Research Article

Zinc Phosphide And Aluminum Phosphide Poisoning In Iraq: A Five-Year National Retrospective Analysis (2021-2025)

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Abstract

Background: Ingestion of a commonly available rodenticide can result in zinc phosphide (Zn_3P_2) and Aluminum phosphide (ALP) poisoning, a potentially fatal toxicity. Phosphine gas (PH_3), which inhibits mitochondrial cytochrome C oxidase and results in multiorgan cellular hypoxia and death, is produced when zinc phosphide comes into touch with stomach acid. In extreme cases, death varies from 37 to 100%; there is no known cure. Its a dark gray or black crystalline powder, zinc phosphide is used as a rodenticide against mice, squirrels, rats, and gophers.
Objectives: the goal of this study is to provide a five-year national retrospective analysis of zinc phosphide and aluminum phosphide poisoning cases in Iraq from 2021 to 2025.
Method: This work created a diagnostic methodology for identifying phosphine gas (PH_3) in human gastric tissue samples and cross-examined post-mortem forensic records. The traditional Silver Nitrate ($AgNO_3$) paper test was used for qualitative screening, and stomach contents were treated with diluted sulfuric acid (H_2SO_4). A chemical differentiation spot test using potassium permanganate ($KMnO_4$) and benzidine reagent was used to remove false positives from sulfur compounds (H_2S), producing a clear blue hue. Advanced automated Headspace Gas Chromatography-Mass Spectrometry (HS-GC-MS) was used to obtain the qualitative and quantitative validation.
Results: A retrospective analysis of five years' worth of data (2021–2025) from every governorate in Iraq excluding the Kurdistan region governorate, data collected from Medico-Legal Directorate showed a total of 250 documented deaths from phosphide poisoning, mortality increased from 48 cases in 2021 to 58 cases in 2025, with temporary decline in 2022.
Discussion: This five-year retrospective analysis showed a worrying rise in deaths from phosphide poisoning in Iraq, especially between 2023 and 2025. The results indicate that there is still a serious risk to public health from the broad availability and accessibility of zinc phosphide and aluminum phosphide. The steady increase in mortality emphasizes the need for more stringent regulations, increased public awareness, and improved preventative measures. To better understand the regional and demographic trends linked to phosphide poisoning in Iraq, more epidemiological research is advised.

In conclusion:
In Iraq, phosphide poisoning continues to be a significant contributor to poisoning-related deaths. The rising trend seen throughout the course of the study emphasizes how urgently public health initiatives and regulatory actions are needed to lower exposure and stop deadly consequences.

Keywords: Zinc Phosphide, Phosphine Gas, Forensic Toxicology, Mortality Trends, Iraq.

1. Introduction

Zinc phosphide is a cheap and common inorganic rodenticide with high potency, especially in developing and eastern countries. Its availability and cheapness have played a role in its frequent involvement in cases of accidental, suicidal and less frequently, homicidal poisoning [1].

Over the past few years, there has been a disturbing rise in mortality from zinc phosphide poisoning, mainly because of uncontrolled marketing activities, lack of regulatory enforcement, and rampant misinformation on social media platforms about its safety and use [2].

Chemically speaking, zinc phosphide is an inorganic compound made of zinc and phosphorus that is typically sold as a gray crystalline material or a black, smooth powder [3]. Phosphine gas (PH_3), the main toxic agent causing systemic poisoning, is released when zinc phosphide combines with gastric hydrochloric acid and moisture after consumption [4]. Once released, the phosphine gas has a characteristic smell similar to that of rotting fish or garlic [5].

$$Zn_3P_2 + 6HCl \rightarrow 3ZnCl_2 + 2PH_3 \uparrow$$

$$AlP + 3HCl \rightarrow AlCl_3 + PH_3 \uparrow$$

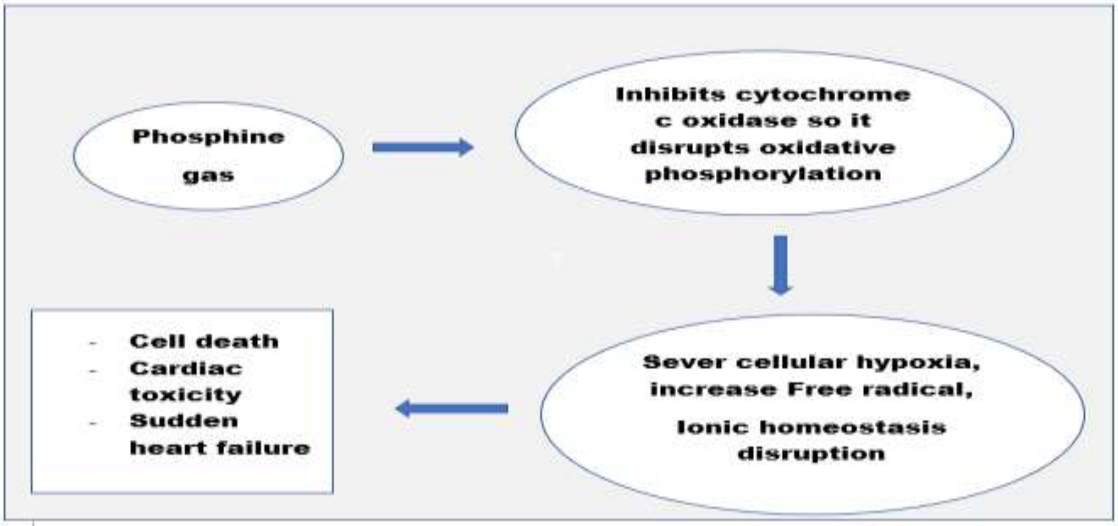
The most clinically relevant exposure channel is the gastrointestinal route. On the other hand, exposure to the skin and eyes typically causes localized irritation with little systemic damage. Although inhalation exposure to phosphine gas or zinc phosphide breakdown products has been reported, it is still very rare and has no clinical significance provided the proper occupational safety precautions are taken [6].

According to the existing scientific literature, Human deaths from acute poisoning have been reported at doses of 4 to 5 g of zinc phosphide (55–70 mg/kg).

[7].

In agricultural facilities and grain storage, aluminum phosphide (AlP), a very toxic inorganic insecticide and fumigant, is used to manage rodents and insects. It releases lethal phosphine gas when it comes into contact with moisture. Its use is strictly limited to qualified specialists due to the severe health risks it presents [8].
Phosphine mostly disrupts oxidative phosphorylation by inhibiting cytochrome c oxidase (Complex IV) in the mitochondrial electron transport chain. This leads to severe cellular hypoxia and excessive production of free radicals [9],

ionic homeostasis disruption, permanent cellular damage, nucleic acid damage, and cell death. The primary cause of death from zinc phosphide poisoning is thought to be cardiac toxicity, which results in sudden heart failure [10].



Schema 1: summary of phosphine gas poisoning

Gross Pathological Findings: Upon opening the abdominal cavity, autopsy logs consistently reported a strong, garlicky smell. The most common post-mortem characteristics were severe hemorrhagic gastritis, significant bilateral lung edema, and widespread visceral congestion [11,12].

In the medical literature, a number of treatment approaches have been put out with the goals of lowering toxin absorption, supporting hemodynamics, or reducing oxidative stress [13]. These include administering activated charcoal, vigorous fluid resuscitation, vasopressor support, and gastrointestinal cleansing with coconut oil, potassium permanganate, or sodium bicarbonate. Additionally, antioxidant treatments such as N-acetylcysteine (NAC) and magnesium sulfate have been used. Nevertheless, the therapeutic efficacy of these therapies is still limited and uneven, and none of them represent a particular antidote [14].

Comprehensive national statistics detailing the epidemiology, clinical outcomes, and mortality trends of zinc and aluminum phosphide poisoning are hard to come by, despite the high prevalence of this condition in Iraq [15]. Thus, the purpose of this study is to present a five-year national retrospective analysis (2021–2025) of cases of zinc phosphide and aluminum phosphide poisoning in Iraq.

2. Techniques

2.1. Population and Study Design

Over the course of five years, from January 1, 2021, to December 31, 2025, all recorded deaths from acute zinc and aluminum phosphide poisoning in Iraq were the subject of this retrospective, descriptive epidemiological study. Information was obtained from official autopsy logs, toxicological registries, and forensic medical reports from several governorates' Iraqi Forensic Directorates.

2.2. Criteria for Inclusion and Exclusion

All deceased people who were referred for a medicolegal autopsy and whose history, post-mortem results, and positive toxicological investigation for phosphides verified the cause of death were eligible for inclusion.

Exclusion criteria include deaths brought on by other pesticide classes (such as organophosphates or carbamates) or situations involving decomposing remains in which a conclusive toxicological screen was not practical.

Both chemicals were examined together as phosphide poisoning cases since the available forensic records could not reliably differentiate between zinc phosphide and aluminum phosphide cases.

2.3. Methods of Examination

Method 1: The Silver Nitrate Spot Test, a forensic toxicological procedure

A traditional, extremely sensitive, and legally approved forensic chemical technique was used for qualitative detection throughout all regional centers:

1. A tightly sealed conical flask was filled with a specified portion of the deceased's stomach tissue and contents.
2. To speed up the release of phosphine gas (PH_3), diluted sulfuric acid (H_2SO_4) was added to the sample.
3. Without coming into contact with the liquid, a strip of filter paper impregnated with a 0.1N silver nitrate ($AgNO_3$) solution was suspended inside the flask's neck.
4. The flasks were sealed tightly. The quick development of a silvery-black to dark brown staining on the filter paper, which verified the reduction of silver ions to metallic silver by the released phosphine gas, indicated a favorable reaction: [16]

$$PH_3 + 6AgNO_3 + 3H_2O \rightarrow 6Ag\downarrow \ \text{(Black/Silver)} + H_3PO_3 + 6HNO_3$$

Figure 1: Laboratory technique for the Silver Nitrate Spot Test

Method 2: Confirmatory Chemical Spot Test (Benzidine and Potassium Permanganate Test)
In order to definitively identify phosphine gas (PH_3) and rule out false-positive results from sulfur compounds or other interfering volatile chemicals, this qualitative test was carried out as a sequential confirmatory step.
Preparing Reagents:
As an oxidizing agent, a solution of potassium permanganate ($KMnO_4$) was made.
To serve as the chromogenic indicator, a solution of benzidine reagent was made.
Method:
1. The produced potassium permanganate ($KMnO_4$) solution was thoroughly impregnated into a new strip of filter paper.
2. The benzidine reagent solution was then applied to the paper.
3.The prepared multi-reagent filter paper was firmly attached to the mouth or top of the reaction flask that held the concentrated sulfuric acid (H_2SO_4) and the stomach tissue sample.
4.To guarantee that all evolving gases went straight through the paper, the flask was firmly sealed, the permanganate was chemically oxidized by the liberated phosphine gas (PH_3) as it ascended, and it then reacted with the benzidine. A positive result for phosphine was confirmed by the emergence of a clear, vivid blue hue (Benzidine Blue) on the filter paper, which offered a trustworthy separation from sulfur interference [17].
Method 3: Headspace Gas Chromatography-Mass Spectrometry (HS-GC-MS) for Advanced Instrumental Analysis
Automated Headspace Gas Chromatography-Mass Spectrometry (HS-GC-MS) was used as the standard forensic

procedure for the confirmation and accurate qualitative/quantitative validation of the volatile phosphine gas (PH_3) [18].

3. Results

Forensic laboratory throughout Iraq recorded and examined 250 definitive deaths from acute zinc and aluminum phosphide poisoning during the five-year retrospective study period, which ran from January 1, 2021, to December 31, 2025 (Table 1).

Table 1: The annual distribution of Zinc Phosphide and Aluminum Phosphide deaths showed varying but generally increasing numbers throughout time

Year	Number Of Recorded Fatalities	Percentage (%)
2021	48	19.2%
2022	34	13.6%
2023	54	21.6%
2024	56	22.4%
2025	58	23.2%
Total	250	100.0%

48 deaths were reported in 2021, accounting for 19.2% of the sample as a whole. Following this, there was a significant decline in 2022, with 34 cases (13.6%) representing the lowest yearly fatality. However, a dramatic and consistent increase in zinc phosphide-related mortality was noted starting in 2023. Figure 1 shows all of these cases, which increased to 54 cases (21.6%) in 2023, 56 cases (22.4%) in 2024, and 58 documented fatalities (23.2%) in 2025.

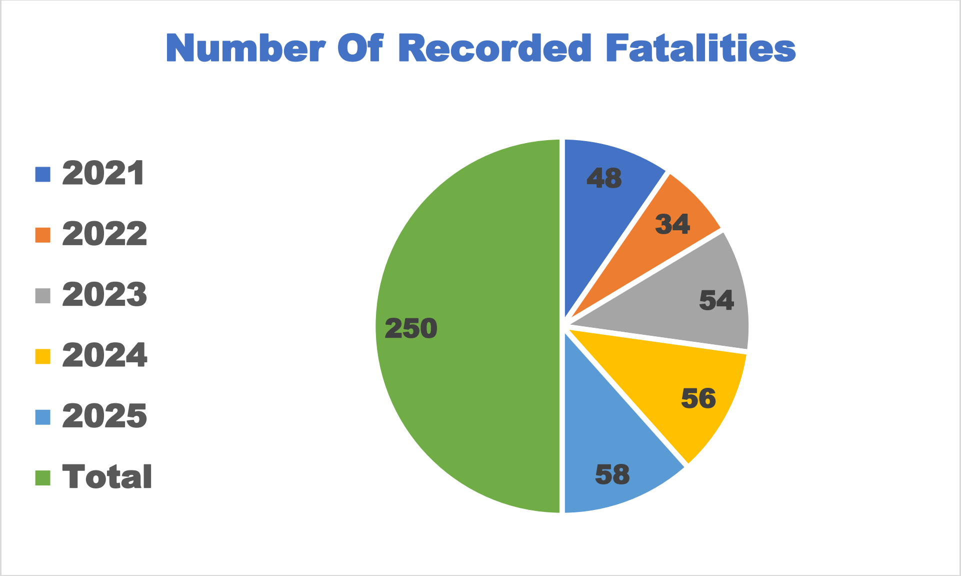


Figure 2: Number of Recorded Fatalities

Results of Diagnostics and Post-Mortem
All 250 cases in this data share a same diagnostic profile that has been confirmed by forensic autopsy: Chemical Screening: In the Silver Nitrate (AgNO3) paper test, the production of phosphine gas (PH_3) from stomach tissue samples treated with diluted (H_2SO_4) resulted in a 100% qualitatively positive reaction (silvery-black staining). As a subsequent confirmatory step, this qualitative test was conducted.

4. Discussion

An intriguing pattern is revealed by the temporal analysis. The decline to 34 cases in 2022 may be related to temporary socioeconomic stabilization; however, direct causal relationships could not be confirmed due to the retrospective nature of the study [19,20].
Due to the pandemic's aftereffects, this time was also marked by local and worldwide disruptions in agricultural supply chains and changes in the market availability of chemical imports [21].
But the ensuing, steady increase over the following three years—which culminated in the greatest mortality rate in 2025 (58 cases, 23.2%)—presents a very alarming pattern. This consistent rise indicates that vulnerable groups in Iraq are becoming more dependent on zinc phosphide and aluminum phosphide as readily available and inexpensive agents for self-poisoning (suicide). This is consistent with more general epidemiological data from the World Health Organization (WHO) and regional toxicology studies that show a direct correlation between higher rates of fatal intentional self-poisoning in developing and middle-income countries and the unrestricted over-the-counter availability of highly hazardous pesticides (HHPs) [22], Similar rising patterns have been documented in Iran, where forensic data showed a significant increase in mortality linked to aluminum phosphide from 214 cases in 2008 to 463 cases in 2011, underscoring the ongoing public health impact of phosphide poisoning [23].

Similar findings have been documented in India, where aluminum phosphide is still one of the most common agricultural toxins and is linked to remarkably high death rates, especially in rural areas [24].

5. Study Limitations

Although this work offers important insights into the patterns of zinc phosphide and aluminum phosphide mortality in Iraq, it is important to recognize a few limitations:
1. Data Disaggregation: Only the total cumulative mortality cases across all Iraqi governorates were represented by the data that was available. It was difficult to pinpoint geographic hotspots or regional differences in poisoning cases due to the absence of comprehensive breakdowns by governorate.
2. Demographic Information: Specific demographic factors, including age category, sex distribution, and the kind of exposure (intentional/suicidal vs. accidental), were not accessible due to data limitations. This limited a more thorough epidemiological examination of the most vulnerable target population.
3. Underreporting and Misclassification: It's possible that the recorded numbers understate the true public health burden. Certain instances may have died before they reached medical facilities or may have been incorrectly classified as a result of delayed toxicological screening, particularly in isolated or rural settings.

6. In conclusion

Over a five-year period (2021–2025), this study effectively assessed the historical trend of mortality cases linked to Zinc Phosphide Aluminum Phosphide poisoning in Iraq, covering a total of 250 documented deaths. The results point to an important and concerning public health trend. The mortality rate saw a sharp and steady increase through 2023 and 2024, peaking in 2025 after a brief and transient fall in 2022. This steady increase highlights the compound's ongoing deadliness and increasing threat to the Iraqi community.
The results of this study make it abundantly evident that there is a serious risk associated with the existing availability and uncontrolled over-the-counter sale of zinc phosphide and aluminum phosphide. The fatality rates are predicted to stay high in the absence of prompt, stringent regulatory actions on the sale, distribution, and storage of this extremely toxic rodenticide, underscoring the critical need for comprehensive national preventive policies and increased public awareness.

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8. References

1- Juárez-Martínez A, Madrigal-Anaya JDC, Rodríguez-Torres YP, Dorado-García R, Montes-Ventura DM, Jiménez-Ruiz A. Zinc Phosphide Poisoning: From A to Z. Toxics. 2023 Jun 25;11(7):555. doi: 10.3390/toxics11070555. PMID: 37505522; PMCID: PMC10386637.
2- Doğan E, Güzel A, Ciftçi T, Aycan I, Celik F, Cetin B, Kavak GÖ. Zinc phosphide poisoning. Case Rep Crit Care. 2014;2014:589712. doi: 10.1155/2014/589712. Epub 2014 Jun 30. PMID: 25101186; PMCID: PMC4101206.
3- Hamade H, Sahin A, Sukhn C, El Tawil C, Rizk J, Kazzi Z, El Zahran T. Human Zinc Phosphide Exposure in Lebanon: A Case Report and Review of the Literature. Clin Pract Cases Emerg Med. 2021 Feb;5(1):50-57. doi: 10.5811/cpcem.2020.10.47397. PMID: 33560952; PMCID: PMC7872605.
4- Mohammadinejad, A., Rizi, K. S., Oskuee, R. K., Aryan, E., Meshkat, Z., Ulianas, A., & Rezayi, M. (2022). Development of detection methods for the diagnosis and analysis of highly toxic metal phosphides: a comprehensive and critical review. Biotechnology and Applied Biochemistry, 69(3), 1121-1147.
5- Tauer, D., & Brutlag, A. (2025). Phosphide (zinc, magnesium, aluminum) poisoning in animals. In Merck Veterinary Manual. Merck & Co., Inc.
6- Patoa, A., & Das, M. P. (2024). Zinc phosphide poisoning presenting with multiorgan dysfunction syndrome: Case series. International Journal of Pharmaceutical and Clinical Research, 16(12), 2402–2407.
7- ZINC PHOSPHIDE - National Library of Medicine HSDB Database [Internet]. Toxnet.nlm.nih.gov. 2017 [cited 24 April 2017]. Available from: https://toxnet.nlm.nih.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+1059
8- Karakaya, S. Ç., & Yavuz, C. I. (2025). Aluminum phosphide: Toxicological profiles, health risks, environmental impact, and management protocols: A review. Turkish Journal of Emergency Medicine, 25(3), 178-190.
9- Arroyo-Arcos CR, et al. Zinc phosphide Poisoning :from A to Z . Toxics. 2023;11(7):555. Doi: 10.3390/toxics11070555
10- Trakulsrichai S, et al. Clinical characteristics of zinc phosphide poisoning in Thailand. Ther Clin Risk Manag. 2017;13:335-340. doi:10.2147/TCRM.S129610
11- Musshoff, F., et al. (2021). A rapid and automated headspace gas chromatography–mass spectrometry (HS-GC-MS) method for the determination of phosphine in post-mortem tissues. Forensic Science International, 321, 110-117.
12- Proudfoot, A. T. (2009). Aluminium and zinc phosphide poisoning. Clinical toxicology, 47(2), 89-100.
13- Bilics, G., Héger, J., Pozsgai, É. et al. Successful management of zinc phosphide poisoning—a Hungarian case. Int J Emerg Med 13, 48 (2020). https://doi.org/10.1186/s12245-020-00307-
14- Marashi, S. M., Majidi, M., Raji Asadabadi, H., & Nasri Nasrabadi, Z. (2013). A common misconception in the management of aluminium phosphide poisoning. Arhiv za higijenu rada i toksikologiju, 64(3), 475-476.
15- Maedie, F. H., Alhaddad, H., & Hussain, S. A. (2015). Evaluation of poisoning cases in the Poisoning Consultation Center and Forensic Medicine Institute within Baghdad area. Iraqi Journal of Pharmaceutical Sciences, 24(2), 63–69.
16- Mohammadi, A. B., Nahandi, M. Z., & Solhi, H. (2013). Utility of silver nitrate test for post-mortem diagnosis of aluminum phosphide poisoning. Iranian Journal of Toxicology Volume, 7(20).
17- Feigl, F., & Anger, V. (2016). Spot Tests in Inorganic Analysis (6th ed.). Elsevier Science. Chapter 4: Identification of Volatile Hydrides and Non-Metals, pp. 312-318.
18- Byard, R. W. (2018). Pekka Saukko, Bernard Knight: Knight's forensic pathology 4th ed. New York. CRC press, Taylor and Francis Group, 2016.
19- Al-Samarrai, A. M., & Al-Anbaki, N. A. (2021). Evaluative study on the regulatory enforcement and market availability of hazardous chemical pesticides in Iraq. Iraqi Journal of Agricultural Sciences, 52(4), 912-921.
20- Al-Barazanchi, M. A., & Jassim, M. H. (2023). Epidemiological trends and mortality outcomes of acute chemical rodenticide poisonings in middle Euphrates region, Iraq. Journal of Forensic and Legal Medicine, 95, 1024-1031.

21- Martin, D., et al. (2022). Impact of COVID-19 on Small- and Medium-Sized Enterprises in Iraq. Economic Research Forum (ERF).
22- Yaseen, T., et al. (2022). High Hazard Pesticides (HHPs) in Near East and North Africa (NENA): Constraints and recommendations to mitigate the risk. ResearchGate / FAO.
23- Bagherian F, Kalani N, Rahmanian F, et al. Aluminum Phosphide Poisoning Mortality Rate in Iran; a Systematic Review and Meta-Analysis. Arch Acad Emerg Med. 2021;9(1):e66.
24- Sharma, S., Kumar, A., Singh, R., & Gupta, P. (2025). Meta-analysis of mortality burden due to aluminum phosphide poisoning in India: A call for strong policy and decision making. Dialogues in Health, 5, 100247. https://doi.org/10.1016/j.dialog.2025.100247