International Journal of Advanced Research in Medicinal Chemistry
Volume 2, Issue 1 - 2020, Pg. No. 20-27
Peer Reviewed Journal

Review Article

Barium Poisoning with Analytical Aspects and its Management

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I N F O

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How to cite this article:
Krishna S, Jaiswal AK, Sujata et al. Barium Poisoning with Analytical Aspects and its Management. *Int J Adv Res Med Chem* 2020; 2(1): 20-27.

Date of Submission: 2020-06-01
Date of Acceptance: 2020-06-16

A B S T R A C T

Barium is a non-essential nutrient to terrestrial organisms and reported to be toxic at elevated concentrations. Barium is a heavy divalent alkaline earth metal. It is denoted by the symbol Ba and has an atomic number 56. Barium occurs in nature as baryte ore (Barium Sulphate, $BaSO_4$) and witherite ore (Barium Carbonate, $BaCO_3$). Barium is used in various industrial processes. The common-mode is accidental ingestion and the common compound is barium carbonate. Barium carbonate is a highly toxic substance used in the past as Rodenticides. The insoluble form of barium, such as Barium Sulphate, commonly used in radiographic procedures is harmless whereas soluble salts of barium such as barium carbonate are highly toxic. Weakness, paralysis, and hypokalemia being the characteristics signs of the barium poisoning. The clinical features of barium poisoning along with the appropriate diagnosis has been discussed in this paper. The analytical techniques such as Voltammetry, AAS, ICP-OES, NAA, UV-Vis Spectrophotometry can be routinely used to analyze biological and non-biological samples from poisoning as well as overdose cases. This paper can assist officials, toxicologist, physicians and researchers, understand barium poisoning and its management in a much simpler way.

Keywords: Barium Poisoning, Hypokalemia, Sodium Potassium ATPase Enzyme, AAS etc.

Introduction

Barium is named after the Greek word 'Barys' meaning 'heavy' and is a relatively dense and reactive earth metal. The element is chemically represented by the symbol 'Ba' with atomic number '56' with atomic weight 137.4 and a melting point of 1000K (1). It is a divalent cation in its compounds. Physically Barium metal has a soft, silvery-white appearance, with a slight golden shade when ultrapure. On exposure to air, the silvery-white appearance rapidly oxidizes to the dark grey oxide layer. Like the other members of the group, barium reacts violently with water to produce hydrogen gas, so it is normally stored in kerosene, petroleum, mineral oil, or in an argon rich atmosphere to prevent reaction with oxygen and moisture in the air. Barium, owing to its high reactivity does not occur free in nature rather it occurs mostly as Sulphate (baryte) and Carbonate (witherite) ores and other natural minerals (2). It is the fourteenth most abundant element in the earth's crust, with its abundance estimated to be 0.034% (3).

In the early 1600s, Vincenzo Casciarolo, an alchemist, of

Bologna, Italy, found some unusual pebbles near volcanic rocks in Italy which if heated to redness during the day, would shine during the night for years. He named the pebble as 'Bologna stone'. When these Bologna stones, as it became known, was investigated by Carl Scheele in 1774, he realized that it was the sulfate of an unknown element, which were later identified to be mineral Barite (Barium Sulfate, $BaSO_4$). Meanwhile, a mineralogist, Dr. William Withering, had found another curiously heavy mineral in a lead mine in Cumberland which was not a lead ore. He named it 'Witherite'; which was later identified to be Barium Carbonate, $BaCO_3$. Neither the sulfate nor the carbonate yielded up the pure metal itself using the conventional process of smelting with carbon (4). However, Sir Humphry Davy, an English Chemist at the Royal Institution in London in 1808isolatedthe pure metal by doing electrolysis of molten barium salts such as Barium Hydroxide ($Ba(OH)_2$) (5). But due to its reactivity to air, barium cannot be found in its pure form but rather extracted from its mineral, Barite.

Two forms of barium occur naturally in the environment, barium sulphate (Baryte) and barium carbonate (Witherite) and often in underground ore deposits. These salts can be commonly found as white orthorhombic crystals or powder. These forms of barium are not very soluble in water 0.020g/litre (at 20°C) for barium carbonate and 0.001 15g/litre (at 0°C) for barium sulphate. The presence of other salts of barium in water and soil is chiefly attributed to dumping and contamination by waste sites (6,7). Other barium salts like barium chloride, barium nitrate, and barium hydroxide are manufactured from barium sulphate.

Barium can be found in trace amounts in both igneous and sedimentary rocks. The water-soluble Barium salts like acetate, carbonate, chloride, fluoride, hydroxide, nitrate, and sulfide are highly toxic, whereas the insoluble salts like barium sulphate are considered comparatively nontoxic because it is poorly absorbed through oral route (8). Very uncommon, but Barium poisoning results from accidental contamination of food & water sources, suicidal ingestion, or occupational inhalation exposure (9). The ingestion of soluble barium salts can produce effects such as hypokalemic paralysis leading to respiratory and cardiac arrest (10). Barium isn't carcinogenic and does not bioaccumulate, but on inhalation of insoluble compounds, it can accumulate in the lungs to cause a benign condition called 'Baritosis'. It is widely known that barium is a 'Muscle Poison' and effects on skeletal and smooth muscle and Myocardial excitability and may cause significant Hypokalemia, Malignant arrhythmia, and Secondary respiratory paralysis, in serious consequences.

Major Uses of Barium

- Barium is used in oil and gas industries to manufacture drilling muds.
- Barium sulphate is used in making soaps, bricks, paints, glass, tiles, rubber (11).
- Barium compounds such as Barium Carbonate, Barium Hydroxide, and Barium Chloride are used in making ceramics, insecticides, and rat poison.
- Barium has its uses in plastic, rubber, electronics, textiles, sugar-refining, seal-nuts, and paper manufacturing.
- Barium has its presence in many products, like depilatories and fireworks, ceramic grazes (12).
- Barium nitrate and chlorate are added to firecrackers which emit green colour on ignition.
- The modern use of barium is in radiodiagnosis. It is used by doctors to perform medical tests and X-ray photographs of the stomach and intestine.
- Barium can be used for diagnosis of cancer, ulcers, Crohn's disease, irritable bowel syndrome, and treat dropsy (edema).
- Barium styphnate has been used in detonators.

Major Routes of Exposure To Barium

- People who work in industries that manufacture barium compounds or use them are at maximum risk of exposure.
- Barium (barium chloride or barium hydroxide) can be introduced in the body through breathing its dust or by getting them in contact with the skin.
- Barium carbonate would be harmful if eaten accidentally as it will dissolve in acids within the stomach.
- Exposure to barium near dangerous waste sites.
- Exposure of barium can occur by using water, soil or plant polluted with it, usually near the waste sites.

Pharmacokinetics of Barium

Barium is not considered to be an essential element for human nutrition. An average adult contains about 22 mg of barium salts in his body which are introduced naturally by foods and drinks like carrots, onions, beans, and cereal grains (13). Low levels of barium up to serve no biological role and are not harmful in any way. However, large quantities of salts up to can be toxic and even cause death. If someone has been exposed to barium or its salts several factors will determine its toxicity. These factors include the dose, duration, route of exposure, age, sex, genetics, lifestyle, and state of health. Barium carbonate can be harmful if ingested through the oral route as it can be dissolved by acid in the stomach, unlike barium sulphate which his insoluble in the stomach. Major routes of administration of barium and its salts can be breathing, eating, drinking, or application across mucous membranes. The barium compound most commonly used in toxicology studies is barium chloride (water solubility at 375 g/litre at 20°C).

Absorption

Soluble barium salts are absorbed rapidly (5–30%) into the

blood through the digestive mucosa. The absorption rate barium compounds are barium chloride > barium sulfate > barium carbonate (14). Large doses of barium sulfate do not increase the uptakes of this salt because it has low solubility. Oral or inhalant exposure can create systemic toxic effects. Barium sulfate is commonly used as a radiopaque as a contrast compound to visualize the digestive tract for diagnosis of cancer, ulcers, Crohn's disease, irritable bowel syndrome, and dropsy (edema) (15). Barium sulfate is often considered to be otherwise very poorly absorbed in the systemic circulation.

Distribution

A rapid distribution phase is followed by a slow decrease in concentration. The highest concentrations of barium in humans are found in the bones and teeth. Approximately 91% of the total body burden is in the areas of active bone growth (8). A small amount of barium is found in soft tissues i.e., aorta, brain, heart, kidney, spleen, pancreases, lung, etc. A high concentration of barium is sometimes found in the eye, primarily in the pigmented structures. Additionally, quantification of levels of barium in skeleton muscles and kidneys were reported to be higher than whole blood suggesting the ability of soft tissues to concentrate the metal more than blood.

Bauer et al., 1957 in his study reported for the first time that barium accretion rates for the whole skeleton, tibia, and incisors were 1.4–2.4 times greater than accretion rates for calcium suggesting that deposition rates of barium were on a faster rate than calcium (4). In bones, the half-life of barium is found to be up to 50 days.

Metabolism

The mechanisms of barium metabolism are not well characterized. However, the general patterns of uptake are similar to the uptake of calcium and strontium in the body (16).

Excretion and Elimination

Barium is excreted majorly in the urine and faces following oral, inhalation, parental exposure. The faeces are a major route for the excretion with 90% excretion through this route and 10–28% reported to be excreted in the urine. Barium can be irreversibly stored in the bone.

Systemic Effects on the Body

The quantity of barium which is detected in water and food is generally not that much high to become a health concern. The maximum contaminant level of Ba in drinking water has been set at 2 mg/Lby the USEPA (13). People who work in barium industries are at greatest risk to barium exposure. Most of the risk to the health that they can face is inhaling the air contaminated with barium carbonate or barium sulfate. Exposure to barium can be designated as acute (<14days), intermediate (15–365days), or chronic (more than 1year). The health effect depends upon the solubility of compounds in water. In large amounts of water-soluble barium may cause paralysis but in some cases death and small amounts of water-soluble barium can cause breathing difficulty, high blood pressure, heart rhythm, change in nerve reflexes, muscle weakness, swelling in brain, kidney, liver and heart damage (16). No case of barium causing cancer has been seen till date in humans, and also no proof of barium causing infertility or birth defect has been found so far.

In Case of Acute Exposure

Most human exposure to toxic barium salts occurs via ingestion or inhalation. Diagnostic radiographic examination in gastrointestinal mucosa can be performed by comparing it with radiopaque barium sulfate, which is used worldwide because of its very low water solubility and lipid solubility. Absorption of barium sulfate does not generally occur. Suicidal or accidental poisoning with barium containing household or medical products includes nitrate, sulfide, carbonate, chloride of barium.

Gastrointestinal

Gastrointestinal tract effects such as abdominal cramps, gastric pain, diarrhea, nausea, vomiting are common symptoms of barium poisoning in humans exposed to a large amount of barium and barium compound by ingestion, inhalation exposure.

Cardiovascular

Cardiovascular abnormalities such as changes in heart rhythm and increased or decreased blood pressure have been observed after exposure to large amounts of barium and its compound which are soluble by ingestion or inhalation. The cardiovascular effects could be hypokalemia (a reduction in blood k^+ levels)(17)which may lead to significant hypokalemia and have serious consequences. This paper reports a case of unprecedented barium intoxication in which the patient, who suffered from depression, swallowed at least 3.0 g barium chloride to commit suicide. On admission, the patient presented with nausea, vomiting, stomach burning feeling, dizziness, and weakness. Emergency biochemical testing showed that the patient was suffering from severe hypokalemia (K\n +\n 1.7 mmol/L.

Musculoskeletal

Musculoskeletal effects like muscle weakness, numbness, or paralysis may occur due to exposure to a high level of barium or its soluble compounds either by inhalation or by ingestion (16). These effects are somewhat similar to that of hypokalemia.

Neurological

Tremors, seizures, and mydriasis may occur severe poisoning.

In Case of Chronic Exposure

High chronic exposure to barium or its soluble compound can cause extreme renal effects. When inhaled action of barium sulfate or baryte causes a pulmonary reaction involving mobilization of polymorphone nuclear leukocytes, macrophages and radiographic changes are seen in the lungs (baritosis). These effects can be much more serious to children due to their potential for a life span longer than adults.

Carcinogenicity

The US EPA has concluded that barium does not cause cancer to humans by oral exposure and after inhalation exposure, its carcinogenic potential could not be determined.

Reproductive and Developmental effects

The potential of barium induced reproduction or developmental effect has not been assessed in humans.

Mechanisms of Toxicity/Action

The specific toxic mechanism of barium is a blockade of passive transmembrane Potassium (K+) conductance in excitable cells by the barium ions. The characteristic systemic effects of barium poisoning are violent contraction of smooth, striated and cardiac muscles.

Barium induces hypokalemia by following two mechanisms

- It competitively blocks potassium channels. It is associated with sodium-potassium pump (Na^+-K^+ - ATP enzyme).
- The Na^+-K^+-ATP enzyme is involved in transmembrane, transport of K^+ against concentration in intake within the cell. After a barium chloride intake, Ba^+ activity of Na^+ - K^+ - ATP enzyme can be increased by Ba^+ and it can block potassium (K^+) channel to introduce in passive K^+ diffusion, which is leading to a continued decreased in extracellular potassium and leads to:
- Depolarization and paralysis.
- It also increased vascular resistance, reduced blood flow and is the likely mechanisms for hypertension and lactic acidosis.

Hypokalemia is a major cause of paralysis and muscle weakness is related to barium concentration instead of potassium concentration.

Onset and Duration of Action

Symptoms of barium poisoning are evident mostly after 12 hours of administration through the oral route. The quantity of barium that may cause poisoning depends on the age group, duration, and amount of exposure. Usually in acute barium poisoning conditions can cause ventricular dysrhythmias. Symptoms of barium poisoning have been observed in the kidney of several adult cases.

Fatal Dose and Fatal Period

Ingestion of 3 gm results in moderate symptoms. Ingestion of more than 3.8 gm causes severe toxicity and leads to morbidity and mortality within 12 hours of ingestion (18–20).

Normal/Reference values

The reference and normal dose value depend upon sub-chronic and chronic. In case of sub-chronic oral reference value 0.07 mg/kg/day and in case of chronic oral reference value 1- 0.07 mg/kg/day (13, 21). These reference values are based upon a weight of evidence approach using sub-chronic to chronic human drinking water.

Table 1.Normal Reference Value of Ba in Biological Material

Matrixes	Normal Level	Toxic Level
Blood	7.15 ± 2.05 µg/L	150 ± 12 µg/L
Serum	12.07 ± 1.70 µg/L	20.45 ± 3.15 µg/L
Urine	12.07 ± 0.25 µg/L	10.50 ± 5.20 µg/L

Management/Treatment

Household Remedies

Thorough washing should be done if skin is contaminated with barium carbonate, barium chloride, or barium nitrate. Mild detergent or soap should be used while washing if the contaminant is barium carbonate. If route is oral, then, water can be given as it can dilute the contaminant.

Pre- hospital management

Hot Zone

Proper training and appropriate attire are necessary for rescuers who are entering the hot zone. A properly equipped response organization can be called upon if proper equipment or trained rescuers are not available.

Removal of Victim

Those victims who can walk can be mobilized from hot zone to decontamination zone. backboards, gurneys can be utilized to carry those victims who are unable to walk; carefully carry or drag victims to safety if needed.

Decontamination Zone

Victims can be transferred immediately to the support zone that have only inhalational exposure of barium and have no skin or eye irritation. Decontamination of other patients can be as described below:

ABC Reminders

The airway should be quickly established; ensure breathing

and circulation. If trauma is suspected, stabilize the cervical spine with a collar and a backboard. Administer supplemental oxygen as required. Bag-valve-mask device assisted ventilation can be used if needed.

Basic Decontamination

- With assistance, self-decontamination can be tried. Remove clothing which is contaminated and all personal belongings packing them into a double bag.
- The exposed skin and hair have to be washed with copious amounts of water.
- If eyes have irritation, flush with tepid water for 20 min. Contact lenses should be removed without causing additional trauma to the eyes.
- Neutralization should not be attempted as it causes an exothermic reaction. Do not induce emesis in cases of ingestion. Soluble sulfates, if administered orally, will precipitate an insoluble form of barium (barium sulfate) and may limit the absorption of barium. In victims who are conscious and able to swallow, 5 mL/kg up to 200 mL of water for dilution can be administered. Magnesium sulfate (250 mg/kg up to 30 g maximum single dose) can be given orally for reducing the absorption of barium from the gastrointestinal tract. Decontamination can be delayed if the victim is symptomatic. Wait until other emergency measures have been instituted.

Hospital Management

Gosselin et al. describe the oral lethal dose in humans as1–15 g (22). A research chemist attempted suicide by ingesting a teaspoon (approximately 13 g) of $BaCl_2$. He was rushed to a hospital and survived after treatment with $MgSO_4$ and KCl. Barium has no antidote. Treatment consists of respiratory and cardiovascular support and regulation of serum potassium levels. The speed of potassium supplementation can be slowed after the serum potassium level increases to 3.0 mmol/L in the initial 3 hours. The serum potassium level should be monitored every two hours by performing blood chemistry testing. Changes in the ECG and urine volume should be taken care of to prevent high potassium levels. Aerosolized bronchodilators such as albuterol can be used in patients who have bronchospasm. Consider that barium poisoning may include tachycardia and hypertension, in which case the use of bronchodilators that are known as cardiac sensitizing agents may pose an enhanced risk. Hypotension, seizures, ventricular arrhythmias should be treated conventionally. In the first 24 hours post-exposure, Serum potassium, CBC, glucose, and electrolyte should be monitored. Chest radiography, pulse oximetry (or ABG measurements), peak-flow and/or spirometry may be required by patients who have respiratory complaints (17,23)which may lead to significant hypokalemia and have serious consequences. This paper reports a case of unprecedented barium intoxication in which the patient, who suffered from depression, swallowed at least 3.0 g barium chloride to commit suicide. On admission, the patient presented with nausea, vomiting, stomach burning feeling, dizziness, and weakness. Emergency biochemical testing showed that the patient was suffering from severe hypokalemia (K\n +\n 1.7 mmol/L.

Clinical Appearance/ Symptoms in Barium Poisoning

Clinical appearances/ symptoms in case of barium poisoning depend upon different forms of barium and amount of doses taken.

In case of acute toxicity

- Gastrointestinal effects.
- Nausea, abdominal pain, vomiting, diarrhea occur within 60 minutes of ingestion.
- Esophagitis.
- Hemorrhagic gastritis.

In case of chronic toxicity

Signs and symptoms associated with hypokalemia.

- Lactic acidosis.
- Ventricular dysrhythmia.
- Hypophosphatemia.
- Respiratory failure.
- Intense flaccid muscle weakness
- Rhabdomyolysis
- Basal ganglia manifestations.

Diagnostic Investigation in Case of Barium Poisoning

Barium can be diagnosed via many techniques such as:

- ICP-MS which can quantitate barium present in urine and blood.
- Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS) can be useful to identify barium level in biological materials.
- The acute exposures, serum electrolytes of patients should be measured hourly while performing continuous ECG monitoring.
- Generally, barium levels more than 0.2 mg/l values are abnormal.
- Barium might be shown by plain abdominal radiograph but the specificity and the sensitivity of radiography have not checked for barium poisoning.
- Toxicological etiologies for flaccid paralysis like hypermagnesemia, botulisms and the neuromuscular blockers administration also should be considered.
- CBC, glucose, and electrolyte determinations, particularly serum potassium levels for the first 24 hours post exposure.
- Patients who have respiratory complaints may require

pulse oximetry, chest radiography, and peak-flow and/or spirometry.

Chemical Tests for Barium Poisoning

Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma- Atomic Emission Spectrometry (ICP-AES), and ICP-Mass Spectrophotometry (ICP-MS) is the most commonly used analytical methods for measuring low levels of barium and its compounds in the air, water, geological and various other non-biological and biological materials (24). The other analytical techniques include the less sensitive methods of X-ray Fluorescence Spectroscopy and Neutron Activation Analysis and the less commonly used methods of Scintillation Spectroscopy, and Spectrography. In general, analytical procedures measure total barium ion present and do not allow for speciation of barium compounds.

Qualitative Chemical Analysis

Potassium Dichromate Test(25)

Residue obtained by dry digestion is dissolved in 2 ml of conc. Hydrochloric acid, boiled and filtered.

The acidified test solution is boiled with a few drops of concentrated nitric acid. It is made alkaline by adding ammonium chloride and ammonium hydroxide solutions.

Filter it, if required and add an excess of ammonium carbonate appearance of white ppt indicates presence of Barium.

- Precipitate is dissolved in acetic acid and is divided into 3 portions.
- To '1' portion, add sulfuric acid it gives white ppt, which is insoluble in Nitric acid& Hydrochloric acid.
- To '2' portion, add few drops of potassium chromate solution, which gives yellow precipitate of barium chromate.
- The third portion is evaporated to dryness and the residue is dissolved in water. A drop of it is spotted on the filter paper and dried. A drop of sodium rhodizonate is added on the spot. Brown or brownish-red color spot on paper is obtained, which confirms the presence of barium.

Flame Test

- Dry residue obtained after dry digestion is coated on a platinum wire and heated on a flame.
- A persistent apple green flame is observed confirmatory for presence of barium.

Quantitative Analysis

UV-Vis Spectroscopy method

Barium can be detected quantitatively by using UV-Vis spectroscopy (26,27). Barium can form a complex organic compound which will give absorbance at a specified wavelength.

Atomic Absorption Spectrophotometric method

It is a good technique to determine barium in the biological method. Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS) can be useful to quantify barium. The absorption of the standard solution is plotted against the concentration. The concentration of barium is obtained from the calibration curve. Flame AAS and graphite furnace AAS determine levels of barium in water and wastewater from 200 µg/L (28). Plamboeck et al. (2003) have developed a sensitive method for determination of barium in water, bone, and liver-based on Flow Injection Analysis and Flame Atomic Emission Spectrometry (FIA-FAES) with a detection limit of 0.8µg/L (21).

Ion chromatography

Ion chromatography is another important technique for the quantitative estimation of barium in biological material such as tissue, hair, urine, blood and gastrointestinal tract (29).

Voltammetry/Polarography method

This method is another technique for the quantitative analysis of barium in any biological material. The instrumentation presents a reliable, cost-effective, rapid, and in-filed voltammetric determination of barium. Glassy carbon (GCE) has been the most commonly employed electrode in combination with a linear sweep or differential pulse mode for potential delivery (30–33).

ICP-AES/ICP-MS method

Inductively Coupled Plasma-Atomic Emission Spectroscopy and Inductively Coupled Plasma - Mass Spectroscopy is an analytical technique that uses the emission spectra/mass spectra to quantify the trace metal barium. It is a screening technique in acute poisoning. This technique is the latest advanced technique for the determination of heavy metals in micrograms, nanograms, and picogram levels. This is an instrument by which multiple elements can be determined simultaneously. By use of ICP-MS, detection limits have been reported for analysis of barium in the urine of 1µg/L and water of 0.001µg/L (2,34–36).

Neutron Activation Test (NAA)

This technique is used for the low level of barium in blood, in explosives and gunshot residue (37–39). The interaction of the nucleus of the barium atom with irradiation neutrons results in the emission of x-rays forms the basis of this technique. The advantages of NAA technique includes minimum preparation of the sample and the fact that destruction of the sample is not needed to conduct the analysis.

Conclusion

Barium is a naturally occurring element, non-essential for human nutrition. The toxicity of its compounds

depends on their salt form, their solubility, and mode of administration. The free ion can be readily absorbed from the lung or gastrointestinal tract, but barium sulphate will comparatively remain unabsorbed. Barium poisoning is easy to be misdiagnosed and this has a direct effect on treatment methodologies. Therefore, timely and accurate diagnosis is crucial for the treatment of acute barium poisoning. If poisoning occurs, wash hands, affected skin, and drink plenty of water and electrolytes. The victim should be promptly monitored as dangerous hypokalemia can develop which can even cause death. Radiographic methods that use barium as contrast can also rarely lead to complications. Ingestion of certain forms of barium (e.g., barium carbonate or barium fluoride) in toxic amounts can lead to gastrointestinal signs and symptoms (e.g., vomiting, abdominal pain, and watery diarrhea). Within 1–4 hours of ingestion, profound hypokalemia, and generalized muscle weakness can develop which may progress to paralysis of the limbs and respiratory muscles. Severe hypokalemia induced by barium toxicity can cause ventricular dysrhythmias. Barium sulfate is not absorbed when taken by mouth and therefore is commonly used as a contrast agent for radiographic procedures.

At high concentrations, barium causes vasoconstriction by its direct stimulation of the arterial muscle, peristalsis as a result of the violent stimulation of smooth muscles and convulsions and paralysis following stimulation of the central nervous system. Depending on the dose and solubility of the barium salt, death may occur in a few hours or a few days. The acute toxic oral dose is between 3 and 4 g. Repeated exposures to barium chloride in table salt are believed to have caused recurrent outbreaks of “pa-ping” disease (a transient paralysis resembling familial periodic paralysis) in China, but recovery was usually rapid. Barium induces hypokalemia in two ways one is by competitively blocks potassium channels, which is associated with a potassium pump and the other is the sodium-potassium-ATP enzyme involved in trans-membrane. Barium can increase the activity of the ATPase enzyme. It can direct effect on either skeletal muscle or neuromuscular transmission.

Traditional methods of chemical analysis although require time-consuming sample preparation, are easy to do in any lab setup. The results of chemical analysis are qualitative in form of colour changes of the products. Barium being an elemental heavy metal can be easily analyzed using sophisticated instruments like AAS, ICP-OES, NAA, Polarography & Voltammetry, Ion Chromatography. The sensitivity of these techniques can be achieved as low as 0.11mg/ml, well below any limit recommended by environmental guidelines (36). The technique requires less sample preparation and can be easily prepared otherwise by acid digestion or microwave digestion.

This mini-review can assist officials, toxicologists, physicians and researchers understand barium poisoning and its management in a much simpler way. Forensic pathologists, physicians should be aware of the clinical presentations of barium compound poisoning and especially look for any evidence of hypokalemia (40). Other health conditions, for example, botulism and Guillain-Barre´ syndrome, which present with very similar signs and symptoms as barium intoxication must be excluded using analytical techniques (41).

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