



REVIEW ARTICLE

A Proper Diet Plan for Arsenic Elimination in Chronic Arsenic Poisoning Patients

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Abstract

Background: Chronic arsenic poisoning has become a global health hazard due to intake of contaminated subsoil water. A large population in West Bengal, India and in Bangladesh is suffering from chronic arsenicosis due to drinking of contaminated subsoil water. It affects mostly the poorest part of the community.

Objective: Malnutrition is one of the causes for manifestation of symptoms of chronic arsenicosis. The aim of this article is to propose a proper diet plan containing vegetables and spices for elimination of arsenic in chronic arsenicosis patients and those are easily available and affordable too.

Methods: Therapeutic uses of arsenicals and management of adverse effect may cause by the improperly prepared arsenic preparations are mentioned in the Ayurvedic texts. Many plant drugs are included in the management. Vegetables and spices are found out from those plant drugs. Google, Scholar Google, and Pub-Med database were searched for works on medicinal plants effective in arsenic poisoning and could be used as vegetables and spices.

Results: Amaranthus leaves, skunkvine leaves, Eclipta leaves, moringa leaves, bitter gourd, ash pumpkin as vegetables; cumin seeds, turmeric powder, sesame seeds, garlic, ginger as spices; papaya and corn fruits are mentioned in Ayurvedic texts and in the published literatures for ameliorating arsenic poisoning.

Conclusion: A diet plan including these vegetables, fruits and spices has been proposed. The proposed plants are easily available from cultivation and collection sources and are economically cheap. The proposed diet can prevent absorption of arsenic, can eliminate arsenic from the body, can prevent toxic effects of arsenic. The proposed diet plan may be taken by the governments and the NGOs for generating awareness amongst the arsenic exposed population for an easy and economically viable prevention.

Keywords

Ayurveda, Arsenic, Diet, Medicinal plants, Spices, Vegetables

Abbreviations

DNA: Deoxyribonucleic Acid; NGO: Non-Governmental Organization; ROS: Reactive Oxidant Species

Introduction

Diet is very important for prevention and cure of diseases. Diet is given outmost importance in Ayurvedic system of medicine, it is termed as best medicine (Mahabhaishajyam) [1]. Disease specific lists of wholesome and unwholesome foodstuffs are mentioned in Ayurveda [2]. A right diet helps to control many diseases like diabetes mellitus, cardio-vascular disease, obesity and others. Planning for proper diet is necessary for a better control of the diseases. To control the chronic arsenic poisoning, proper and nutritious food, safe drinking water and adequate physical exercise are considered as the proven measures [3].

Chronic arsenic poisoning due to arsenic pollution has become a threat to the population globally. A large population in West Bengal, India and in Bangladesh is suffering from chronic arsenicosis due to drinking of contaminated subsoil water. It is estimated that at least 140 million people in 50 countries are suffering from chronic arsenicosis due to contaminated foods and drinking water [4]. Arsenic poisoning has become a

global public health hazard due to entering of arsenic in the food chain [5].

In chronic arsenic poisoning, arsenic accumulates in the vital organs in the body including the liver, spleen and others [6]. Chronic exposure to arsenic leads to different malignant and non-malignant symptoms like hyperpigmentation, hyperkeratosis, anaemia, chronic respiratory and neurological disorders, gastro-intestinal diseases, epigenetic DNA modification, induction of genomic instability and others [7].

Orpiment (As_2S_3), realger (As_2S_2), white arsenic (As_2O_3) and many preparations from these arsenicals are used as therapeutic entities in Ayurveda after proper purification treatment. These are used for treatment of fever, rheumatoid arthritis, osteoarthritis, asthma, diabetes mellitus and others. The adverse effects caused by improperly processed arsenicals are mentioned in the texts of Ayurveda. Management of those adverse effects are also mentioned [8]. Wholesome and unwholesome diet during arsenicals therapy are also mentioned in the texts of Ayurveda [9,10]. The drugs mentioned for management of adverse effects and the wholesome diet include many plant drugs, which are used as vegetables and spices in many parts of India.

It is noted that the poorest part of the exposed populations suffers most from chronic arsenicosis related disorders. Malnourishment due to lack of nutrients, protein, carbohydrate, vitamins in improper diet leads to manifestation of arsenicosis. Dietary intervention may appear as a practical and inexpensive approach for mitigation of chronic arsenic poisoning [11]. Study reported that proper diet regime can be able to improve the conditions in patients of chronic arsenicosis [12]. In this article, an attempt has been taken to propose some plants as foodstuffs, which help to eliminate arsenic from the body and those are easily available and affordable too.

Methods

The published Ayurvedic texts related to preparation and application of arsenic containing drugs and management of adverse effect may cause by the improperly prepared arsenic preparations were referred. Google, Scholar Google, and Pub-Med database were searched for internet-assisted literature study [13]. The articles related to diet for arsenic poisoning patients, Ayurvedic drugs effective on chronic arsenicosis, and medicinal plants used for arsenic poisoning patients published in last two decades (2000-2020) were considered. The pharmacological and clinical studies on medicinal plants effective in chronic arsenic poisoning were selected.

The medicinal plants could be used as vegetables, fruits and spices from the list of the plants were selected. Amongst those vegetables, fruits and spices, which are available easily and are economically cheap,

are proposed for the proper diet plan for arsenic ameliorating in patients of chronic arsenicosis

Drugs mentioned in Ayurvedic texts

Many plant drugs are mentioned in texts of Ayurveda for management of the adverse effects caused by improperly processed arsenicals, as adjuvants with arsenic preparations and as wholesome diet during therapy by arsenic preparations [8,14].

Drugs for adverse effects management: Turmeric (*Curcuma longa*), ginger (*Zingiber officinalis*), cumin (*Cuminum cyminum*) seeds, sesame (*Sesamum indicum*) seeds, bitter gourd (*Momordica charantia*), Meghnada (*Amaranthus spinosus*), Kushmanda (*Benincasa hispida*), Agastya (*Sesbania grandiflora*), Bhringaraj (*Eclipta alba*), Jayanti (*Sesbania sesban*), Duralabha (*Alhagi camelorum*), Rajhamsi (*Adiantum lunulatum*), Swarnapushpi (*Jasminum auriculatum*), Kalmegh (*Andrographis peniculata*), Khadira (*Acacia catechu*) and Sarpakshi (*Ophiorrhiza mungos*) are mentioned as specific plant drugs for management of adverse effects caused by arsenicals.

Turmeric, dry ginger root, cumin seeds are mentioned to be taken in powder form. Juice expressed from fresh bitter gourd fruits, *A. spinosus* leaves, *B. hispida* fruits, *S. grandiflora* leaves, *S. sesban* leaves, *O. mungos* leaves, whole plant of *E. alba* and *A. camelorum* are used. Decoction is prepared from dry plants of *A. peniculata* and *A. catechu* are used for management of arsenic poisoning.

Adjuvants: The arsenic compounds are advised to prescribe with adjuvants like cumin seed powder, decoction of Guduchi (*Tinospora cordifolia*) stem, honey, ghee, sugar candy and jaggery. The arsenic preparations are mixed with the adjuvants and then are taken by the patients.

Wholesome diet: Rice, horse gram, milk, ghee, butter, sugar candy, honey and sweet foodstuffs are mentioned as wholesome diet in arsenic poisoning.

Unwholesome diet: Salty, sour and pungent foodstuffs are forbidden during schedule of arsenicals therapy. All salts are prohibited except rock salt.

Some of these drugs like turmeric, ginger, cumin seeds and sesame seeds are used as spices in Indian society. These drugs are very commonly available. The market price of these drugs is very low. The others like bitter guard, Kushmanda (*B. hispida*), Agastya (*S. grandiflora*), Bhringaraj (*E. alba*), Meghnada (*A. spinosus*) are used as vegetable. These are cultivated or even available at roadside and wastelands. The poorest part of the chronic arsenicosis affected population may afford these drugs as spices and vegetables in their daily meals.

Studies on plant drugs

Apart from the plant drugs mentioned in Ayurvedic

texts for management of arsenic poisoning, studies have been conducted on many medicinal plants for ameliorating arsenic poisoning; some of those plants are used as vegetables and spices in different parts of India. These plant drugs could eliminate arsenic from the body or caused methylation to combat chronic arsenic poisoning.

Withania somnifera roots, *Mentha piperita* leaves, *Emblica officinalis* fruits, *Azadirachta indica* leaves, *Tephrosia purpurea* leaves, *Boerhavia diffusa* leaves, *Achyranthes aspera* leaf and root, *Camellia sinensis* leaves, *Vitis vinifera* seeds, *Terminalia arjuna* bark, *Phyllanthus fraternus* whole plants, *Moringa olifera* seeds and leaves, *Ocimum sanctum* leaves and *Allium sativum* bulb were tested for ameliorating effect for arsenic poisoning in various animal models. Most of these plant drugs were found to be effective to eliminate arsenic from the body [15].

Carica papaya fruit, pineapple (*Ananas cosmosus*) fruit, *Zea mays* fruit and *Trichosanthes dioica* fruit were also evaluated for ameliorating effect against arsenic poisoning in animals. These fruits were also found to be effective for mitigation of chronic arsenic poisoning [16].

Dietary supplements for arsenic poisoning

A proper concoction of reduction of arsenic intake and dietary supplements is suggested for management of arsenic poisoning patients [17]. Studies are reported on some dietary supplementations to reduce effects of chronic arsenic poisoning. Vitamin-C (L-Ascorbic acid) was reported to have protective activity against inorganic arsenic induced arsenic toxicity in Wistar rats. It exhibited inhibition in altered liver and kidney functions, oxidative stress and DNA damage caused by arsenic [18]. Tetrahydrocurcumin (metabolite of curcumin) showed protective effect on arsenic induced toxicity in rats. It ameliorated arsenic induced mitochondrial toxicity in liver, oxidative damage and dyslipidemia in rats [19]. Combination of ascorbic acid and α -tocopherol inhibited arsenic induced oxidative protein and DNA damage. This co-administration increased protein oxidation, DNA strand breaks, and DNA-protein cross-links in blood, liver, and kidney of arsenic poisoning rats [20]. Tea polyphenols reduced significantly arsenic (III) induced DNA damage in human lymphocytes and helped in repair of DNA damage. The polyphenols might help to combat arsenic induced genotoxicity [21].

A clinical study reported that treatment of chronic arsenic poisoning patients by curcumin for three months significantly reduced DNA damage, restricted reactive oxygen species generation and lipid peroxidation, and increased oxidant activity in the body. Curcumin exhibited protection to the oxidative stress to DNA, which is considered as mechanistic factor for arsenic carcinogenicity [22].

Few dietary factors from the animal products such as folic acid, vitamin B12, protein and methionine facilitate excretion of arsenic from the body. These dietary factors are causing methylation of inorganic arsenic and help in removal of arsenic by the mechanism of one carbon metabolism. A study reported that these dietary factors help in methylation of arsenic and reduced toenail arsenic concentration [23].

Proper foods for arsenicosis

A clinical study was carried out on management of chronic arsenicosis by proper foods and vitamin C supplement in Bangladesh. Total 200 patients having signs of keratosis were included in this study. 500g carbohydrate, 150g protein, 100g fat, 200g vegetables, 50g pulses, 50g fibre rich foods, 3g salt, 2500 mL to 4000 mL water along with 1000 mg vitamin C supplementation was given as daily diet regime. The diet regime and vitamin C supplementation was given for six months. Urine arsenic content, blood hemoglobin level and degree of keratosis were determined before and after study. The study reported that the proposed diet regimen and vitamin C supplementation significantly reduced urine arsenic content, increased blood hemoglobin content and improved condition of keratosis in the patients [12].

Diet plan

A nutritious and healthy diet can be planned from the plants mentioned for elimination of arsenic in the ancient Ayurvedic texts and from published articles. Those will be used as vegetables and spices. The proposed plants are easily available in all parts of India, can be cultivated and are having low cost. The proposed diet plan will be economically viable for the poor affected people.

The affected individual or the people of the arsenic affected area will take green tea in the morning and in the evening. They will take Amaranthus leaves, skunkvine leaves, Eclipta leaves, moringa leaves, bitter gourd, ash pumpkins as vegetables. They will use cumin seeds, turmeric powder, sesame seeds, garlic and ginger as spices for preparation of foods. The person will take papaya, pineapple fruits and corn fruits. Few animal products contain protein, methionine, folic acid and vitamin B12 such as small fish are recommended. Commonly available fruits and vegetables rich in vitamin C such as lemon, guava, gooseberry, orange, banana and others are also advised to take.

The persons will take rice, horse gram, milk, sugar candy, honey and sweet foodstuffs and will avoid excess salty, sour and pungent foodstuffs.

Studies on said plants for ameliorative effect

Studies are carried on some of the above said plants drugs, which may be used as vegetables and spices. It is found that those have significant ameliorative effect and can be able to eliminate arsenic from the body.

Turmeric (*Curcuma longa*) is very commonly used die and spices in Indian foods. Turmeric is rich source of many phytochemicals having medicinal values. The main active principle curcumin has antioxidant, anti-inflammatory, anti-tumor, anti-carcinogenic and chelation properties [24]. Curcumin is capable to prevent DNA damage caused by arsenic toxicity [22]. Turmeric is found to be effective to eliminate arsenic from sodium arsenite induced arsenicosis in calves and sheep and from arsenicosis affected cattle [25-27].

Ginger (*Zingiber officinalis*) is used as spices in all parts of India. Ginger is rich in phenol and flavonoid compounds. It exhibits antioxidant effect due to presence of these phenol and flavonoid compounds [28]. Study carried out on sodium arsenite induced arsenicosis in calves reported that dry ginger powder significantly eliminates arsenic from the body and protects from possible damage caused by arsenic poisoning [26].

Skunkvine (*Paederia foetida*) is used as vegetable in India. It is rich source of iridiod glycosides, steroids and terpenoids. It contains paederolone, paederone, paederine and paederenine. One study reported that *P. foetida* powder eliminate arsenic from the sodium arsenite induced arsenicosis in sheep; It protects from DNA fragmentation caused by arsenic poisoning [27].

Amaranthus spinosus is used as vegetables in many parts of India. *A. spinosus* powder is effective to eliminate arsenic significantly from the chronic arsenicosis affected

cattle. It alters all the haematological and biochemical changes caused by chronic arsenic poisoning. It also gives protection from the DNA damage caused by arsenic [25].

The tender leaves and new shoot of Bhingaraj (*E. alba*) are cooked as vegetables in some rural parts of India. The leaves contain resins, ecliptin, nicotine, glycosides, wedelolactone and others. It has hepatoprotective, antimicrobial, anti-inflammatory and antihyperglycemic effect. *E. alba* powder helps to eliminate arsenic from the body; it brings the arsenic induced hematological and biochemical alterations to normal level; it has cytoprotective and DNA protective activities in chronic arsenicosis affected cattle [25].

Green tea (*Camellia sinensis*) is a common drink all over the World. The green tea has the potential to eliminate arsenic. It eliminates arsenic from liver and is effective on haematological alterations caused by arsenic poisoning in rabbits and rats [29,30]. Moringa (*Moringa olifera*) leaves are used as vegetables in many parts of India. Moringa leaves eliminate arsenic from liver, kidney and heart in mice and rats [31]. Garlic (*Allium sativum*) bulb aqueous extract eliminates arsenic from liver, kidney and bone marrow in mice and rats [32].

Corn (*Zea mays*) fruits are used in many foodstuffs. Corn fruits lower tissue arsenic level from liver, kidney, heart, lung and skin in rats [33]. Papaya (*Carica papaya*)

Table 1: Arsenic ameliorating effect and calorie value of the foodstuffs of proposed diet plan.

Name of the diet	Used parts	Experimental animals	Mechanism	Calorie value/100 g	Reference
<i>Allium sativum</i>	Bulb	Rat, mice	Chelation, antioxidant	149 calories	Chowdhury, et al. 2008 [32]
<i>Amaranthus spinosus</i>	Aerial part	Cattle	Chelation, antioxidant	23 calories	Hazarika, et al. 2015 [25]
<i>Ananas cosmosus</i>	Fruit	Rat	Chelation	50 calories	Desai, et al. 2012 [36]
<i>Camellia sinensis</i>	Leaves	Rabbit, rat	Antioxidant	87 calories	Acharyya, et al. 2014 [29]; Sinha, et al. 2010 [30]
<i>Carica papaya</i>	Fruit	Mice	Chelation	40 calories	Singh, et al. 2013 [34]
<i>Curcuma longa</i>	Rhizome	Cattle, sheep	Chelation, antioxidant	390 calories	Hazarika, et al. 2015 [25]; Biswas, et al. 2017 [26]; Maji, et al. 2020 [27]
Curcumin		Human	Antioxidant		Biswas, et al. 2010 [22]
<i>Eclipta alba</i>	Aerial part	Cattle	Antioxidant	18 calories	Hazarika, et al. 2015 [25]
Folic acid		Human	Methylation		Gruber, et al. 2012 [23]
Methionine		Human	Methylation		Gruber, et al. 2012 [23]
<i>Moringa olifera</i>	Leaves	Rat, mice	Chelation, antioxidant	30 calories	Sheikh, et al. 2014 [31]
Protein		Human	Methylation		Gruber, et al. 2012 [23]
<i>Paederia foetida</i>	Leaves	Sheep	Antioxidant		Maji, et al. 2020 [27]
Tea polyphenols		Human	DNA repair		Sinha, et al. 2007 [21]
<i>Trichosanthes dioica</i>	Fruit	Rat	Antioxidant	20 calories	Bhattacharya, et al. 2014 [35]
Vitamin-B12		Human	Methylation		Gruber, et al. 2012 [23]
Vitamin- C		Rat	Antioxidant		Singh and Rana 2007 [18]
<i>Zea mays</i>	Fruit	Rat	Chelation	85 calories	Chowdhury, et al. 2009 [33]
<i>Zingiber officinalis</i>	Rhizome	Calves	Chelation, antioxidant	79 calories	Biswas, et al. 2017 [26]

fruits have ameliorative effect on chronic arsenic poisoning in mice [34]. *Trichosanthes dioica* fruit extract eliminates arsenic from liver, kidney and heart in rats. Ascorbic acid and quercetin present in fruits have antioxidant properties and help to mitigate arsenic poisoning [35]. Pineapple fruit (*Ananas comosus*) has the potential to chelate with arsenic and to eliminate arsenic from the body in arsenic intoxicated rats [36].

Nutritional values of the proposed diet

The contents of the proposed diet are very nutritious. Arsenic ameliorating effect and calorie value of the plants of proposed diet plan are depicted in Table 1. Turmeric is good source of carbohydrate and fibres. Turmeric powder contains 6.74 g% carbohydrate, 0.94 g% protein, 0.69 g% fat and 2.1 g% fibres. It contains flavonoids, saponins and alkaloids. The powder contains Vitamin B, A and essential minerals like calcium, potassium and iron [37].

Fresh ginger contains crude fibre 21.90%, fat 17.11%, carbohydrate 39.70%, crude protein 12.05%, ash 4.95%, and moisture 3.95%. It also contains essential elements like potassium, magnesium, sodium, calcium, zinc and iron. Tanin, saponins, antraquinones, phytic acid are present in ginger. Ginger is rich source of essential amino acids [38].

E. alba is a rich source of carotene which is an antioxidant. Carotene can eliminate the free radicals that cause macular degeneration. Leaves of this plant contain 2.5% fat, 1.0 % protein and 64% carbohydrate; it gives 240.6 calories nutrition per 100g. Leaves contain saponins, triterpenoids and flavonoids [39].

P. foetida leaves contain 2.57% crude protein, 0.60% crude fat, 9.60% carbohydrate and 8.47% total fibre. The leaves are rich in minerals, 200.40 mg/100g calcium, 844.39 mg/100g potassium and 4.67 mg/100g iron. It also contains 271.40 mg/100g Vitamin C (ascorbic acid). The leaves also contain 3.15 mg/g total phenol [40].

The *Amaranthus spinosus* leaves are good source of protein and carbohydrate. The leaves contain 4.6 g% protein, 0.2 g% fat, 8.3 g% carbohydrate and 1.8 g% fibre. The leaves are source of minerals like Ca 410 mg, P 103 mg and Fe 8.9 mg. It provides 42 calories/100g energy. It contains flavonoids and carotenoids [41].

Cumin seeds are used as food ingredient for thousands of years. The seeds are rich source of nutrition. The seeds can provide high amounts of protein, fat and fibre. It also contains Vitamins B and E and several dietary minerals including iron. These contain bioactive constituents like flavonoids, phenols and terpenes. Flavonoids present in the seeds have antioxidant effect [42].

Ash pumpkin fruits contain 18.6% protein, 25.0% carbohydrate and 13.3% fibre. It also contains many essential minerals 0.67% P, 3.86% K, 0.14% Ca, 0.13%

Mg, 53 mg/kg Fe and 26 mg/kg Zn. The fruits contain ascorbic acid, folic acid and riboflavin. These also contain flavonoids and carotene and have high antioxidant value [43].

The bitter gourd fruits contain 7 g% carbohydrate, 3.6 g% protein, 0.2 g% fat and 1.9 g% dietary fibre. It contains essential minerals like calcium, magnesium, iron, zinc, manganese and potassium. It also contains Vitamin A, C, E, B₁₂ and folic acid [44].

Pointed gourd contains 4.2 g% carbohydrate, 2 g% protein and 3 g% total dietary fiber. It also contains minerals like phosphorus 40 mg, calcium 30 mg, iron 1.7 mg and copper 1.1 mg, and vitamin B2 0.06 mg, vitamin B1 0.05 mg, and vitamin C 29 mg [45].

Possible mechanism for arsenic elimination

Proper diet provides protection from ill effects of arsenic poisoning. Methylation is one of the methods for detoxification of poisons. Diet helps in methylation of arsenic [11]. Most of the plants included in the proposed diet list contain vegetable fat. The vegetable fat prevents absorption of arsenic from the gut and accumulation of arsenic in the tissue. The foodstuffs contain folic acid, vitamin B12, proteins and methionine help in methylation of arsenic [23].

Some foodstuffs are effective as chelating agents. Those bind with arsenic compounds and prevent arsenic from interacting with proteins and DNA. The chelating agents help elimination of arsenic from the body [46]. *M. olifera* seed powder, turmeric, ginger, garlic extracts are reported to have the ability for chelating with arsenic and to remove arsenic from the body [15]. The vegetables and fruits contain thiols such as red pepper, carrot, cauliflower, tomato, potato, green beans, lemons, orange, papaya, banana and others are good chelators. The thiols chelate with arsenic and help in elimination of arsenic from the body [47].

Arsenic exposure leads to production of more free radical species such as nitric oxide, superoxide dismutase and hydroxyl radicals in the body causes damage of DNA and proteins [48]. The proposed vegetables and spices are full of antioxidants. The antioxidant components of diet give protection against free radical species produced by arsenic toxicant. Antioxidant enzymes in the human body are activated through nuclear-factor erythroid-2 related factor-2 (Nrf2) pathway [49]. Many plant phytochemicals help in activation of the Nrf2 pathway, one of the examples is tea polyphenol [50].

Arsenic is a known carcinogenic agent. It acts as a tumor promoting agent, can induce carcinoma, and death occurs in chronic arsenic poisoning due to various carcinoma [51]. Many plant drugs from the proposed diet plan have anticancer effects, *C. longa*, *C. sinensis*, *Z. officinale*, *E. alba*, *C. cyminum* possess anticancer activities [52]. These plant drugs could prevent

carcinoma may cause by the chronic arsenic poisoning. Most of the plant drugs mentioned in proposed diet list are having both chelation and antioxidant properties against arsenic, and help to mitigate arsenic poisoning. The probable mechanism of diet for arsenic alleviation is shown in Figure 1.

Discussion

It is noted and reported that the malnourished population suffer most from chronic arsenicosis due to lack of proteins and nutrients in diet. A study reported that poor nutritional status may increase the

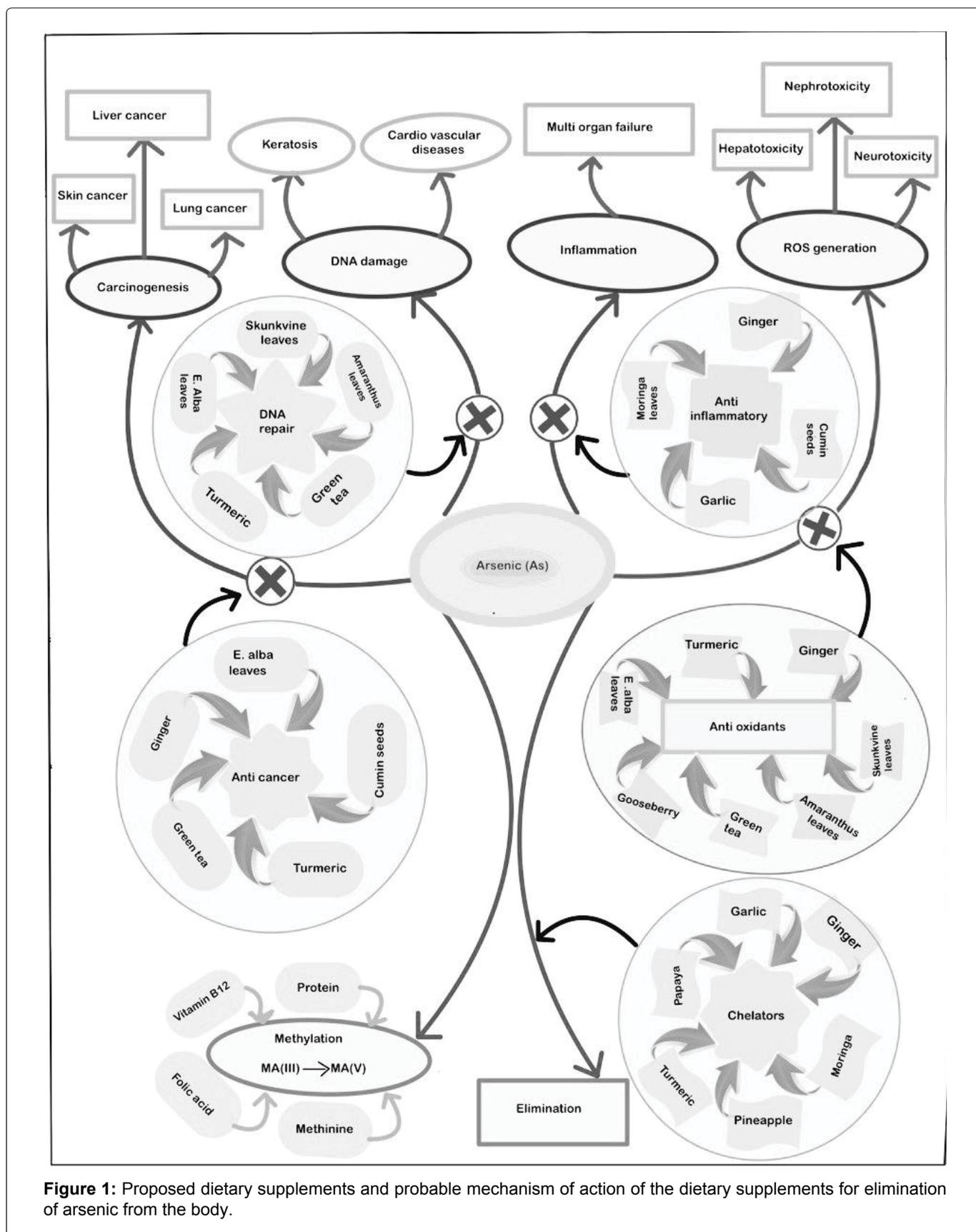


Figure 1: Proposed dietary supplements and probable mechanism of action of the dietary supplements for elimination of arsenic from the body.

susceptibility to chronic arsenic poisoning [53]. A well-balanced diet with good nutritional value and a wide variety of grains are essential to minimize the negative health effects caused by arsenic poisoning. The proposed diet has good nutritional value, and all the proposed vegetables and spices are rich in carbohydrate, protein, fat and minerals.

The proposed diet could prevent the chronic arsenic poisoning. The vegetable fat part of the diet can prevent absorption of arsenic. The vegetables and spices can chelate with arsenic and can expel out from the body. The antioxidant rich proposed diet can prevent possible damage caused by arsenic due to production of free radicals. The carcinogenic activity of arsenic can be prevented by antitumor activity of some of the components of the proposed diet. And finally the absorbed arsenic can be detoxifying by the process of methylation of the proposed diet (Table 1).

Chronic arsenic poisoning leads to various skin lesions, liver disorders, kidney damage, central nervous system disorders due to oxidative stress. It causes DNA fragmentation due to production of reactive oxidant species (ROS). Arsenic poisoning leads to various types of skin, lungs and liver cancers due to unregulated proliferation of the cells by suppressing of p53 pathway. At the end stage, chronic arsenic poisoning causes multiple organ failure due to necrotic cell deaths. The proposed diet regime may prevent these ill effects caused by chronic arsenic poisoning by their antioxidant, DNA repair, anti-inflammatory and anti-carcinogenic effects (Table 2).

Various natural means are suggested to get rid

from chronic arsenic poisoning, include taking arsenic free drinking water and food, taking high protein diet, consuming fruits and vegetables containing ascorbic acid, and taking beverages containing polyphenols [5]. It is very difficult to supply arsenic free drinking water to the entire affected population. It will be a huge economic burden to the government. It is also not possible for the poor affected population to consume protein-rich diet daily [17]. But it is possible to the population to take tea, and fruits and vegetables containing ascorbates and polyphenols. Flavanols, flavonoids and phenolic acids including catechins are the polyphenols present in tea [54]. Ginger, cumin seeds, skunkvine leaves are rich source of phenols. The citrus fruits, papaya, mango, pineapple and others contain ascorbic acids. Skunkvine, cabbage, spinach, pumpkin, gourds and others vegetables contain ascorbates [55]. Skunkvine leaves, ginger, cumin seeds, papaya fruits, pumpkin, gourds are included in the diet for the chronic arsenic poisoning patients in the present study.

This diet plan may be taken by the governments and NGOs for generating awareness amongst the arsenic exposed population. These organizations may conduct awareness programmes in the arsenic affected area regarding proper diet for prevention and curative purposes of elimination of arsenic from the affected population. This approach will help to decrease the susceptibility of the exposed population. These organizations may distribute these spices and vegetables to the poorest part of the exposed population. This may be an important strategy for prevention and mitigation of chronic arsenic poisoning [11].

Table 2: Probable relationship of the proposed diet and mechanism of arsenic poisoning.

Arsenic poisoning	Mechanism	Diet factors	Counter mechanism
Oxidative stress	Oxidation reaction	Green tea, pointed gourd fruit, gooseberry fruit, Vitamin C, turmeric, Amaranthus leaves, <i>E. alba</i> leaves	Antioxidant
DNA damage	Dimethyl arsine peroxy radical generation	Turmeric, skunkvine leaves, Amaranthus leaves, <i>E. alba</i> leaves	DNA repair
Keratosis	Over expression of epidermal keratinocytes	Vitamin B12, Vitamin C, turmeric, ginger, Amaranthus leaves, <i>E. alba</i> leaves	Chelation, DNA repair
Liver damage	Interaction with protein targets in hepatocytes	<i>E. alba</i> leaves, Moringa leaves, garlic, corn fruit, papaya fruit, pointed gourd fruit	Antioxidant, DNA repair
Kidney damage, albuminurea, proteinurea	Endothelial dysfunction	Moringa leaves, Amaranthus leaves, garlic, corn fruit, pointed gourd fruit	Antioxidant, DNA repair
Skin cancer, liver cancer	Unregulated proliferation (suppression of p53 pathway)	Turmeric, ginger, green tea, cumin seeds, <i>E. alba</i> leaves	Anticancer, antitumor, anti-inflammatory
Cardiovascular diseases, Atherosclerosis	Elevation of cell adhesion molecules, Oxidized lipids formation	Garlic, ginger, Moringa leaves, green tea, skunkvine leaves	Antioxidant, DNA repair
Alzheimer's, Parkinson's disease	Dopamine quinone radicals formation	Turmeric, ginger, Moringa leaves	Antioxidant, DNA repair
Multiple organ failure	Necrotic cell death	Turmeric, ginger, green tea, Moringa leaves	Antioxidant, Anti-inflammatory

Conclusion

Chronic arsenic poisoning is a serious global health hazard due to intake of contaminated subsoil water. The poorest part of the community is affected most. Diet can play an important role for ameliorating chronic arsenic poisoning. Many plant drugs are mentioned in the ancient Ayurvedic texts for management of adverse effect may cause by the improperly prepared arsenic preparations. A diet plan has been proposed incorporating those plant drugs. The proposed plants are easily available from cultivation and collection sources and are economically cheap. The proposed diet can prevent absorption of arsenic, can eliminate arsenic from the body, can prevent toxic effects of arsenic and can detoxify arsenic. The proposed diet plan may be taken by the governments and non-government bodies for generating awareness amongst the arsenic exposed population for an easy and economically viable prevention.

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Conflict of Interest Statement

The author declares that there are no competing interests.

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Authors' Contribution

PKS planned the work; he searched the literature; analysed the data and prepared the manuscript.

Statement

The manuscript has been read and approved by all the authors.

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