Bio. Res. Today 2023, 5(10):770-773

Biotica Research Today

e-ISSN: 2582-6654

October, 2023

Article ID: RT1479 Popular Article

Arsenic Menace: Animal Health Hazard through Nutritional Chain

D. Mondal

Eastern Regional Station, Indian Veterinary Research Institute, 37 Belgachhia Road, Kolkata, West Bengal (700 037), India

Open Access

Corresponding Author

D. Mondal

: dayamoy21@gmail.com

Conflict of interests: The author has declared that no conflict of interest exists.

How to cite this article?

Mondal, 2023. Arsenic Menace: Animal Health Hazard through Nutritional Chain. *Biotica Research Today* 5(10), 770-773.

Abstract

Arsenic is a toxic metalloid has several ores mixed in pebbles and soil. It affects animals and plant health worldwide. The toxicity generally occurs through food chain. The worse conditions of arsenicosis are found in countries like India, Bangladesh, Argentina, Mexico and other nations. Twenty states of India are affected with arsenic toxicity where West Bengal and Bihar are worse. Mobilization of arsenic from ores to water comes though seepage water into the aquifers. Animals and humans are affected through food chain. Animals affected with arsenic toxicity show mild clinical signs unlike humans; some clinical conditions occur are hyperkeratosis, chronic bronchitis, diarrhea, oncogenic growth, haematological, diabetes, cardiac dysfunctions, reproductive and neurolocomotor disorders. Diagnosis of the condition can be done with concentration of arsenic in water and soil, clinical signs of animals and estimation of arsenic level in water, soil and animals tissues. Mitigation of arsenicosis can be with drugs, use of arsenic free water, food and feed.

Keywords: Arsenicosis, Clinical signs, Diagnosis, Food chain

Introduction

Arsenic is an element colored with grey steel and yellow tinged. It's position in the periodic table in Group 15. The atomic weight of Arsenic is 74.92, atomic number 33, melting point 814 °C, boiling point 615 °C. It has more than 8 isotopes (65-78). The element is a toxic in its inorganic form while less toxic in organic form. The element can intoxicate animal and human through food chain, particularly seafood origin and arsenogenic plants and vegetables. This metalloid is used for different industry, agriculture and wood preservatives. The pollution can be from extraction of mines and minerals, glass manufacturing, pharmaceutical products and even semiconductor industries. Arsenic toxicity is worldwide in distribution. India and Bangladesh are the much victim with this toxic element. Other countries having this problem are Argentina, Cambodia, China, Chile, France, Hungary, Mexico, Myanmar, Nepal, Pakistan, Taiwan, Thailand, USA, Vietnam and others. The silent killer is due to its colorlessness, deodorant or tasteless which is why animals and humans take up the toxicity without knowing its presence in food and water. Almost all Indian States are affected by Arsenicosis, some of the most affected states are West Bengal, Andhra Pradesh, Assam, Bihar, Manipur, Uttar Pradesh, Jharkhand, Chhattisgarh, Delhi, Gujarat and Haryana.

Several states and districts of India are affected. Some of the states and its districts are affected (Table 1). The level of Arsenic content from 0.01 to 0.5 mg L^{-1} (10-50 ppm) of water is indication toxicity.

Transmission of Arsenic to Groundwater

In India, particularly Ganga-Brahmaputra basin, there are several aquifers which were filled up with mud, sand, pebbles, *etc*. since Holocene periods from the nearby hills like Himalaya, Bindhya hill, Rajmahal hill and Chhotanagpur plateau. These aquifers are fed with water from rivers, rain waters and other sources. From the hilly area small pebbles and sands contains different arsenic ores such as arsenopyrites (FeAsS), realgar (AsS), orpiment (As_2S_3), scorodite ($FeAsO_4 \cdot 2H_2O$), loellingite ($FeAs_2$), Enargite ($CuAsS_4$), *etc*. With the chemical reaction with organic matters, saline water, *etc*. for thousand years the ores decomposed and arsenic are released as arsenate and arsenide. The aquifers can travel slowly and its water contents may contain high amount of arsenic. The groundwater 'As' content may vary from 0.5 to 5000 ppb.

Article History

RECEIVED on 18th October 2023 RECEIVED in revised form 27th October 2023 ACCEPTED in final form 28th October 2023

Table 1: Districts of different states affected with arseniccosis in India

Name of State	No. of district	District affected
Andhra Pradesh	26	Chebralu, Guntur, Tugali and Atmakur
Assam	31	Golaghat, Jorhat, Lakhimpur, Naogaon, Nalbari, Shibsagar, Sonitpur
Bihar	38	Begusarai, Bhagalpur, Bhojpur, Buxar, Darvanga, Champaran, Gopalgunj, Katihar, Khagaria, Lakhisarai, Purnea, Mujafarpur, Saharsa, Samastipur, Baisali
Chhattisgarh	33	Rajnandgaon
Delhi	11	East and North East Delhi
Diu	3	Diu
Gujarat	33	Amreli, Ananda, Bharuch, Bhabnagar, Dahod, Gandhinagar, Mehsana, Patan, Rajkot, Surendranagar, Vadodora, Kacchh
Haryana	22	Bhiwani, Mahendragarh, Palwal, Rhotak, Sirsa, Panipat
Himachal Pradesh	12	Kanga
Jammu & Kashmir	22	Jammu, Kathua, Rajouri
Jharkhand	24	Sahebgunj
Karnataka	31	Raichur, Yadgir,
Madhya Pradesh	52	Betul, Burhanpur, Chhindwara, Dhare, Khandwa, Nimuch, Umaria
Odisha	30	Gujapati
Punjab	23	Faridkot, Gurdaspur, Sangrur, TaranTaran
Rajasthan	50	Ganganagar
Tamil Nadu	38	Koddalor, Dindigul, Nagpattanam, Perambur, R'puram, Turuneliveli, Tuticorin
Telangana	33	Nalgonda
Uttar Pradesh	75	Ajomgarh, Badaun, Baharaich, Basti, Deoria, Gorakhapur, Jhasi, Kausambi, Kushinagar, Pilibhit, Sajahanpur
West Bengal	23	Nadia, Bardhaman, Hoogly, Howrah, Coochbihar, Maldah, Mushidabad, North 24 Pargana, South 24 Pargana

(Source: Anonymous, 2022)

Source of Intoxication with Arsenic

Water Sources

Sources of arsenic poisoning are many. Animals and humans are affected by the consumption of contaminated water particularly groundwater, feed and fodder grown in the arsenic rich soil or crops cultivated with arsenic contaminated groundwater.

Industrial Sources

Industrial establishment like glass, pigments, mines, textiles industry, paper mill, metal adhesives, wood preservatives, gun and shell factory exits arsenic nearby the human and animal habitat and agricultural field where effluent and air contains more arsenicals such as Iron, Aluminum, Manganese, paints and air contaminants (Semiconductor, LED, Laser item factory).

Animal Food Sources

Animal feed is composed of many protein sources from sea fish, crab, shellfish, finfish, sea weeds, soya and oil cake produced in high arsenic-content soil.

Herbal Sources

Herbs contain high amounts of arsenic called hyper accumulator plants such as breaken fern, mastered (*Brescia* sp), lettuce, Collard greens, Kale, Aram (*Colossian* sp), kalmi sak (*Ipomeas rattans*), potato peel, tobacco, *etc*.

Vegetable Sources

Beets, turnips, carrots, radishes and potatoes are cheap source of Arsenic particularly grown on Arsenic rich soil and water (Mondal, 2023). Ground water particularly shallow water table water content in arsenic affected zone is highly contaminated with Arsenic. Human being may use filtrated water but animals use the arsenic contaminated water for drinking, bathing and other regular use. Human and animals like pigs, horses, sheep and cattle are susceptible but other animal species show little clinical signs except weakness, debilitated and dehydrated conditions.

Distribution of Arsenic in Different Districts Ground Water

In West Bengal, several district's ground water is contaminated with high level of arsenic, particularly south Bengal Eastern part parallel to Bhagirathi and Ganga river. The worse affected districts are Nadia, Murshidabad, Bardhaman, Malda and North 24 Pargana. Other districts like south 24 Pargana, Howrah, Hoogly, Kolkata, Coochbihar are also affected. Although ground water supply of Kolkata is from the deep well water is less contaminated. In West Bengal the top soil also contaminated with arsenic as most of the Alluvial area is cultivated with shallow ground water which is contaminated with arsenic level 19-24 mg kg^{-1} soil with depth of 5-10 cm particularly in Nadia, Maldah, Murshidabad and 24 Pargana (Shrivastava *et al.*, 2017). The level of arsenic in ground water varies in different districts, blocks, villages and even in different source of shallow wells. In West Bengal 34000 km^2 is affected with arsenic species of toxic material. The arsenic content in water varies from (0.20-3.7 mg L^{-1}) which is very toxic. Different districts of West Bengal, blocks and level of arsenic in water is given in the table 2.

Table 2: Distribution of arsenic in ground water in district and blocks of West Bengal

District	Total Block	Affected Block	'As' level (mg L^{-1})	People Affected %
Nadia	17	17	0.05-1.00	71.0
North 24 Pargana	22	19	0.06-1.28	42.4
South 24 Pargana	29	9	0.06-1.28	3.4
Maldah	15	7	0.60-1.28	20.2
Mursidabad	26	21	0.05-0.90	57.0
Bardhaman	31	5	0.10-0.50	5.5
Howrah	14	2	0.09	0.1
Hoogly	18	2	0.60	2.5
Coochbihar	12	1	0.01-0.05	0.1
Total	184	83	-	-
Area (km^2)	88,752	34,000	38%	-

(Source: Adhikary and Mondal, 2017)

Chronic Arsenicosis Causes Health Hazards and Animal Production

Acute arsenicosis may occur in animals with sudden ingestion of large amount of arsenicals from an accidental source that leads to serious health condition and death. In real condition arsenicosis is a chronic condition both in animals and human health. Inorganic arsenic is more toxic than organic arsenic. An element As is less absorbed through skin and GIT but compound (trivalent) is readily absorbed than elementary "As". Arsenic toxicity mechanisms with the binding of sulphidryl/thiol radicals of several enzymes (Sulphydryl oxidases, Glutathione peroxidase) perform the pyruvic oxidation pathway, cause defective oxidative phosphorilations. Arsenic being similar to phosphorus in the periodic table (15), it replace the phosphorus anion from phosphate in many biochemical reactions such as rapid hydrolysis ATP that impair mitochondrial respiration and cause cell death. It also damage phosphate bond inhibiting DNA ligation (DNA methylation and oxidative damage).

Animal Heal Hazards by Arsenicosis

In animals several conditions may occur due to chronic arsenicosis in sensitive species of animals.

Hyperkeratosis: Chronic exposure with arsenic ingestion through feed, water *etc.* can cause a change in skin and integument. In human cases the condition is widespread. Humans can suffer from hyperkeratosis and rain-drop hyper-pigmentation on the palm and sole. In animals, alopecia and rough skin with pustule formation are seen in sheep and goats (Keshavarzi *et al.*, 2015). Some animals showing hyperkeratosis suspected with arsenicosis (Figure 2), the same goat population having higher amount of arsenic in their hairs.

Chronic bronchitis, bronchiectasis and obstructive pulmonary diseases in human is common, the same also occurs in animals. The route of entry is mostly through GIT,

Figure 1: Hyperkeratosis in goats

Figure 2: Lameness/ locomotor disturbance on arsenicosis

so intestinal disease is prevalent in chronic arsenicosis being corrosive and caustic.

Diarrhoea: Chronic exposure causes irritation, abdominal pain, diarrhea, mucoid feces and dehydration in horses, sheep, cattle, pigs and birds. In the nervous system, it causes peripheral neuropathy, neuritis characterized by hyperesthesia weakness, locomotor dysfunction.

Cardiovascular disorders in animals were reported with clinical signs of cardiac dysfunction, myositic apoptosis and fibrosis.

Oncogenic development may occur in the integuments, bladder, lungs, liver and GIT. This is due to interference in the DNA repair process causing chromosomal aberrations. The cancerous growth may develop in different organs such as kidney, skin, bladder, heart, lung, liver, brains and many other parts.

Reproductive toxicity with chronic exposure causes malformation, death and growth retardation in lab animals. Spontaneous abortion and stillbirth may also happen in animals. Prolonged exposure of arsenical to animal causes health hazards, weakness and, even death, particularly in pigs, horses, sheep and, cattle.

Neulogical Disorders: Inorganic arsenic compound is much more toxic than organic in animals and human. Long term exposure with arsenic compound causes nervous systemic involvement. In animal it affects at the early life leads to later stage of live nervous disorders. Due to nervous neuronal changes some characteristic changes like encephalopathy, muscle weakness, cramping, delirium, lameness and

peripheral neuropathy (Figure 2). Experimental and accidental exposure with 3-nitro-4-hydroxyphenylarsonic acid can cause degeneration of spinal cord, optic nerve and peripheral nerves with clinical signs of tremors paraparesis, epigenetics, hipocampas, hypothalamus-pituitary-adrenal axis pathway in animals.

Haematology: Several haematological disorders can cause both acute and chronic arsenic toxicity. It may cause anaemia, leucocytopenia and thrombocytopenia. In West Bengal this arsenic toxicity related anaemia and related condition is not less.

Diabetes: Few researchers have reported that chronic low dose arsenic as well as massive environment pollution can induce diabetes in animals and humans.

Diagnostic Investigation

Arsenic toxicity is a very slow process of mineral toxicity in human and animals. Principally, the contamination of arsenic compound occurs through inhalation (fossil fuel burning, cotton gins, glass industry, metallurgical, paper, gun and shell factory), skin penetration (wood industry use of tricolor arsenate), ingestion (feed, fodder. Grass, water, *etc*.), Sea food (Sea fish, shellfish, finfish, Crabs, prawn), crop source (Soya, oil cake, breaken fern, mustard). Therefore, there is wide change of exposure with arsenic compound.

Primarily clinical cases of arsenicosis in animals is not much visible however prolong exposure causes weaken health status and history of the arsenic zone can be a diagnostic goal. Estimation of arsenic in different biological samples and water analysis can be done for confirmatory diagnosis. Animal tissue of liver, kidney, blood, stomach content, urine and feces are indicative. More than 0.1 ppm (wet weight) in tissue indicates arsenic contamination. Bioaccumulation in several biological samples like hair, wool, hooves and skin can be measured. Arsenic contaminant in soil, groundwater, fodder, grass, grains, milk, meat, egg can be determined through different methods. Estimation of contaminant arsenic level can be made by atomic absorption spectrophotometry, Atomic-Emission Spectroscopy, Neutron-Activation Analysis, Electrochemical methods, Gas Chromatography, HPLC, A high-performance liquid chromatography (HPLC) in combination with inductively coupled plasma mass spectrometry (ICP-MS).

Mitigation and Preventives

Arsenic contamination in water, soil, feed, fodder and other edible and non-edible contamination can be reduced by taking action for short term and for long term actions. For the short term we can reduce arsenic-exposure risks include the use of rainwater, deep well water, purified river or pond water, mini water purifier uses for domestic purpose, avoiding contaminated water and food source. For long term need larger initiative by government to implement concrete steps. All communities and larger population may be included in these initiatives. The steps may be supply of purified drinking water for mass population and animals particularly RO (reverse osmosis) water supply, safe water for irrigation and agriculture use, improvement of nutritional status of the animals with minimum arsenic content feed.

In case of clinical cases are found, the case basis treatment may be given. Chemicals like sodium thiosulfate 20-40 g intravenous or per day per cattle for one month show decreasing of tissue and hair levels of arsenic in cattle. The arsenic compound releases through urinary excretion. Chelating agent dimercaprol *i.e.*, BAL (British anti-lewisite) @ 3 mg kg^{-1} 4 hourly can be used in case of an acute toxicity with heavy metals like Arsenic. Herbal preparations with *Glycosmis pentaphylla*, 200-400 mg $kg^{-1}day^{-1}$, *Bauhunia accuminata* bark powder 0.25-3.00 g $animal^{-1}$. These herbal drugs act as antibacterial, anti-diabetic, analgesic, anti-inflammatory, anti-diarrheal, anti-cancerous, skin lesions. Preventives with arsenic free water supply (RO, nanofiltration, cleaned river water) for animal and domestic use and also irrigation with deep well water. Improve health status through good nutrition, vitamins and minerals.

Conclusion

Arsenicosis is chronic condition in human and animals causes through food chain and water. Several pathological conditions may occur for prolong exposure with arsenic such as hyperkeratosis, gastrointestinal disorder, lung involvement, neurological, renal disorder, oncogenic growth, *etc*. Although the clinical signs in animals are not very prominent but some condition may be evident are hyperkeratosis, locomotor dysfunction, GI tract involvement and urinary tract disorders. Diagnosis is not very easy however sometime clinical signs can provide some positive indication besides confirmative diagnosis with estimation of arsenic in different biological samples and water. Avoidance of use of arsenic contaminated water for human, agricultural and animals use. Several steps have been taken to restrict use of contaminated water such as supply of arsenic free water for humans, plants and animal use. Clinical cases are to be treated with specific drugs.

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