

MANAGEMENT OF ALUMINUM PHOSPHIDE POISONING

Manejo de la intoxicación por fosforo de aluminio

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RESUMEN

Introducción: El fosforo de aluminio es un plaguicida utilizado para controlar las plagas de los cereales almacenados. Es altamente tóxico y representa un gran riesgo para el ser humano si se ingiere o inhala. Las intoxicaciones por fosforo de aluminio, tanto accidentales como intencionadas, son frecuentes y difíciles de tratar. Esta revisión analiza sus efectos en la salud humana, así como las opciones de tratamiento y prevención. **Objetivo:** Describir los efectos tóxicos del fosforo de aluminio y sus implicaciones para la salud pública, el tratamiento y la prevención. **Metodología:** Se realizó una revisión bibliográfica narrativa que incluyó 36 estudios entre revisiones, reportes de caso y análisis clínicos. Se incorporaron trabajos que describieran el mecanismo tóxico, manifestaciones clínicas o enfoques terapéuticos, y se excluyeron artículos sin relevancia o con información insuficiente. **Resultados:** La evidencia muestra que la exposición a fosforo de aluminio conlleva a la liberación de fosfina, la cual interfiere con la fosforilación oxidativa e induce estrés oxidativo en la mitocondria, causando muerte celular y deterioro progresivo de órganos vitales. Los síntomas más reportados fueron náuseas, vómitos, dolor abdominal, insuficiencia respiratoria y compromiso cardiovascular. No existe un antídoto específico, por lo que el manejo se basa en soporte intensivo. **Discusión:** La tasa de mortalidad es alta debido a la rápida acción del compuesto tóxico y a la falta de un tratamiento específico. **Conclusiones:** La intoxicación por fosforo de aluminio es una emergencia médica que requiere una intervención inmediata. Deben mejorarse las políticas de control y prevención y aumentar la concienciación pública para reducir los casos de intoxicación.

Palabras claves: intoxicación, fosforo de aluminio, manejo, prevención, tratamiento.

ABSTRACT

Introduction: Aluminium phosphide is a pesticide used to control pests in stored grains. It is highly toxic and poses a great risk to humans if ingested or inhaled. Both accidental and intentional aluminium phosphide poisonings are frequent and difficult to treat. This review discusses its effects on human health, as well as treatment and prevention options. **Objective:** To describe the toxic effects of aluminium phosphide and its consequences for public health, treatment, and prevention. **Methodology:** We conducted a narrative review of 30 studies that included reviews, case reports, and clinical analyses, describing the toxic mechanism, clinical manifestations, or therapeutic approaches, and excluded irrelevant or insufficiently informative articles. **Results:** The evidence shows that the exposure to aluminium phosphide leads to phosphine release, which interferes with oxidative phosphorylation and induces oxidative stress, causing cell death and progressive destruction of vital organs. The most frequently reported symptoms were nausea, vomiting, abdominal pain, and respiratory and cardiac failure. Treatment is supportive since there is no specific antidote. **Discussion:** The mortality rate is high due to the rapid action of the toxic compound and the lack of specific treatment. **Conclusions:** Aluminum phosphide poisoning is a medical emergency that requires immediate intervention. The control and prevention policies should be improved and public awareness increased in order to cut down cases of poisoning.

Keywords: Intoxication, aluminum phosphide, management, prevention, treatment.

1. Introduction

Pesticide poisoning is a serious public health problem worldwide and affects over 3 million people every year. It is estimated that around 200,000 people die each year due to pesticide poisoning^{1,2}. This situation is of great concern, particularly in developing countries, where death rates and contamination by pesticides exceed those of infectious diseases². Aluminum phosphide poisoning has also been reported in Ecuador. A retrospective review shows that between 2001 and 2007, 14,145 cases of poisoning were reported³.

Pesticides are very effective for combating invasive insects at any stage of development, leave a low concentration of residues in treated foods and not affect the viability of seeds. However, various pesticides, including aluminum phosphide, are highly toxic².

Upon contact with moisture, aluminum phosphide releases a lethal gas known as phosphine or phosphine gas, which is colorless but exhibits a characteristic odor that resembles "decomposed fish" or "concentrated garlic". Exposure to this gas may result in poisoning and can be especially dangerous, as gastric moisture accelerates the release of this gas, causing shock, myocarditis, lethal arrhythmias and multiple organ failure³.

Even a small amount of this poison can have devastating effects, since approximately 1 mg/kg of an individual's weight is enough to cause death, which means that a small portion of a tablet can be enough to kill a 70 kg person⁴. It is concerning that aluminum phosphide is used in rural areas in cases of suicide attempts, due to its easy accessibility, low cost and high lethality, causing death in a short period of time⁵.

Patients with risk factors for suicide, especially in vulnerable populations such as children, adolescents and young adults, are the most affected⁶. There are reports indicating that female patients are at higher risk of suicide. This often occurs due to family disintegration or early union dissolution, which can lead to depression or suicidal behaviors⁷.

The mortality associated with aluminum phosphide poisoning can be as high as 80%. Typical features of the patient include clammy, cold skin, weak thready pulse, and severe hypotension often refractory to vasopressors. If the patient survives the initial shock, acute renal failure may supervene. Mentally, the patients remain lucid but

restless until the shock produces cerebral anoxia, manifesting as drowsiness, delirium and coma^{8,9,10}.

The objective of the present review is to describe the toxic effects of aluminum phosphide and its clinical, therapeutic, and public health implications. Additionally, this review aims to synthesize recent evidence on its toxic mechanisms, clinical manifestations, and management strategies implemented in different countries, providing an up-to-date and comparative perspective on this health issue.

2. Methodology

A non-systematic and narrative literature research focused on the management of aluminum phosphide poisoning was conducted, using Boolean operators such as "AND", "OR" and "NOT" together with specific keywords such as "aluminum phosphide", "acute poisoning", "treatment" and "physiopathological mechanism". The main platform used for the search was Google Scholar, complemented by medical journals and scientific databases such as Medscape, SciELO, Redalyc, Medline Plus and PubMed, among others. The information collected was exhaustively analyzed, selecting only the most relevant, updated and reliable data related to the mechanisms of toxicity, clinical manifestations and treatment of this intoxication. Scientific articles published in the last twenty years were included, applying a three-stage filter: initial review of articles according to thematic relevance, reading to verify useful content and final approval of those that met the established criteria. Articles outside the specified time range or containing irrelevant data were excluded, but articles published in English language were included because of their relevance and up-to-date information.

3. Results

Following a comprehensive analysis of various articles, the main characteristics of aluminum phosphide poisoning, including its toxicity and management, were identified. It is essential to underscore that aluminum phosphide poisoning is one of the most serious medical emergencies with a mortality rate ranging between 40% and 80% depending on the time elapsed since the exposure and access to medical care, it occurs more frequently in rural areas. It is important to know the mechanism of toxic action since it is due to the release of phosphine gas in contact with moisture

which generates severe multisystemic damage mainly in the cardiovascular, respiratory and renal systems; those patients may present diverse symptoms that most of them are non-specific among which are included the deterioration of the state of consciousness, multiorgan failure and even death.

The treatment of this type of intoxication lacks a specific antidote, so it is mainly based on providing supportive care including decontamination, administration of intravenous fluids, complementary therapies in which magnesium sulfate can be used as the main antioxidant and antiarrhythmic.

Finally, aluminum phosphide poisoning represents a very significant challenge due to its severity. Current strategies are based on supportive management but reflect a high mortality rate, so there is a need to develop specific antidotes to improve interventions.

»» 4. Discussion

Aluminum phosphide poisoning is a serious medical condition that occurs due to the ingestion, inhalation or contact with highly toxic chemical compounds. Aluminum phosphide is a common pesticide used for the storage of grains or other agricultural products.

Symptoms of aluminum phosphide poisoning may vary depending on the route of exposure, but generally include gastrointestinal symptoms (nausea, vomiting, abdominal pain, diarrhea, burning in the mouth and throat), respiratory symptoms (shortness of breath, chest tightness, cough, choking sensation), cardiovascular symptoms (tachycardia or rapid heart rate and hypotension or low blood pressure) and neurological symptoms (dizziness, weakness, confusion, convulsions and coma). Therefore, aluminum phosphide poisoning requires immediate treatment. Treatment for aluminum phosphide poisoning may involve different approaches including stomach pumping, activated charcoal or respiratory support. Additionally, treatment should be provided for other complications based on symptoms. Considering its toxicity, aluminum phosphide should only be handled by trained professionals who can take all the necessary measures to avoid exposure. Handling changes depend on each country and guide used¹¹.

1.1. Management of aluminum phosphide poisoning in El Salvador

In El Salvador, the management of aluminum intoxication follows the guidelines and recommendations established by the country's health system, regulated by the Ministry of Health, in which it states:¹²

At the first level, vital function support must be maintained with intravenous fluids and oxygen to maintain a saturation greater than or equal to 94% according to availability. On the other hand, check the airway and make sure it is clear and remove any foreign body or remains of vomit or secretions, start invasive mechanical ventilation according to availability, prevent aspiration in case the patient vomits. The patient should be transferred to the second or third level of care and gastric lavage should not be performed if the airways are not protected.

In the second and third levels of care, we proceed as follows: everything described in the first level of care, as well as continuous monitoring of vital signs, maintaining the support of vital functions, with intravenous fluids with a target SBP of 90 mmHg¹³.

A central venous catheter will be placed and dopamine or norepinephrine will be started even in the absence of hypotension, since the mechanism of action of shock is imminent, in order to decontaminate the patient and decrease respiratory absorption and increase respiratory elimination, assisted mechanical ventilation with a respiratory frequency of at least 20 per minute with PEEP of 3 to 5 should be started¹⁴.

In case of not having a mechanical ventilator and using a bag-mask, the personnel providing ventilation should wear a mask to avoid inhalation of the toxic substance. Once the airways are protected, gastric lavage is performed and then activated charcoal (single dose) will be started at a dose of 1 g/kg in adults and children with a maximum dose of 50 grams per dose and 20% mannitol 15 to 20 ml orally, every 6 hours until catharsis is provoked. Diuresis will be maintained at 0.5 to 1 ml/kg/hour¹⁵.

Magnesium sulfate is used as an anti-peroxidant agent and as a free radical scavenger, it has also been described to reduce cardiac arrhythmias by 50% and mortality. The loading dose of 1 gram in 200 ml of 5% dextrose serum is taken in 30 minutes. The first day maintenance dose: 6 grams

in 250 ml of 5% dextrose serum to be administered in 24 hours. The second maintenance day dose is 4 grams in 250 ml of 5% dextrose serum and is given after 24 hours to 48 hours. N-acetylcysteine, at a dose of 25 mg/kg is given every 6 hours by nasogastric tube or intravenously for five days. This reduces endothelial injury by free radicals. It has also been reported to decrease the duration of hospitalization, mechanical ventilation and mortality¹⁶.

1.2. Management of aluminum phosphide poisoning in Costa Rica

In Costa Rica, the management of aluminum intoxication follows the guidelines and recommendations established by the country's health system by the Ministry of Health, in which it mentions:

Supportive measures are usually all that can be offered, fluid therapy, vasopressors, early gastric lavage with potassium permanganate, sodium bicarbonate and coconut oil have also been recommended in some literatures, and charcoal administration and sorbitol suspension have been described as helping to reduce absorption¹⁷.

Despite advances in intensive care and management to eliminate the symptoms of aluminum phosphide poisoning, consumption of this chemical still results in high mortality, which would make a new method of management extremely valuable¹⁸. Unfortunately, there is no known specific antidote, so management is mainly based on supportive care¹⁹.

1.3. Management of aluminum phosphide poisoning in Honduras

In Honduras, the management of aluminum intoxication follows the guidelines and recommendations established by the country's health system by the Ministry of Health, which include:

- Support of vital functions (ABC), decontamination, antidote, and maintaining stable vital signs and treating complications as they arise.
- Management carried out in an intensive care unit with immediate endotracheal intubation accompanied by mechanical ventilation to prevent further absorption of the toxicant and thus increase its elimination. It is recommended a respiratory rate of more than 20 per minute, with high PEEP²⁰.

From the beginning, vital signs and blood pressure should be monitored every 5 to 10 minutes, then the restitution of intravenous fluids should be started to keep the patient hydrated. If the patient is in shock, expander solutions such as Hartmann's or Ringer's solution should be used. Then vasopressors such as dopamine should be started in order to prevent phosphine from taking up the dopamine receptors. The initial dose of dopamine should be 5 to 10 mcg/kg/min, which can be gradually increased up to 20-50 mcg/kg/min if the clinical situation so indicates until blood pressure control is achieved. The use of hydrogen pump inhibitor is also recommended to reduce acidosis²¹.

Decontamination is performed by placing the patient in a well ventilated place since the elimination of aluminum phosphide occurs through airways; in addition, gastric protection must be provided by means of a nasogastric tube to avoid aspiration of vomit; once the airway and gastric tract have been protected, gastric lavage with saline solution and activated charcoal using a similar approach as in El Salvador²².

Then, any complications should be treated, among the most common are ventricular fibrillation, ventricular extrasystoles, sinus tachycardia, sinus bradycardia and atrioventricular block, acute pulmonary edema, renal failure and convulsions²³.

1.4. Management of aluminum phosphide poisoning in Mexico

In Mexico, the management of aluminum intoxication follows the guidelines and recommendations established by the country's health system by the Ministry of Health, which include:

- In medical management, the main focus is on fluid restitution and management of the shock state. This is done through the generous administration of saline solution of 2 to 3 liters in the first 8 to 12 hours, adjusted according to the measurement of central venous pressure. It is recommended to maintain central venous pressure in the range of 12 to 14 cm of water. Some authors suggest a rapid infusion of 3 to 6 liters of saline in 3 hours²⁴.
- The use of low doses of dopamine (4-6 mg/kg/min) is recommended to maintain a systolic pressure greater than 90 mmHg, good renal perfusion and adequate hydration status.

Hydrocortisone (200-400 mg every 4-6 hours) is also recommended to combat shock and reduce the dopamine dose. Epinephrine may also be an appropriate option. It is important to maintain a well-ventilated room, as the gas phosphine released by aluminum phosphide poisoning is highly toxic in enclosed spaces²⁵

As for gastrointestinal treatment, gastric lavage as in Costa Rica. Activated charcoal with a dose similar to El Salvador and cathartics (such as liquid kerosene) can then be administered to accelerate phosphate excretion. The use of vegetable oils and proton pump inhibitors may also be beneficial²⁶.

In cases of metabolic acidosis, sodium bicarbonate can be used to raise serum bicarbonate levels and correct the acidosis. In severe cases of acidosis, dialysis may be considered, especially if acute renal failure is present. The use of magnesium sulfate has disputed benefits and should be evaluated on a case-by-case basis²⁷.

It is important that medical and nursing personnel and any person who has direct contact with the patient be protected with gowns, gloves, masks and special goggles during care and decontamination, since there have been cases of intoxication in personnel without the necessary precautions²⁸.

1.5. Management of aluminum phosphide intoxication in Argentina

In Argentina, the management of aluminum poisoning follows the guidelines and recommendations established by the manual of primary care of poisoning of the country by the Ministry of Health of the Nation Republic of Argentina, which include:

- If dust, gases or toxic fumes are present, move the patient to a well-ventilated area and use respiratory protection equipment to avoid possible poisoning. Give first aid according to the guidelines established in Chapter 5 of Volume I - General Part. If the patient is unconscious or drowsy, place him on his side in the recovery position and monitor his breathing every 10 minutes to avoid cooling. Transport the patient to the hospital as soon as possible²⁹.
- In case of delay in transport to hospital, if the chemical has been ingested and the individual is conscious, breathing normally and not vomiting, administer activated charcoal and

offer water to drink. If signs of renal failure, liver injury or pulmonary edema are observed, treat according to the recommendations set forth in Chapter 9 of the General Part³⁰.

It is important to provide the local physician with the following information: in addition to the above mentioned effects, acute intoxication may cause heart rhythm disorders, while chronic intoxication may cause liver damage, kidney damage, anemia and electrolyte disorders (sodium, potassium, magnesium, calcium). It is recommended to perform a rapid and thorough gastric lavage, monitor pulse, respiration and blood pressure, as well as monitor liver and kidney function. In some cases, oxygen administration and assisted ventilation may be necessary³¹.

Fluids and electrolytes should also be replenished to compensate for losses caused by vomiting and to treat shock. There is no specific antidote and, in the case of chronic intoxication, a complete blood count and other tests are recommended³².

1.6. Management of aluminum phosphide poisoning in Ecuador.

No country-specific studies were found, however, different forums indicate that general measures are used for the management of aluminum phosphide poisoning in Ecuador, which indicate:

- Seek medical attention immediately: In case of any suspicion of intoxication, it is essential to seek medical attention as soon as possible³³.
- Not delaying treatment: Time is of the essence in cases of poisoning, so do not wait to seek medical attention³⁴.
- Not inducing vomiting: No attempt should be made to make the affected person vomit, as some chemicals may cause further damage if they come into contact with the digestive system again.
- Not administering home remedies: Home remedies, milk or similar substances should not be used in an attempt to treat poisoning, as this may worsen the situation³⁵.
- Providing medical information: If possible, inform medical personnel of the substance involved, approximate amount and time since exposure.
- Trying to keep the affected person calm and at rest until medical attention is received³⁶.

A major strength of this review is the comparative synthesis of treatment approaches reported across several Latin American countries, offering an

overview of current clinical management in the absence of a specific antidote. Its main limitation is that available treatments are largely supportive, heterogeneous, and based on limited evidence from case reports and national guidelines rather than robust clinical trials. Future efforts should focus on conducting well-designed clinical studies to evaluate therapeutic efficacy and on developing standardized, evidence-based treatment protocols to improve outcomes in aluminum phosphide poisoning.

3. Conclusions

Aluminum phosphide poisoning is a serious and potentially fatal medical condition that can occur from ingestion, inhalation, or skin contact. Aluminum phosphide is commonly used as a pesticide for pest control in grain and other agricultural storage facilities. Symptoms of poisoning can vary depending on the route of exposure and include gastrointestinal problems such as nausea, vomiting, abdominal pain, diarrhea and respiratory. In addition, there may be symptoms related to the cardiovascular and neurological systems, among other serious complications, which underscores the urgency of immediate intervention in cases of suspected poisoning. The treatment of aluminum phosphide poisoning is complex and requires supportive care, including fluid resuscitation and close monitoring of shock status. Decontamination measures are also necessary to prevent further absorption of the toxin. Nevertheless, supportive care is the cornerstone of management, being used to maintain vital body functions and to treat the complications that can occur in the absence of a specific antidote. In different countries, the management of aluminum phosphide poisoning may vary following their specific guidelines and recommendations. It is essential that medical and nursing personnel are adequately protected during patient care and ensure proper decontamination to avoid accidental exposure.

4. Conflicts of interest

The authors declare no conflicts of interest.

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