

ARTICLE

# White phosphorus poisoning by oral ingestion of firecrackers or little devils: Current experience in Ecuador

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**Background.** White phosphorus (WP) is widely used illicitly in fireworks in South America. We report our experience in seven Ecuadorian hospitals. **Methods.** A cross-sectional study of patients presented during 2009. Inclusion criteria included: reported oral ingestion of firecrackers (*little devils*) in any age. Data were gathered using inpatient records and a written survey of the victims. **Results.** The mean age of the patients was  $21.6 \pm 7.1$  years (women 63.5%); 64.7% of cases occurred in November, December and January. In 46% of cases, the number of units ingested was between 1 and 5 ( $\sim 0.3$  to 1.5 g WP), maximum 40 ( $\sim 12$  g). Forty-seven cases attended within 12 hours (55.3%); 5.9% died and 2.4% were readmitted. The remainder were eventually discharged well. Clinical features included: abdominal pain, cramps, diarrhoea, jaundice, nausea and vomiting, abnormal liver enzymes, and coagulation times and hypoglycaemia. **Conclusions.** The typical case was an adolescent woman between 16 and 19 years with self-harm around Christmas. There was no specific treatment, but early attendance was associated with improved prognosis. Further studies are necessary to establish an adequate protocol of treatment.

**Keywords** Poisoning; Phosphorus; White phosphorus; Oral ingestion; Suicides; Toxicology; Epidemiology; Mental health; Ecuador

## Introduction

White phosphorus (WP) poisoning by oral ingestion is an uncommon presentation. This is mainly because the domestic use of WP has been banned or restricted in most developed countries. In Ecuador, it is still used in the traditional and homemade manufacture of explosives and firecrackers, especially in the manufacture of “*little devils*”<sup>1</sup> or *diablillos*, even though this is illegal. In a former retrospective study, we reported 590 cases of WP poisoning in Ecuador over 19 years.<sup>1</sup> This problem also occurs in Colombia<sup>2</sup> and Venezuela.<sup>3</sup>

*Little devils* or *diablillos* are explosive tablets that flame by violent friction. They weigh approximately 0.3 g and include quantities of WP that vary between 1 and 10% of their total weight. Firecrackers are wrapped in a heavy paper casing to contain the explosive compound, each one is called unit. They also comprise up to 40% potassium chlorate in addition to a mixture of flour, red phosphorus and other non-identified compounds.<sup>4</sup>

The toxic dose is said to range from 15–100 mg, therefore for adults, the toxic dose would be approximately 0.2 to 1.4 mg/kg (assuming a 70 kg per person), i.e. approximately

1 mg/kg weight.<sup>5</sup> The fatality rate has previously been reported to be between 10 and 50%.<sup>6</sup> The prognosis depends on the quantity of phosphorus absorbed from the intestine, which seems to be greater if the ingested vehicle is liquid.<sup>7</sup>

We report our recent experience of this unusual poison as a reminder of the potential toxicity of this agent.

## Subjects and methods

### Study design

This is a cross-sectional study of all patients presenting oral WP poisoning in seven Ecuadorian hospitals during 2009. Inclusion criteria included: reported oral ingestion of firecrackers (*little devils*) presenting to one of the seven study hospitals. It excluded poisoned patients that remained at home, with or without medical treatment, whose prognosis and outcome were unknown to us. A total of 85 patients were thus identified and studied.

### Source of information

Data were gathered from inpatient records and data were tabulated by researchers. The seven hospitals are located in four provinces of the highland region of the country: Pichincha (Eugenio Espejo Hospital and Enrique Garcés Hospital); Tungurahua (General Hospital of Ambato and County Hospital of Pillaro); Cotopaxi (General Hospital of Latacunga and County Hospital of Pujilí) and Chimborazo

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(General Hospital of Riobamba), all under the management of the Ministry of Public Health. The physicians were also asked to report patient demographics, coexisting health conditions and key clinical findings, such as patient history, laboratory values, vital signs and clinical signs and symptoms, from the beginning of the inpatient stay.

The five variables studied were: epidemiological parameters; time and site of ingestion dose, time to presentation, duration of hospital stay and outcome; psychological and psychiatric factors; clinical findings and treatments administered. We compared our findings with epidemiological parameters registered in the register of the National Institute of Statistics and Censuses. This register has been extensively used in former epidemiological studies.<sup>8,9</sup>

### Analysis

Descriptive statistics include means, standard deviations, medians and modes for continuous data. For categorical data, we report frequencies and percentages. Chi-square was used to assess differences in proportions.

### Some definitions used

Firecracker is a small explosive device primarily designed to produce a large amount of noise, especially in the form of a loud bang, any visual effect is incidental to this goal. They have fuses and are wrapped in a heavy paper casing to contain the explosive compound. *Little devil or diablillo* is a particular form of firecracker locally produced in Ecuador; for this study, these elements are shown as units. *Suicide* is defined as an intentional death when a preponderance of the evidence indicates that the event was intentional. *Undetermined intent* is used when a death results for which the evidence indicating one manner of death is no more compelling than evidence indicating another.

### Results

Patients mean age was  $21.6 \pm 7.13$  years, ranged between 12 and 50 years of age, with a median of 19 and mode of 16. Women were the most affected with 54 cases (63.5%), (female:male ratio, 1.7:1). Most cases occurred in December (26), with 18 in January and 11 in November, together accounting for a 65% of cases.

Table 1 shows doses ingested and outcomes. In roughly 46% of cases, 1 to 5 firecrackers were ingested (0.3 to 1.5 g), with a mean of  $7.7 \pm 7.04$  units ( $2.3 \pm 2.11$  g), and the maximum number of used units was 40 (12 g). In seven cases, coingestants were involved, included pesticides, anxiolytic or recreational drugs and in 20 cases, alcohol. Forty-seven cases were seen in the ER within 12 hours (55%) and 18 patients between 12 to 24 hours (21%). Five (6%) patients died, two were readmitted because of continuing symptoms and the remainder were discharged well. Forty-eight patients (56%) had a length of stay between 4 to 10 days, and 25 (29%) between 10 and 20 days

**Table 1.** Dose, time to presentation, hospital stay and outcome.

	Grams by unit	Estimated amount of WP (10% by unit)	n (%)
Number of used units of <i>little devils</i>			
1 to 5 units	0.3–1.5	0.03–0.15	45 (45.9)
6 to 10 units	1.8–3.0	0.18–0.30	32 (37.6)
11 to 20 units	3.3–6.0	0.33–0.60	9 (10.6)
More than 21 units	> 6.3	> 0.63	5 (5.90)
Time before reaching the emergency room			
1 to 12 hours			24 (28.2)
1 hour or less			23 (27.1)
12 to 24 hours			18 (21.2)
Unknown			12 (14.1)
	More than 24 hours (maximum time 72 hours)		8 (9.4)
Hospitalization time			
4 to 10 days			48 (56.5)
10 to 20 days			25 (29.4)
2 to 3 days			8 (9.4)
More than 20 days			4 (4.7)
Discharge diagnostic			
Good condition			78 (91.8)
Died			5 (5.9)
Readmission			2 (2.4)

WP toxic dose, 0.015–0.10 g. Source and elaboration: authors.

(mean length of stay  $9.4 \pm 4.9$  days, median 9 days, mode 9 days, maximum number of days 30 and minimum 2).

The most common features following ingestion were related to the gastrointestinal system. Abdominal pain, cramps and diarrhoea were found in 60 patients (71%); jaundice and hyperbilirubinemia in 31 cases (37%); liver enzymes increased in 27 cases (32%); nausea and vomiting in 21 patients (25%); alkaline phosphatase increased in 20 patients (24%); coagulation times increased in 15 cases (18%) and hypoglycaemia in 11 patients (13%). A wide range of treatments were used, the majority symptomatic or based on local physician opinion. The most frequent were gastric decontamination procedures and acetylcysteine for liver dysfunction. There are no effective antidotes based on experimental data.

Almost all cases (96.5%) were intentional. Eighty cases (94%) were first attempts and only five cases had a record of a previous self-harm attempt. Only 10 patients (8.5%) had previous symptoms relating to formal psychiatric disorders such as depression, anxiety or post traumatic stress disorder, the latter usually triggered by a rape or child abuse event (Table 3).

### Discussion

WP is an allotropic form of elemental phosphorus containing four phosphorus atoms. It is a solid at room temperature

**Table 2.** Clinical findings by organ system.

Affected system	Most common symptom/sign found	n (%)
Gastrointestinal	Gastrointestinal effects (abdominal pain & cramps)	60 (70.6)
	Diarrhoea	60 (70.6)
	Vomit & nausea	21 (24.7)
	Haematemesis	3 (3.5)
Hepatic	Jaundice	31 (25.2)
	Hyperbilirubinemia	31 (25.2)
	Liver enzymes increased	27 (22.0)
	Alkaline phosphatase increased	20 (16.3)
	Hepatitis	5 (4.1)
	Acute liver failure	4 (3.3)
	Cholestatic syndrome	3 (2.4)
	Cirrhosis	2 (1.6)
Haematologic	Coagulation times increased	15 (55.6)
	Leukopenia	6 (22.2)
	Leukocytosis	4 (14.8)
	Thrombocytopenia	2 (7.4)
Metabolic	Hypoglycaemia	11 (55.0)
	Hyperproteinemia	5 (25.0)
Neurologic	Hyperuricaemia	4 (20.0)
	Encephalopathy	8 (9.4)
	Headache	5 (5.9)
Cardiologic	Temporary loss of consciousness	4 (4.7)
	Tachycardia	3 (3.5)
	Other dysrhythmias	2 (2.4)
	Bradycardia	1 (0.9)

Source and elaboration: authors.

and may be stored as a solid in water without breaking down or significantly dissolving, yet it is soluble in oils and lipids. It is unstable in air, either volatilizing or spontaneously combusting at room temperature.<sup>10</sup> Pure WP is colourless-to-white waxy solid, but commercial WP is usually yellow. It is also known as yellow phosphorus and phosphorus tetramer and has a characteristic garlic-like smell. When exposed to air, it spontaneously ignites and is oxidized rapidly to phosphorus pentoxide.<sup>11</sup> Large quantities of heat are produced by this reaction and it bursts into a yellow flame and produces a dense white smoke.<sup>12</sup> Phosphorus is luminous in the dark, and this continues until either all the material is consumed or the element is deprived of oxygen.<sup>13</sup>

WP does not occur naturally in the environment. It has been manufactured in the past for use in such products as matches, fireworks, pest poisons and incendiary munitions. It is primarily in the manufacture and use of these products where human exposure has occurred. In the past, WP poisoning was observed in match factory workers,<sup>14</sup> where a life-threatening condition called phosphorus necrosis, also known as *phossy jaw* following intermediate or chronic occupational exposure to WP.<sup>15</sup>

**Table 3.** Psychological and psychiatric factors related with the incident\*.

Issue	Observation	n (%)
Cause	Intentional	82 (96.5)
	Undetermined event	3 (3.5)
Trigger event or cause attributed by the patient, it can be more than one	Dysfunctional family	60 (70.6)
	Relationship concerns	28 (32.9)
	Economical issues	5 (5.9)
	Chronic diseases	1 (0.9)
	Accidental	3 (3.5)
Other findings found before the incident	Others	5 (5.9)
	Suicidal thoughts	50 (58.8)
	Histrionic personality	5 (5.9)
	Sleep disorders	3 (3.5)
	Previous drugs consumption (antidepressants 2 cases; anxiety drugs 2 cases)	4 (4.7)

Source and elaboration: authors.

\*When the patient was unconscious, the information was collected from relatives, acquaintances and healthcare providers, when the patient was awake the information was provided by itself.

WP is highly toxic when inhaled, ingested or absorbed through burned areas. People have attempted suicide by ingesting matches, fireworks, roach poison or rat poison containing WP. Animal data are consistent with human data on the effects of acute oral exposure. Many case reports of deaths resulting from intentional or accidental ingestion of WP in rat and cockroach poison and firecrackers have been reported.<sup>16</sup>

The classical progression of symptoms in fatal oral WP poisoning in humans involves three stages, listed in the Table 4.<sup>17</sup> Not all cases of fatal WP poisoning follow the classic scenario. Death by cardiac arrest may occur rapidly. On the other hand, second- and third-degree burns occur when WP is in contact with the skin.<sup>18</sup> Respiratory symptoms have been described following inhalation.<sup>19</sup> Authors have also described lesions due to spontaneous combustion and explosion during WP handling.<sup>20</sup>

A medical literature search<sup>4,16,17,21-30</sup> reveals studies or case reports reporting acute oral exposure to WP and are limited to case reports of match heads, rat poison, cockroach poison, firecrackers or from military operations. There is one previous report of a case series of 85 *diablillos* poisoning, 19 years.<sup>1</sup> Most other studies do not report intake levels. High doses of WP nearly always induce vomiting. In addition, gastric lavage has often been performed. Thus, actual ingested dose is rarely accurately known.

In our experience, the typical victim of WP poisoning was an adolescent woman between 16 and 19 years with an unrecognised psychiatric disorder. The incidents are most common in December, because of the increased availability of firecrackers at this time of year. The epidemiology appears similar to many other reports of self-harm behaviour, but the agent of choice here is available and cheap US \$0.25 (25 cent). Thus, less of one dollar may result in a fatality. In this study, most patients consumed

**Table 4.** Clinical phases of acute WP poisoning.

Phase	Duration time	Clinical findings*	Prognosis
I	0 to 24 hours	<i>Gastrointestinal</i> effects and acute symptoms such as vomiting, nausea, diarrhoea, abdominal pain and cramping, GI bleeding all related with the local corrosive injury. A garlic-like odour can be detectable.	Good, if the patient receives early and proper treatment
II	1 to 3 days	Quiescent stage of a transient improvement; patients experience some degree of anorexia, nausea, vomiting, diarrhoea or abdominal discomfort.	Reversible, mild increase of laboratory indicators can be seen, reversible with proper treatment also
III	More than 3 days, variable duration	<i>Clinical deterioration</i> with end-organ toxicity. Patients can show liver failure, renal failure, coagulation disorders, hepatic encephalopathy, cardiac dysrhythmias, chorea, parkinsonisms, bone marrow and multi-systemic failure,	Irreversible damage, death. Bad prognostic factors are: high dose ingested, late medical attention (after 3 days), coma, hypoglycaemia and metabolic acidosis presence.

\*In the routine practice this three stages tend not to be well defined.

between 1 and 5 firecrackers, but we cannot be sure that patients are aware of the likely fatal dose.

Most symptoms were from the GI tract and liver. These included abdominal pain, cramps, diarrhoea, jaundice, nausea and vomiting and abnormal liver enzymes, alkaline phosphatase, coagulation times and hypoglycaemia. Our findings are in agreement with previously published findings. In addition, alterations in the electrocardiogram, such as altered or inverted T waves and changes in the QRS complex, tachycardia, arrhythmias, atrial fibrillation and decreased ventricular contractility, were observed in our patients as previously reported.<sup>4</sup>

Most case reports list vomiting as an early effect following ingestion of a single high dose of WP. In the literature,<sup>4</sup> the doses that induced vomiting ranged from 2 to 23 mg/kg. Vomiting generally started within hours after ingesting the WP and sometimes continued for many days.

In the Table 2, we report the clinical findings by frequency and system affected. There are similarities to our clinical findings with previous literature; however, the clinical presentation can be very diverse and lead to confusion in diagnosis. Our experience suggests that if the patient does not improve in the first 3 days, prognosis is often poor. In addition, the more severe neurological or haematological effects are, the less chance of survival.<sup>31</sup>

## Conclusions

In our experience, WP poisoning is most commonly a deliberate in a woman between 16 and 19 years who has grown up and lives in an urban area. This most often occurs in November, December and January. Availability of the product may affect this pattern.

Clinical scenario of WP poisoning in our series typically involved abdominal pain, cramps, diarrhoea, nausea and vomiting, and hepatic dysfunction, abnormal coagulation and hypoglycaemia.

The main public health issue is the removal of this toxic chemical in the local environment. There was no specific treatment but the early attention improved the prognosis. Further studies are necessary to establish an adequate protocol of treatment.

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## Contribution of the authors

All authors contributed equally to the conception, design, analysis and interpretation of data, drafting the article, further revision of this paper and critical review of the content.

## Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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