appliances (heating, water heaters, barbecues, etc.), mainly affecting low class population. This poisoning, preventable and treatable, is a public health issue, which must be treated urgently, mainly during the winter period.

Keywords: carbon monoxide, assessment, asphyxia, household appliances and poisoning

Introduction

As a reminder, there is no life without oxygen: Be careful, the carbon monoxide poisoning danger often appears in enclosed spaces. The gases used or generated by some domestic equipments can deplete the ambient air. When the oxygen content in the air, is usually 21%, decreases below 15%, there is a risk of carbon monoxide poisoning [1-3]. Under-oxygenation causes a diminution in physical and mental capacities, without the victim being aware of it [4-6]. At 10% oxygen in the air, the victim faints. Below 10%, s/he dies in few minutes, unless immediately resuscitated [7, 8]. This situation may be linked to inert gases accumulation (nitrogen, argon, helium, Co, etc.) in poorly ventilated enclosed or semi-enclosed spaces (wells, cistern, cellars, silos, caulked rooms or rooms, etc.). For example the inhalation of a simple asphyxiating such as carbon monoxide, the element of our study, is followed by recovery (if the effect was not fatal!) after removal from exposure.

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Regardless of the equipment used, as soon as there is household equipment or device that uses fuel in a closed environment, there is a risk of exposure and poisoning with CO if no actions are taken [9-11]. Therefore, we must know the sources and causes of CO poisoning, the prevention and protection measurements as well as the right actions to do in the event of an accident.

Carbon monoxide, a poisonous gas, is the cause of several deaths around the world [12-15], and our country is no exception [16-19]. CO is invisible, odourless, non-irritating and tasteless, nothing indicates its presence. It is a treacherous killer. It is produced from incomplete combustion of fuels such as propane, natural gas, gasoline, wood and diesel, etc. and it spreads very quickly by being mixed with the ambient air, causing then a lot of damages [20-22] and creating tragedies from which families will never recover in several regions of the country. These gas calamities are at the origin of a hecatomb. From now on, even if the source is known, CO is sneaky and kills where it is not necessarily suspected; be careful! As every year, gas is causing damages in Algeria, especially in dilapidated homes, where gas pipes and domestic appliances are in general poorly maintained.

Experimental

Carbon monoxide (CO) poisoning is responsible for the deaths mostly linked to the use of household appliances (heating, water heaters, barbecues, etc.) that emit carbon monoxide, Fig. 1. Thus, various poorly maintained or faulty devices generate fumes and gases that put their users at risk [23]. These can turn into drama affecting mainly poor population, and generally occurring in winter. This preventable and treatable poisoning is a public health issue. Despite the implementation of a national action plan and increasing people's awareness through the various media and associations on poisoning, Algeria deplores each year more than 2000 victims, who require immediate medical care, and hundreds of deaths.

Thus, the victims of gas leaks follow one another lately in Algeria. Since the start of the New Year 2022, 38 people have died. While more than 483 persons have been rescued from certain death by members of the Civil Protection (PC) Revealed in a public statement. These statistics show how this gas is dreadful and every year at the beginning of the winter, warnings have been issued.

This is a cross-sectional descriptive study. The data were analysed retrospectively on file, in situ on certain places of the dramas and the reports of the various media reported. To get an idea of the damage caused by carbon monoxide across the national territory, we present the results of the distribution of cases of carbon monoxide poisoning during the 2017-2021 season through the different departments of the Algerian Republic, which is detailed in Table 1

Fig. 1. Poorly maintained equipment responsible for carbon monoxide emissions.

Table 1. Distribution of carbon monoxide poisoning cases in Algeria (2017-2021) [24].

Wilayah	Case	Death	Wilayah	Case	Death
Adrar	30	0	Tlemcen	176	6
Chleff	23	0	Tiaret	75	3
Laghouat	15	0	Tizi Ouzo	632	20
Oum El Bouaghi	65	0	Alger	1120	115
Batna	432	22	Djelfa	305	17
Bejaïa	223	15	Jijel	212	10
Biskra	10	0	Setif	950	47
Bechar	60	0	Saïda	25	8
Blida	146	12	Skikda	480	16
Bouira	225	15	Sidi Bel Abbes	122	12
Tamanrasset	35	0	Annaba	718	27
Tebessa	232	11	Guelma	320	12
Constantine	1013	25	Tindouf	10	0
Medea	325	13	Tissemsilt	5	0
Mostaganem	95	4	El Oued	7	0
M'Sila	152	8	Khenchela	225	18
Mascara	12	0	Souk Ahras	132	8
Ouargla	60	1	Tipaza	201	12
Oran	1124	55	Mila	302	15
El Bayadh	40	0	Ain Defla	95	2
Illizi	20	1	Naâma	15	2
Bordj Bouarreridj	102	0	Ain-Temouchent	52	0
Boumerdes	125	8	Ghardaïa	17	0
El Taraf	85	0	Relizane	30	0

According to these recorded data indicated in the table above, it is noticed that the highest cases of poisoning have been found in the large states of the country. Particularly there is a big number of cases of carbon monoxide carbon monoxide poisoning and deaths linked to gas accidents. , essentially in the States of Constantine, Algiers, Annaba, Oran and Tizi-Ouzou with the recording of the highest lethality rates of deaths respectively in the states of Algiers 16%, Oran 8%, Setif 7% and Constantine 3%. However, for the rest of the states, the rate is around 1%, Fig. 2. Then, most of the states of the north of the republic take place in second position recording between 100 and 400 cases. While, the southern cities do not exceed 30 cases. For a step forward, we can say that this is due to the demographic distribution (80% of Algerian people live in the north) and the climatic difference between the warmer south (desert) and the north where people need warming in the cold period, mainly in winter.

Among these deaths, it is respectively recorded that a frequency of carbon monoxide poisoning of 65%, 40% of them are women and 25% are men; a frequency of 35% are children Fig. 3.

For a detailed presentation of our study, the focus of our research is on the wilayah off Constantine, our hometown.

Results and Discussion

The Main Causes of Carbon Monoxide Poisoning

Based on our *in situ* exploration and referring to the civil protection reports of the various tragedies raised, the main causes that lead to carbon monoxide poisoning are summarized as follows:

– A bad evacuation of combustion products (obstructed or wrong sized flue);

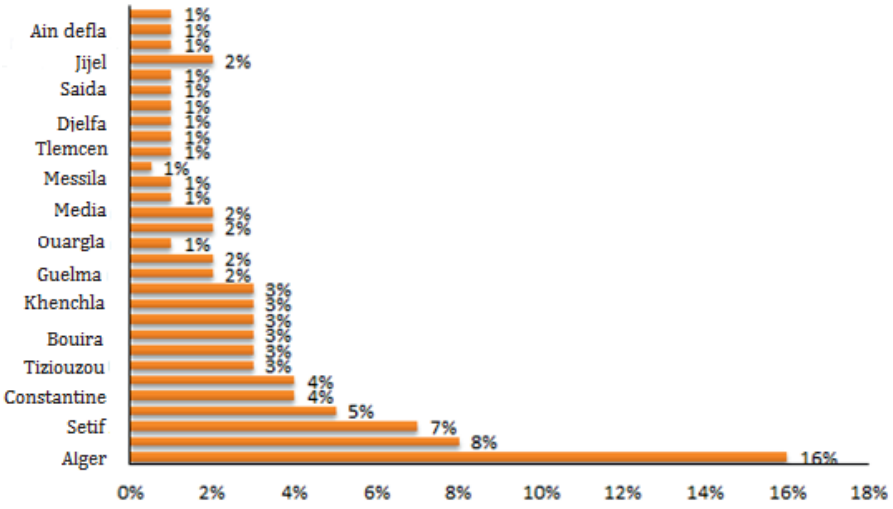

Fig. 2. Distribution of lethality rates of deaths across the wilayah of Constantine.

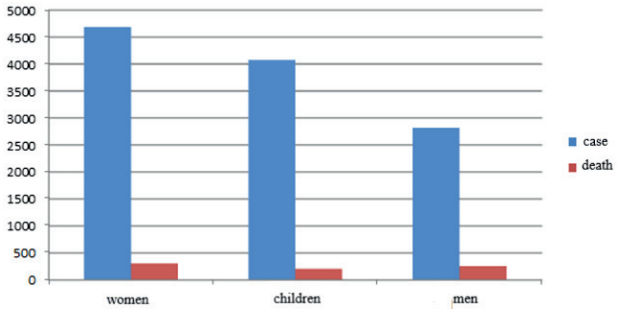

Fig. 3. Frequencies of intoxication during the period between 2017 and 2021.

- An absence of ventilation in the room where the appliance is installed (caulked rooms, blocked air outlets);
- A defect or absence of maintenance of heating and hot water production devices as well as inserts, stoves, cookers, mobile auxiliary heaters;
- A dilapidated heating and hot water production equipment;
- An incompatibility between the various installations present in the same house (example: gas boiler and hood);
- An inappropriate use of combustion devices (continuous auxiliary heating, generator in a closed place, etc.);
- This is in almost cases due to the negligence and ignorance of users.

Thus, the main finding is that most of the poisonings mentioned could have been avoided. According to our viewpoint, this is mainly due to the negligence, ignorance and poor information of users, even simple unknown gestures and insufficient social care.

Case of Study: Poisoning with Carbon Monoxide in Constantine

As part of the efforts deployed to avoid cases of death caused by the misuse of domestic appliances running on natural gas. The Civil Protection services have multiplied awareness campaigns through the 12 municipalities of the wilayah, carried out in collaboration with the various sectors concerned with a view to raising public awareness of the dangers of carbon monoxide and spreading the prevention culture. The aim of these campaigns is essentially to instil in citizens the safety measures and the correct methods of installing natural gas-powered domestic appliances and their maintenance.

In addition to the use of materials non-compliant with the required standards, there is also the ignorance and negligence noticed in the various installations as well as bad quality of heating appliances. These anomalies constitute a potential danger to the lives of citizens, especially the poor layout of the chimneys and the burnt gas evacuation system, burnt gas leaks were observed at this on-site visit, at the civil protection seat.

Presentation of Constantine Wilayah

Constantine is the capital of the wilayah of Constantine in Algeria. Metropolis of north-eastern Algeria, it accounts more than 740,000 inhabitants (1,000,000 in the agglomeration). It is the third largest city in Algeria in terms of population. It has 947,712 inhabitants over an area of 2,308 km². The population density of the wilayah of Constantine is therefore 410.7 inhabitants per km². The largest cities of Constantine wilayah are: Constantine; El Khroub and Hamma Bouziane mong the 12 cities that compose it, Fig. 4.

Fig. 4. Presentation of Constantine city.

Table 2. Distribution of carbon monoxide poisoning deaths during the 5 years.

Years	Men	Women	Children
2017	32	88	78
2018	44	79	44
2019	39	120	125
2020	27	62	85
2021	43	78	86
Total	204	427	418
%	19%	41%	40%

Situation of the City vis-à-vis the Risks Associated with Carbon Monoxide

The Distribution of Cases and Deaths during the Last 5 Years Related to Their Sex and Age

The civil protection department of the wilayah of Constantine recorded during the period (January 2017 - December 2021), 1063 cases of carbon monoxide poisoning. This represents 17 poisonings per month, Table 2 and a frequency of carbon monoxide poisoning respectively of 41% in women, 40% in children and 19% in men.

Distribution of Case Fatality Rates Across the Constantine City

The results are presented in Table 3 and Fig. 5.

Findings: We note that the number of victims recorded during these five years, are respectively the years 2018 and 2021 with a rate of 42% and 28% of deaths. In our opinion, this is due to the cold wave recorded in these two periods. As the weather is colder, as the risks and damage from carbon monoxide is more catastrophic.

Table 3. Distribution of case fatality rates across the wilayah of Constantine.

Years	Number of case	Number of death
2017	195	3
2018	157	10
2019	276	8
2020	184	0
2021	201	15
Total	1013	36

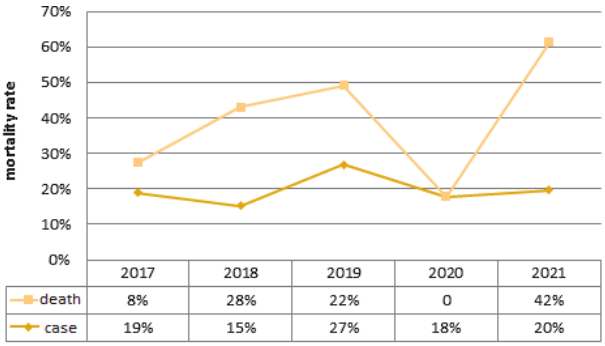

Fig. 5. Distribution of case fatality rates across the wilayah of Constantine (2017-2021).

Distribution of Incident Cases Recorded in the Wilayah

The distribution results of carbon monoxide poisoning in the different municipalities of the wilayah of Constantine are presented in Table 4.

Findings: The Constantine Center and El-Kharroub region recorded the largest number of victims, where the number of poisoning cases is more than 710 (67.95%

Table 4. Distribution of incident cases recorded in the wilayah.

Municipalities	Case	Death
Constantine centre	336	12
El Khroub	348	14
Ouled Rahmoune	116	06
Ain Smara	40	2
Zighoud Yousef	13	0
Ibn Ziad	20	0
Ain Abid	53	0
Ibn Badis	11	0
Hamma Bouzian	24	0
Didouch Mourad	52	2
Total	1013	36

of the total cases), 687 among which were rescued and 23 deaths (85.18% of the deaths), while, Oulad Rahmon recorded 122 cases of poisoning, including 6 deaths, and the regions of Al-Hamma, Didouch, Ain Asmara, Ain Abbaid and Ibn Ziyad recorded between 15 and 50 cases of poisoning.

Distribution of Carbon Monoxide Poisonings per Year

To give an idea on the poisonings' mapping of the five years period of our study, each year is presented separately, namely:

– (January 1, 2017 – December 31, 2017): The study results are shown in Table 5 and Fig. 6.

Findings: in 2017, 198 poisonings were recorded by the civil protection of Constantine, which were due to the carbon monoxide Co. The largest numbers were in Constantine city and in El Khroub with 166 cases (83.83% of all cases), 164 of which were rescued, including 12 women in Constantine. However, one death was recorded in Ain Smara.

– (January 1, 2018 – December 31, 2018): The results of this period are presented at Table 6 and Fig. 7.

Findings: 72 poisonings were recorded in Constantine city and 55 cases in El Khroub with 9 deaths including (3 men, 5 women and a child). Moreover, 24 poisonings were recorded in the Awled Rahmoune and Ain Smara region. However, in Ain Abid, Hamma Bouziane and Didouch Mourad only 2 to 5 poisonings were recorded.

– (January 1, 2019 – December 31, 2019): Table 7 and Fig. 8 present the results of this period.

Table 5. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2017).

Regions	Men		Women		Children	
	Case	Death	Case	Death	Case	Death
Constantine	14	0	35	2	41	0
Khroub	12	0	33	0	29	0
Ouled Rahmoune	02	1	08	0	01	0
Ain Smara	00	0	01	0	0	0
Zighoud youcef	00	0	00	0	0	0
Ibn ziad	00	0	00	0	0	0
Ain Abid	03	0	05	0	06	0
Ibn Badis	00	0	00	0	0	0
Hamma Bouziane	00	0	00	0	0	0
Didouch Mourad	00	0	04	0	01	0
Total	31	1	86	2	78	0

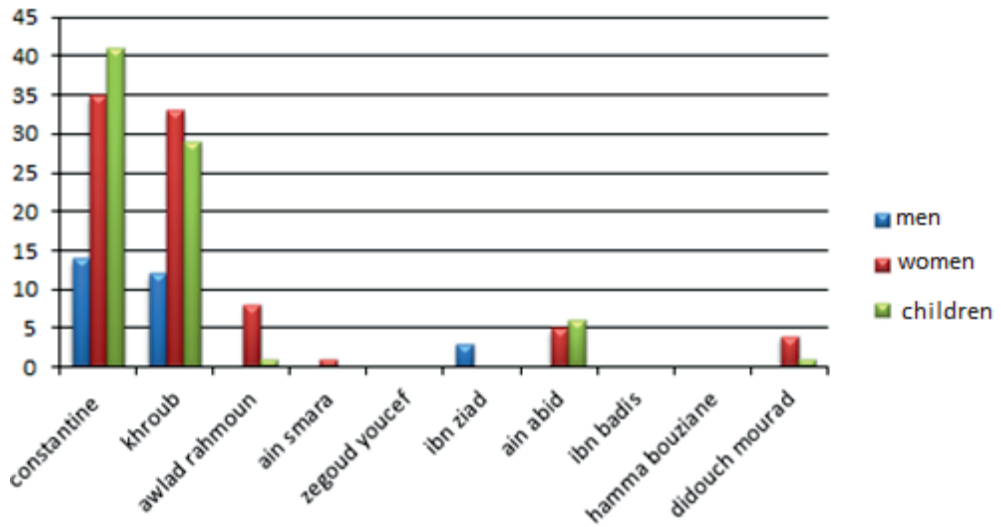

Fig. 6. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2017).

Table 6. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2018).

Regions	Men		Women		Children	
	Case	Death	Case	Death	Case	Death
Constantine	24	0	32	0	16	0
Khroub	07	3	27	5	12	1
Ouled Rahmoune	01	0	05	0	04	0
Ain Smara	03	0	05	0	06	0
Zighoud youcef	00	0	00	0	0	0
Ibn ziad	00	0	00	0	0	0
Ain Abid	03	0	02	0	01	0
Ibn Badis	00	0	00	0	0	0
Hamma Bouziane	03	0	00	0	0	0
Didouch Mourad	00	0	02	1	04	0
Total	41	3	73	6	43	1

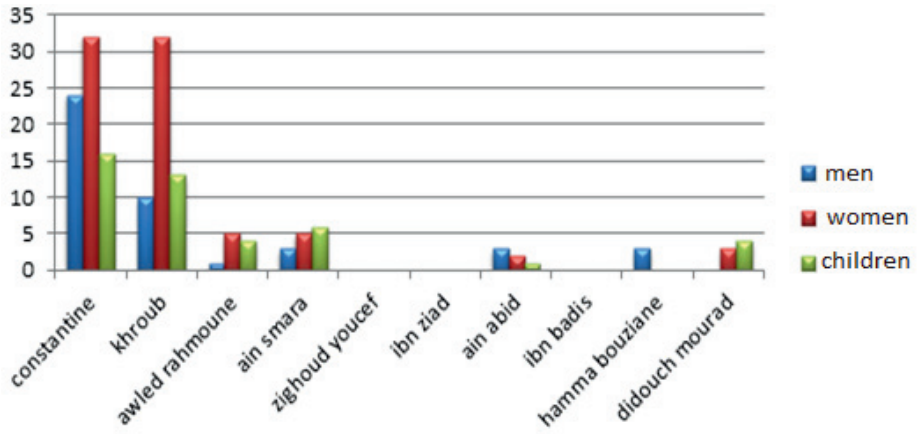

Fig. 7. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2018).

Table 7. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2019).

Regions	Men		Women		Children	
	Case	Death	Case	Death	Case	Death
Constantine	10	2	43	1	45	2
Khroub	9	1	40	1	44	0
Ouled Rahmoune	02	1	10	0	01	0
Ain Smara	01	0	01	0	02	0
Zighoud youcef	01	0	02	0	03	0
Ibn ziad	02	0	02	0	05	0
Ain Abid	03	0	05	0	06	0
Ibn Badis	01	0	04	0	01	0
Hamma Bouziane	02	0	04	0	05	0
Didouch Mourad	04	1	07	0	10	0
Total	35	4	118	2	123	2

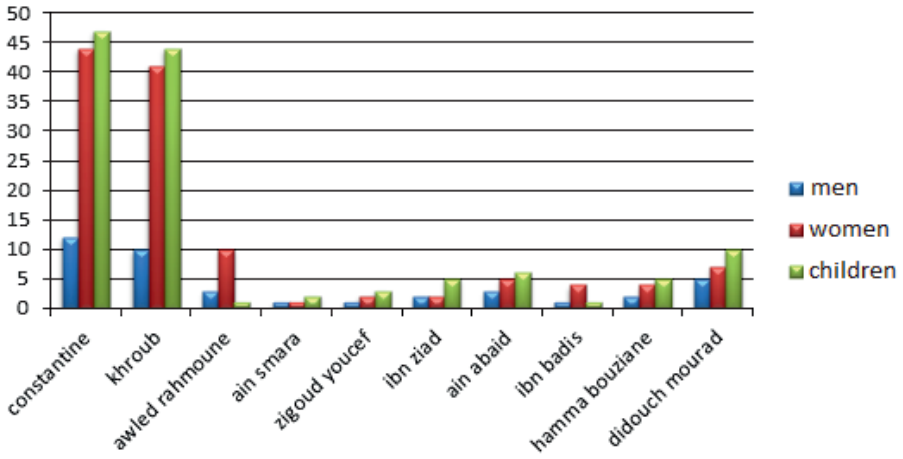

Fig. 8. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2019).

Table 8. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2020).

Regions	Men		Women		Children	
	Case	Death	Case	Death	Case	Death
Constantine	10	0	15	0	20	0
Khroub	13	0	23	0	24	0
Ouled Rahmoune	8	0	10	0	20	0
Ain Smara	02	0	03	0	06	0
Zighoud youcef	00	0	01	0	02	0
Ibn ziad	01	0	02	0	03	0
Ain Abid	02	0	05	0	06	0
Ibn Badis	00	0	00	0	00	0
Hamma Bouziane	00	0	02	0	02	0
Didouch Mourad	01	0	01	0	02	0
Total	37	0	62	0	85	0

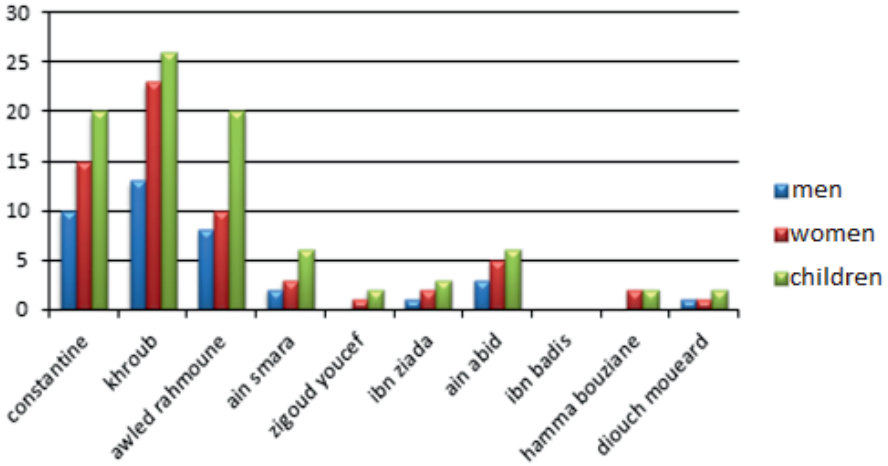

Fig. 9. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2020).

Table 9. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2021).

Regions	Men		Women		Children	
	Case	Death	Case	Death	Case	Death
Constantine	8	1	12	3	10	3
Khroub	20	0	25	1	30	2
Ouled Rahmoune	10	0	15	1	19	2
Ain Smara	03	1	04	1	03	0
Zighoud youcef	00	0	02	0	02	0
Ibn ziad	01	0	01	0	03	0
Ain Abid	02	0	02	0	02	0
Ibn Badis	01	0	01	0	03	0
Hamma Bouziane	02	0	02	0	02	0
Didouch Mourad	03	0	08	0	05	0
Total	50	2	72	6	79	7

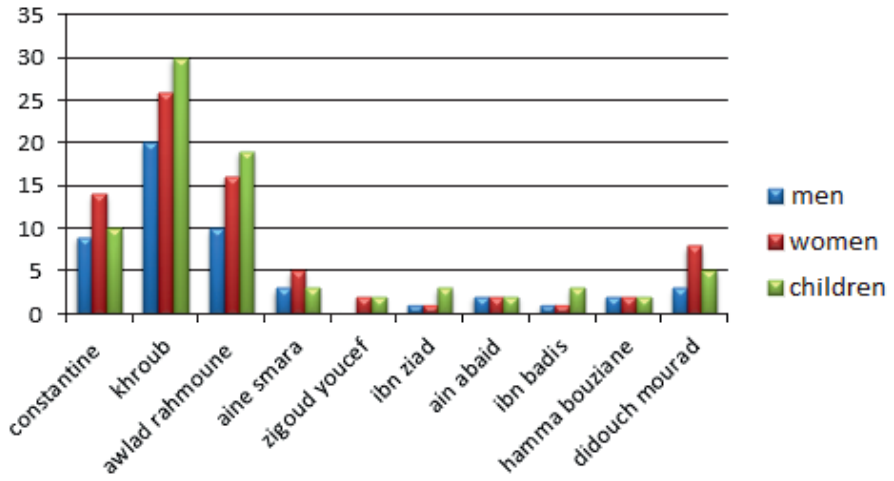

Fig. 10. Distribution of carbon monoxide poisoning cases in the wilaya of Constantine (January 1 – December 31, 2021).

Findings: 2019 is the most unfortunate year with 284 cases recorded, Including 276 rescued from certain death and with eight (8) deaths. Constantine city and El Khroub record the highest number of victims 198 cases (69.71% of cases), seven (7) deaths (2 men, a woman and two children in Constantine, against a man and a woman in El Khroub). For the other municipalities, between one (1) and ten (10) poisonings were recorded.

– (January 1, 2020 – December 31, 2020): The results of this period are presented in Table 8 and Fig. 9.

Findings: Constantine city and El Khroub are always, predominating the number of intoxications cases. In El Khroub 45 cases were recorded for each sex including a dead woman and two children against Constantine 20 cases including one man and three women deaths. In the third position, it is Awled Rahmoune with 10 men 15 women, 19 children and one child death. Ain Smara records one death and the other regions record between one to 5 cases, with no deaths.

– January 1, 2021 – December 31, 2021): The results of this period are presented in Table 9 and Fig. 10.

Findings: The two most affected municipalities are respectively the center city of Constantine and El-Khroub which record the highest cases of intoxication with 8 men, 12 women and 10 children in Constantine represented by a rate of 14.9% of cases including 7 deaths represented by a rate of 46% deaths while the city of El-Khroub records a rate of 37.3% of cases and 20% of deaths. However, this year Didouch Mourad has recorded a little more cases 16 cases represented by rate 7.91%

We can say that Co poisoning accidents are important in Algeria and the large proportion of cases is located in the north of the country. This is due to the different climatic zones - the north is much colder

than the south. It was also noted that the large wilayahs are the most affected because of the high population density and demographic distribution. This is on one hand. It has also been found that women are the most exposed with children to a lesser extent to Co than men because of the use of different domestic appliances, besides men are outside most of the day. On the other hand, we notice that most of the dramas have a link with the heating devices, especially the heaters and the water heater.

Concerning our case of study, the results show that the two municipalities of Constantine city and the Municipality of EL Khroub are the most affected by carbon monoxide poisoning. In our view, this is due to the population density «in Constantine city surface 232 km^2 with 448374 inhabitants therefore 1935.7 inhabitants/km^2 and El Khroub city spreading over an area of 630km^2 with 242163 inhabitants which gives 384.6 inhabitants/km^2"; this is also due to the architecture of the houses which are very crowded with small surfaces.

Conclusions

Carbon monoxide (CO) is a very dangerous gas: Invisible, odourless and non-irritating. It is very dangerous for both health and environment. It is generated from a bad combustion within a device or a combustion engine. Thus, the domestic environment represents a potential source of exposure to this gas that results in significant health problems in terms of morbidity and mortality. In addition, it can lead to neurological lesions in short-term which may be responsible of long-term neuropsychological effects [25, 26].

Thus, to avoid carbon monoxide poisoning during the use of domestic appliances or their maintenance, Algeria authorities suggest strongly to the population to carry out maintenance and verification of heating appliances every year. Furthermore, awareness campaigns in progress for more than 20 years are practiced and despite all this, poisonings are recorded even the death of entire families. Thereby, we suggest as a primary safety measure legislative texts concerning the maintenance and verification of household appliances giving rise to carbon monoxide. In addition, we advise and recommend the installation of a CO detector. This type of device has shown its effectiveness elsewhere in reducing the severity of poisoning.

A very positive point of this study to note that the notoriety of carbon monoxide CO represents a preliminary step, which is quite successful because a very large proportion of the population says they know CO. This observation is very encouraging. On the other hand, knowing the sources of CO and the symptoms present some deficits that must be filled in terms of awareness because they can threaten the lives of the occupants of residences at risk: awareness campaigns on the risks of carbon monoxide is suggested at the beginning of each cold season (the media, associations, civil protection, local authorities, etc.) given that changes in behaviour are slow to take place, there are many examples in public health. From now on, the use of means of communication which take into account the preferences of the population is to be reinforced by the authorities. It has also been found that there is a flagrant lack of knowledge of the symptoms and effects among citizens. This represents a big danger that harms the people exposed to CO, because they will not be able to adopt the appropriate behaviour once in exposure to CO poisoning. This study allowed us to have a map of the risks related to carbon monoxide, which permits the authorities to identify preventive actions' plans that can meet the situations' expectations in terms of time and space everywhere. This mapping provides data that make it possible to quantify the situation and conduct regular monitoring in order to assess the efforts that should be made over the next few years.

Recommendations

To reduce the risk of CO poisoning, we recommend the following:

- Reinforcement of the regulatory means to fight carbon monoxide poisoning;
- Primary prevention of CO poisoning includes public awareness and communication campaigns mainly before and during the winter months;
- Make visits to poor regions and information sessions for the citizens;
- Make open doors – exhibitions - stands on the risk of Co and its preventive means.
- Radio program with local radio stations;
- Lessons on this theme for schoolchildren in schools every year;
- Respect the combustion appliances' instructions use.
- Do not stall water heaters in bathrooms;
- Activate a national carbon monoxide poisoning surveillance network that includes all organizations active in this field for alerting; estimation the magnitude of the phenomenon, identification of cases of poisoning and evaluation of preventive measures;
- Applying safety standards concerning the installation and operation of combustion appliances;
- Training of heating and building professionals in the identification of dangerous devices and installations;
- Acquisition of carbon dioxide sound detectors, which could facilitate the early detection of air pollution by this gas.

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Conflict of Interest

The authors declare no conflict of interest.

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