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REPORT

ARSENIC IN THE ENVIRONMENT – AN OVERVIEW ON GLOBAL AND SRI LANKAN CONTEXT

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SUMMARY

This paper reviews the status of arsenic contamination and its sources at global and national levels and provide an operational response of the designated authority to a claim raised on Arsenic contamination in Sri Lanka, with a special focus on pesticides. Three out of 23 active ingredients of pesticide products used in Sri Lanka were detected with minute quantities of Arsenic (limit of quantification is 50 µg/L). The paper also extracts information from many published sources providing details on the maximum allowable limits of Arsenic in different countries. The need to follow proper protocols under Sri Lankan context for quick and effective action, and establishing the maximum allowable limits of Arsenic in pesticide and other products are highlighted to mitigate the negative impacts of the contaminant.

KEYWORDS: Arsenic, Contamination, Pesticides, Sri Lanka

INTRODUCTION

Today, the mankind is exposed to high levels of toxic metals in recorded history. Human civilization and a concomitant increase in industrial activity has gradually redistributed many toxic metals from the earth's crust to the environment and increased the possibility of human exposure. Among the various toxic elements, namely heavy metals Cadmium, Lead, and Mercury, and metalloids (semi-metals) such as Arsenic are prevalent in soils (Nakayama *et al.*, 2011).

Arsenic, a metalloid and a natural element, is a known contaminant of groundwater causing a set of health symptoms commonly called as arsenicosis (Indu *et al.*, 2007). It is a natural component of the earth's crust, generally found in trace quantities in all rock, soil, water and air. This element ranks 20th in its abundance in the earth's crust, 14th in sea water, and the 12th in human body (Woolson, 1975). Arsenic can exist in many different chemical forms as inorganic or organic substances in combination with other elements. Inorganic Arsenic exists in four main chemical forms known as valency or oxidation states. The dominant forms are arsenite with a valancy of 3, and arsenate with a valancy of 5. Elemental Arsenic is not soluble in water and Arsenic salts exhibit a wide range of solubility depending on pH and the ionic environment.

Inorganic arsenic of geological origin is found in groundwater used as drinking-water in several parts of the world, for example Bangladesh. Organic arsenic compounds such as arsenobetaine, arsenocholine, tetramethylarsonium salts, arsenosugars and arsenic-containing lipids are mainly found in marine organisms although some of these compounds have also been found in species (IPCS, 2001).

Arsenic, as a labile element, is subject to several processes in the soil where under various conditions, it could get oxidized, reduced, methylated, volatized, adsorbed, and desorbed (Woolson, 1977). When the soil and/or environmental conditions cannot detoxify the Arsenic levels applied, soil Arsenic toxicity becomes a problem. Arsenic cycling may take place in the absence of oxygen and can contribute to organic matter oxidation. In aquifers, microbial reactions may mobilize Arsenic from the solid to the aqueous phase, resulting in contaminated drinking water (Oremland and Stoltz, 2003). The main source of Arsenic in drinking-water is Arsenic-rich rocks through which the water has filtered (http://www.who.int/water_sanitation_health/dwq/arsenic/en/). Arsenic exposure may also occur due to mining or industrial activity in some areas such as coal burning, use of Arsenic as pesticides and exposure to wood preserving arsenicals (Garelik *et al.*, 2008).

High concentrations of Arsenic in soil and irrigation water often lead to high levels of arsenic in crops and are posing an increased food safety risk (Northoff, 2007). FAO (2007) reported that Arsenic-contaminated rice could aggravate human health risk when consumed along with Arsenic-laden drinking water. Jayasekera and Freitas (2005) report that concentration of a variety of major and trace elements, including Arsenic, Cadmium and Mercury, in rice from Sri Lanka were very low or within normal limits for food plants. The United States Food and Drug Administration has identified the maximum allowable limits of Arsenic as 2 mg/kg residue levels in edible by products of chickens and turkeys; 0.5 mg/kg as residue in muscle meat of chickens and turkeys, in eggs, and in muscle meat and by-products (except liver and kidney) (http://www.fda.gov/Food/FoodIngredientsPackaging/FoodAdditives/FoodAdditiveListings/ucm091048.htm). In 2010, the joint FAO/WHO committee on food additives (WHO, 2010) withdrew the previous established provisional tolerable weekly intake (PTWI) of Arsenic, *i.e.* 15 μg/kg body weight (equivalent to 2.1 μg/kg body weight/per day). This was because the benchmark dose for a 0.5 % increased incidence of lung cancer ($BMDL_{0.5}$) was determined to be 3.0 μg Arsenic/kg body weight/day (2–7 μg/kg bodyweight/day), based on the range of estimated total dietary exposure.

Fear of Arsenic contamination in rice, ground water and surface water and hence Arsenic poisoning in human beings has surfaced in the recent past in Sri Lanka. The speculations that were propagated among the Sri Lankan people through mass media has prompted the Government of Sri Lanka to take several steps towards minimize such risks, if prevails and scientifically proven. The pressure groups have focused on agrochemicals claiming that Arsenic contamination in Sri Lanka is due to the use of pesticides. The power of information and misinformation on Arsenic contamination in food and ecosystems has caused a serious panic in the minds of people in Sri Lanka. The level of impact of Arsenic on environment and human health and economy have been well documented for many other countries in the region (Safiuddin and Karim, 2001; Lokuge *et al.*, 2004; Indu *et al.*, 2007; Nahar, 2009). The objective of this article is to provide a brief overview of the status of Arsenic in the environment and the efforts taken by the relevant authorities, especially the Office of the Registrar of Pesticides (ROP) in mitigating the potential impacts of Arsenic in Sri Lankan ecosystem.

ARSENIC IN THE ENVIRONMENT

Arsenic is present in more than 200 mineral species, of which about 60% are arsenate, 20% sulfide and sulfosalts and the remaining 20% include arsenides, arsenites, oxides and elemental Arsenic (Onishi, 1969). The most common of the Arsenic minerals is arsenopyrite (Boyle and Jonasson, 1973) as a constituent in several other sulfide minerals (Garelik *et al.*, 2008). About one-third of the atmospheric flux of Arsenic is of natural origin. Volcanic action is the most important natural source of Arsenic, followed by low-temperature volatilization. Inorganic Arsenic of geological origin is found in groundwater used as drinking-water in several parts of the world. Organic Arsenic compounds such as arsenobetaine, arsenocholine, tetramethylarsonium salts, arsenosugars and Arsenic-containing lipids are mainly found in marine organisms (Taleshi *et al.*, 2010).

Arsenic contamination

The Arsenic-contamination scenario around the world, especially in Asian countries, has changed considerably in the recent past. Apart from the major incidents of Arsenic contamination in groundwater in Asian countries namely, Bangladesh, West Bengal in India, and few sites in China, Arsenic-related groundwater problems have emerged in different Asian countries including new sites in China, Mongolia, Nepal, Cambodia, Myanmar, Afghanistan, DPR Korea, Pakistan, Vietnam (Mukherjee *et al.*, 2006; Figure 1).

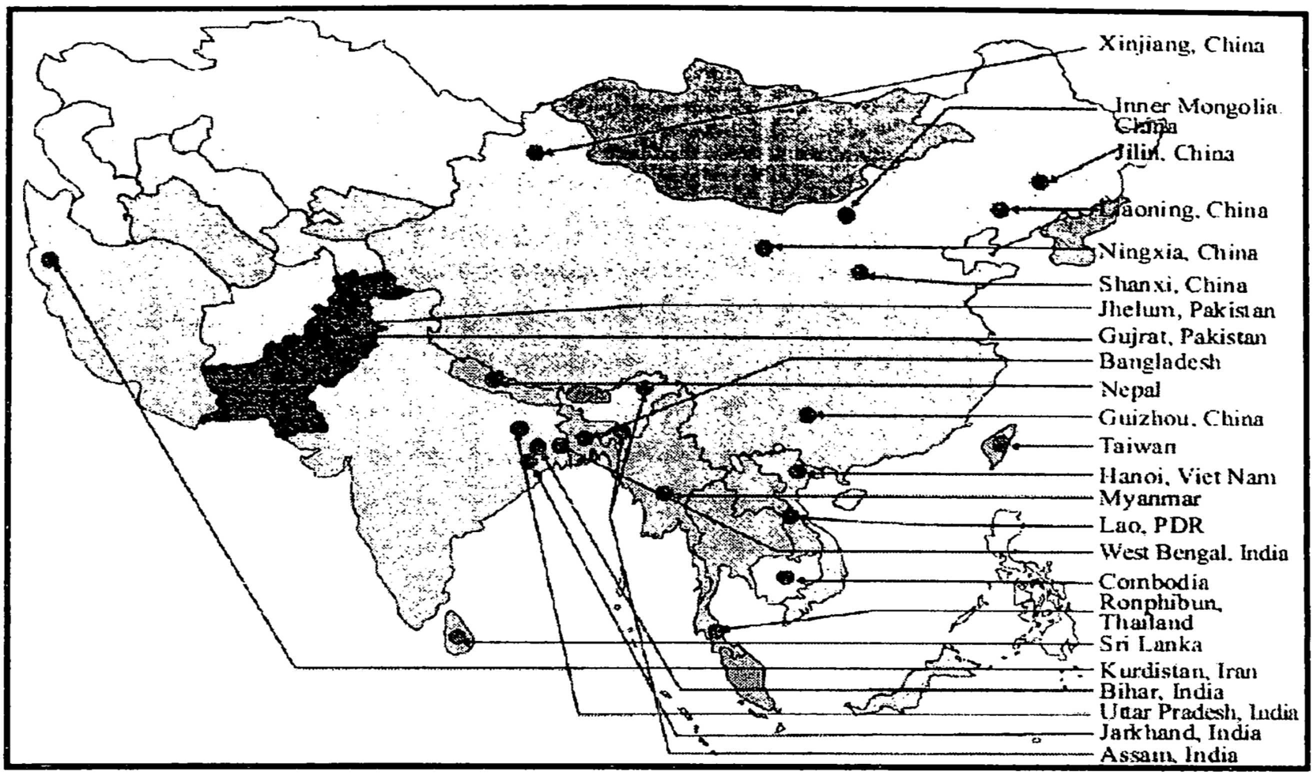

Figure 1. Arsenic contamination in Asia (adopted from: Mukherjee *et al.*, 2006)

Marine organisms naturally accumulate considerable quantities of organic Arsenic compounds. In marine animals the bulk of this Arsenic is present as arsenobetaine, whereas marine algae contain most of the Arsenic as dimethylarsinoylribosides. Humans are therefore, exposed to these Arsenic compounds through any diet that includes seafoods. Some Arsenic compounds are relatively volatile and consequently contribute significant fluxes in the atmosphere. It has been estimated that the atmospheric flux of Arsenic is about 73,540 t/year of which 60% is of natural origin and the rest is derived from anthropogenic sources (Chilvers and Peterson, 1987). Volcanic action is the next most important natural source of Arsenic after low-temperature volatilization, and on a local scale it will be the dominant atmospheric source.

Maximum limits of Arsenic allowed in food and beverages

The WHO permissible limit of Arsenic for drinking water is 0.01 mg/L and the FAO permissible limit of Arsenic for irrigation water is 0.10 mg/L (FAO/WHO, 2011). For certain regions of the world where concentrations of inorganic arsenic in drinking-water exceed 50–100 µg/L, some epidemiological studies provide evidence of adverse effects (WHO, 2011; the WHO guideline value of Arsenic in drinking water is 10 µg/L). However, in other areas where arsenic concentrations in water are elevated but are less than 50 µg/L, though there is a possibility that adverse effects could occur as a result of exposure to inorganic arsenic from water and food, according to WHO (2011), these would be at a low incidence that would be difficult to detect in epidemiological studies.

China have established maximum limits for total Arsenic in many foods, including 0.01 mg/L for drinking water, 0.5 mg/kg for raw cereals and/or cereal-based foods (except rice and rice-based products), vegetables, edible fugues, meat and its products, sugar, condiments, milk powder, coca and its products included in chocolates, and 0.1 mg/kg for the oil and fats as well as raw milk. China has also established the maximum limits for inorganic arsenic in rice and rice-based products (0.2 mg/kg), fish and fish-based condiments (0.1 mg/kg), other sea food and seafood-based condiments (0.5 mg/kg), cereal-based infant formula (0.2 mg/kg), and seaweed-based infant formula (0.3 mg/kg) (FAO/WHO, 2011).

According to the Codex Alimentarius FAO/WHO (2011), Japan has established MLs for total arsenic in soft drink beverage (including mineral water) in provisions of Specifications and Standards for Food, Food Additives, etc. under Food Sanitation Law, 0.05 mg/L for the water used as the raw materials, and "Not detected" for the final product when analyzed by the specified method (limits of detection is 0.2 mg/L). In addition, maximum residue limit 1 ppm is set for potato, tomato, cucumber (including gherkin), spinach, pulp of *Citrus natsudaidai*, peach, strawberry and grape, 3.5 mg/L is set for peels of *C. natsudaidai*, apple and Japanese pear, which come from lead arsenate used as a pesticide. Malaysia have established the maximum limits for total arsenic in many foods in provisions of Food Regulations 1985 as 0.05 mg/L for natural mineral water, and 1 mg/kg for some food. Singapore (Agri-Food and Veterinary Authority of Singapore) have established the maximum limits for total arsenic in many foods ranging from 0.1 mg/L for edible oils and fats, infant formula and baby food, milk and milk products in tin, to 5 mg/kg for some beverages not specified, as well as other colors (on dry matter) included in caramel. In Sri Lanka, standards for food contaminants such as Arsenic, Lead, Flouride, Zinc, Mercury, Cadmium and Ferrous was set by the Sri Lanka Standards Institute during late 1980s (Jayawardene, 1987) and maximum limits of Arsenic allowed for various types of food is 1 mg/kg.

Status of Arsenic contamination in Asia

Concentrations of Arsenic in unpolluted surface water and groundwater are typically in the range of 1–10 μg/L, and elevated concentrations in surface water and groundwater of up to 100–5000 μg/L can be found in areas of sulfide mineralization (Welch *et al.*, 1988; Fordyce *et al.*, 1995). Elevated concentrations (> 1 mg Arsenic/L) in groundwater of geochemical origins have been found in Taiwan (Chen *et al.*, 1994), West Bengal, India (Chatterjee *et al.*, 1995; Das *et al.*, 1995, 1996; Mandal *et al.*,

1996) and in most districts of Bangladesh (Dhar *et al.*, 1997; Biswas *et al.*, 1998), in the drinking-water in Chile (Borgono *et al.*, 1977), North Mexico (Cebrian *et al.*, 1983), and several areas of Argentina (De Sastre *et al.*, 1992), and parts of PR China and the USA (Valentine, 1994). Arsenic concentrations of < 0.98 mg/L have been found in wells in south-western Finland (Kurttio *et al.*, 1998). Levels as high as 35 mg Arsenic/L and 25.7 mg Arsenic/L have been reported in areas associated with hydrothermal activity (Kipling, 1977; Tanaka, 1990). Reported levels of total arsenic in rice are < 0.01–2.05 mg/kg for Bangladesh, 0.31–0.70 mg/kg for China and < 0.10–0.76 mg/kg for Taiwan, 0.03–0.044 mg/kg for India, 0.11–0.66 mg/kg for the U.S.A., 0.03–0.47 mg/kg for Vietnam, and 0.08–0.38 mg/kg for Italy and Spain (Williams *et al.*, 2005; Duxbury *et al.*, 2003; Caroli *et al.*, 2002, 2007; Pizarro *et al.*, 2003).

Arsenic contamination scenario in Sri Lanka

Senanayake *et al.* (1972) reported that Arsenic contamination in Sri Lanka that could be due to natural occurrences (Mukherjee *et al.*, 2006), and found that 7 cases reported for Arsenic poisoning was as a result of well-water contamination. Chandrajith *et al.* (2005) has found Arsenic in 70 paddy soils covering major agro-ecological regions of Sri Lanka, with a mean value of 0.84 µg/g, and concluded that Arsenic content found in soils of all tested locations were similar. Chandrajith *et al.* (2005) also reported that this trace element in paddy soils of Sri Lanka is mainly inherited from the soil parent materials. Chandrajith *et al.* (2008) reported that tank sediments in the center of the tank and deposited close to the bund, are mostly submerged throughout the year, thus favouring for the removal of Arsenic from sediments. Arsenic is stable, exhibiting weak affinity toward clays and gibbsite (Weerasooriya *et al.* 2003) and thus, is mostly bound to iron oxides, which are known to absorb Arsenic effectively (Vithanage *et al.* 2006).

USE OF ARSENIC AS PESTICIDES

Arsenic has a long history of use both as an insecticide and herbicide. Arsenicals have been used in various forms. White arsenic (arsenic trioxide) was one of the first materials used and was also the base arsenic used to develop other arsenic compounds. Lead arsenate was a mainstay in chemical pest control from 1892 until its cancellation in 1988. Its use was most popular prior to the marketing of DDT in the 1940s. The use of phosphate fertilizers significantly increases the amount of arsenic leached from soil contaminated with lead arsenate pesticide residues (Davenport and Peryea, 1991). The organic arsenical pesticides consist of monosodium methane arsonate (MSMA), disodium methanearsonate (DSMA), calcium acid methanearsonate (CAMA), and cacodylic acid and its sodium salt (http://www.epa.gov/oppsrrd1/reregistration/ organic_arsenicals_fs.html). Some of the first concerns about pesticide safety were raised over lead arsenate residue on fruit and in orchards, and to this day, some orchard soils remain contaminated with lead and arsenic. Arsenic in the form of chromated copper arsenate (CCA) is used today as a wood preservative.

The International Code of Conduct on the Distribution and Use of Pesticides (FAO, 2005) is the worldwide guidance document on pesticide management for all public and private entities engaged in, or associated with, the distribution and use of pesticides. Based on the framework of the Code of Conduct, various guidelines have been developed. Many countries in the world including Sri Lanka use these guidelines and specifications for the purpose of registration and quality control of pesticides. The FAO/WHO "Joint Meeting on Pesticide Specifications" (JMPS) is composed of scientists collectively possessing expert knowledge of the development of specifications, and the ROP in Sri Lanka uses these specifications when registering a pesticide in Sri Lanka. There are no maximum allowable limits for Arsenic in FAO specifications, except for the active ingredients that utilize Arsenic compounds in the process of production.

Arsenic in pesticides – a case from Sri Lanka

The Control of Pesticides Act No 33 of 1980 and its amendment No 6 enacted in 1994 regulate the importation and use pesticides in Sri Lanka, with the ROP as the designated authority, and requires that all pesticide products used in the country to be registered under the Act. In Sri Lanka, importation of pesticides with Arsenic as the active ingredient (a.i.) is prohibited by a gazette notification (Gazette No.1190/24, 2001). However, it does not provide any authority to prohibit importation of pesticides with Arsenic as minute impurities. The MSMA, a herbicide containing Arsenic as the active ingredient (a.i.), was imported to Sri Lanka previously in the latter part of the 20^{th} century mainly to be used for rubber plantations, has been stopped due to the enactment of the above Act.

A group of academia from two universities of Sri Lanka recently claimed, through media networks, that the cause for Chronic Kidney Disease of Unidentified Etiology (CKDu) in the North Central and Uva Provinces of Sri Lanka is deposition of high levels of Arsenic compound in kidney. It was implied that people acquire Arsenic from eating rice contaminated with high levels of Arsenic, and the use of pesticides containing high levels of Arsenic was stated as the reason for such contamination. In addition, the same group of scientists has also claimed the presence of high levels of Mercury in most of the pesticides used in the region (*Note*: this article does not deal with Mercury. However, it is important to note that the Gazette No.1190/24, also prohibits importation of pesticides with Mercury as the a.i.) This prompted the Department of Agriculture of Sri Lanka to launch a series of activities to respond to these allegations as the issue was given extensive media coverage.

As an initiative the Office of the ROP wrote to individual members of the group of scientists who claimed to have found Arsenic in pesticides and requested a report of their findings including the names of pesticides that contained the element, their points of sale, method used for detecting Arsenic, and the accuracy and precision of the instrument used for analysis. However, instead of a scientific report, only a list of 28 pesticides with no other information was received from this group. Based on this list, the office of the ROP took action to collect samples from sales outlets in Padaviya Siripura areas in the North Central Province and Girandurukotte and Dehiattakandiya areas in the Uva province, where CKDu incidence is reported to be high (Navaratne *et al.*, 2009).

(a) Sampling procedure and analysis

The sampling procedure followed the guidelines given in the Control of Pesticides Act No. 33 of 1980. Accordingly, pesticides in a single container was divided into three equal samples and sealed in front of the shop owner. One of the sealed samples was given back to the shop owner with written instruction keep it safely. Other two samples were brought to the Office of the ROP and one sample was kept securely stored and the other was sent for analysis to check for the presence of Arsenic and Mercury. The sample kept at the point of sale can be used by the affected party, with the permission of the ROP, to analyze the same samples from any laboratory the affected party wishes in case the analytical reports of the Office of the ROP is positive on the presence of elements tested. The analytical results of the affected party, if contravene the results of the Office of the ROP, can be used to challenge the ROP in a court of law and the court can order the release of the sample kept in the ROP office to a laboratory of choice of the court, for resolution of the conflict.

The Control of Pesticides Act No. 33 of 1980 designates 'authorized analyst' where the ROP can accept analytical results. Accordingly, samples of 23 a.i. (28 pesticide formulations) were tested at the Industrial Technology Institute (ITI) of the Ministry of Technology and Research, Sri Lanka using a hydride generation atomic absorption spectroscopy. Three of the tested pesticides were found to contain Arsenic in low quantities (Table 1).

The alleged presence of Arsenic in pesticides and the use of media by proponents have led to a media frenzy in the country. This has resulted in the ROP giving directives to temporarily hold importation, distribution and sales of the Arsenic-positive products. Before ordering the restrictions, the Office of the ROP took stock of those products in hand of the companies and ordered them to inform their agents around the country not to sell the products. The Office of the ROP also has directly informed the agents of companies and took steps to monitor the retail sale shops in releasing such pesticides, through the

'Authorized Officers' across the country who have been appointed by the Director General of Agriculture according to the provisions of the Act. This monitoring was possible as all shops, which sell pesticides, are registered in the Office of the ROP.

Table 1. Presence of Arsenic in Pesticides used in Sri Lanka.

Sample No.	*Arsenic µg/kg**	*Generic name of the pesticide*
ROP 1	Not detected	Bispyribac-Sodium 10 SC
ROP 2	334	Glyphosate (acid equivalent) 360 g/L EC
ROP 3	Not detected	Ethofenprox 100 g/L EC
ROP 4	Not detected	Imidacloprid 70% WG
ROP 5	Not detected	Profenofos 500 g/L EC
ROP 6	Not detected	Carbosulfan 200 g/L SC
ROP 7	Not detected	MCPA 600 g/L SL
ROP 8	Not detected	Fenoxaprop-p-ethyl 69 g/L
ROP 9	166	Carbofuran 3% G
ROP 10	Not detected	Chloprifos 400 g/L EC
ROP 11	Not detected	Fenoxaprop-p ethyl 69 g/L OD
ROP 12	Not detected	Chlorpyrifos 400 g/L EC
ROP 13	Not detected	Ptretilachlor+Pyribenzoxim 300+20 g/L EC
ROP 14	Not detected	Quinalphos 250 g/L EC
ROP 15	Not detected	Fenoxaprop-P-ethyl + Ethoxysulfuron 69+20 g/L OD
ROP 16	Not detected	MCPA 600 g/L SL
ROP 17	Not detected	Chlopyrifos 400 g/L EC
ROP 18	Not detected	Fenobucarb 500 g/L EC
ROP 19	Not detected	Mancozeb 80% (w/w) WP
ROP 20	Not detected	Quinalphos 250 g/L EC
ROP 21	Not detected	Tebuconazole 250 g/L EW
ROP 22	Not detected	Diazinon 500 g/L EC
ROP 23	370	Glyphosate (acid equivalent) 360 g/L SL
ROP 24	156	Thiocyclam 50% SP

*Limit of Quantification (LOQ) = 50 µg/L; Note: There is no maximum permissible level of Arsenic given in FAO pesticide guidelines, for the three pesticides that were found positive for the presence of the element.

Meanwhile the Rice Research and Development Institute (RRDI) of the Department of Agriculture took representative sample of different rice varieties throughout the country, including CKDu prevailing areas, submitted them to the ITI for analysis for the presence of Arsenic. The results revealed that Arsenic was not present in rice at detectable levels, *i.e.* the limit of quantification (LOQ) is 50 µg/L. The Sri Lanka Customs Department (SLCD), has also detained few pesticide consignments on the suspicion of containing Arsenic and Mercury. Instead of referring these containers to the Office of the ROP, which should have been the proper procedure to follow, the SLCD obtained samples and analyzed them with the help of a university that is not an authorized analyst for the purpose of the Control of Pesticides Act No 33 of 1980. In responding to a request made, the Office of the ROP has advised the SLCD that results provided by the Universities cannot be accepted, and that the confiscated pesticide consignments should be re-shipped if excessive amounts of Arsenic and Mercury were found.

(b) Recommendation of the Pesticide Technical Advisory Committee

Whether the levels of Arsenic detected are harmful for the human health and environment is to be decided by the Pesticide Technical and Advisory Committee (PeTAC) appointed according to the Act. This committee, chaired by the Director General of Agriculture, consists of 15 members of which 10 members are ex-officio including the Secretary to the Ministry of Health, Directors of Tea, Rubber and Coconut Research Institutes, the government analyst and representatives from Sri Lanka Standard Institute (SLSI) and the Labor Commissioner's office. Other five members are appointed by the Minister of Agriculture to include respected professionals with experience in research and use of pesticides who do not have any commercial interest related to the pesticide industry.

Assessing all the available information, the PeTAC has advised the ROP to request from the Industry to submit a quantitative analytical report from an independent accredited laboratory for Arsenic, Cadmium, Cobalt, Chromium, Mercury, Nickel, Lead, Tin, Thallium and Cyanide, for every consignment of future pesticide imports. These chemicals should not be present in detectable levels or should be at levels below the FAO standards if there are any such limits identified. The ROP has also been advised by PeTAC to randomly check imported consignments of pesticides for the presence of above chemicals through an authorized analyst in Sri Lanka at the expense of the pesticide importer. The Office of the ROP has thus, informed the industry that this procedure will be operational from 1st of January 2012 for all the agricultural and household pesticides. However, for the pesticides that have been reported to contain Arsenic (Table 1), namely Glyposate, Carbofuran and Thiocyclam, the new procedure will be operational immediately. Therefore, no import permit will be issued for above chemicals without the required analytical report irrespective of the trade name or manufacturer.

CONCLUDING REMARKS

People are all exposed to arsenic due to its natural presence in water, food, soil, and air, as well as its addition to the environment due to anthropogenic activities. The potential for arsenic to be harmful, however, depends on the chemical form and extent of exposure. Many countries have adopted maximum limits for Arsenic as a contaminant in food and feed due to its unavoidable presence during processing. Groundwater contamination from Arsenic due to natural and man-made activities, which has also resulted in Arsenic contamination in plant matter including grains, have affected a large number of people, especially in Bangladesh and West Bengal, India. Arsenic contamination in rice, different soils, and tank beds have been reported in Sri Lanka but in minute quantities. Pesticides have been identified as culprits by various investigating groups in Sri Lanka for such contaminations. Though a wide media coverage have been given to the issue by interested parties, the claim is yet to be proven scientifically. The analysis carried out by the Office of the Registrar of Pesticides (ROP) with a scientifically valid sampling procedure and using a laboratory approved for such analysis by the Control of Pesticides Act No 33 of 1980, found only three active ingredients (a.i.) out of 23 tested at the Industrial Technology Institute (ITI) containing Arsenic in minute quantities. Although, the current regulations does not give provisions to stop imports or sales of pesticides containing Arsenic if the element is not the a.i. of the pesticide product, the Office of the ROP with the advise from the Pesticide Technical Advisory Committee (PeTAC) has taken prompt action to mitigate the impacts of such pesticides products. There is a paucity of information on the maximum allowable limits of Arsenic in pesticides at the global scale. The FAO/WHO limits are applicable for drinking and irrigation water. Several countries such as China, Malaysia and Singapore have imposed maximum limits for Arsenic in food materials. The Sri Lanka Standards Institution (SLSI) has developed the Arsenic standards as a food contaminant, together with other food contaminants in 1987.

Considering the nature of occurrence of Arsenic, the need has arisen to decide on the maximum allowable limits (MAL) of Arsenic in food and feed materials used in Sri Lanka, and the products imported to the country, including pesticides. The MAL should be according to the levels of quantification (LOQs) of the laboratories identified by the Office of the ROP for analysis of Arsenic. Importers, dealers (whole-sellers and retailers) and consumers should be educated on the impacts of Arsenic and every effort should be taken to minimize the contamination.

REFERENCES

Biswas, B.K., R.K. Dhar, G. Samanta, B.K. Mandal, D. Chakraborti, I. Faruk, K.S. Islam, M.M. Chowdhury, A. Islam, and S. Roy. 1998. Detailed study report of Samta, one of the arsenic-affected villages of Jessore District, Bangladesh. Current Science, 74: 134–145.

Borgono, J.M., P. Vicent, H. Venturino, and A. Infante. 1977. Arsenic in the drinking water of the city of Antofagasta: epidemiological and clinical study before and after the installation of a treatment plant. Environmental Health Perspectives. 19: 103–105.

Boyle R.W. and I.R. Jonasson. 1973. The geochemistry of arsenic and its use as an indicator element in geochemical prospecting. J. Geochem. Explor. 2: 251–296.

Caroli, S., C, Frazzoli, M, D'Amato, and Gy. Záray. 2007. Arsenic and other potentially toxic trace elements in rice. In: The Determination of Chemical Elements in Food: Applications for Atomic and Mass Spectrometry (Ed. S. Caroli) John Wiley: Rome, Italy.

Caroli, S., S. D'Ilio, M. Alessandrellim and R. Cresti. 2002. Arsenic content of various types of rice as determined by plasma-based techniques. Microchem. J., 73: 195–201.

Cebrian, M.E., A. Albores, M. Aguilar, and E. Blakely. 1983. Chronic arsenic poisoning in the North of Mexico. Human Toxicology. 2: 121–133.

Chandrajith, R., C.B. Dissanayake, and H.J. Tobschall. 2005. The abundances of rarer trace elements in paddy (rice) soils of Sri Lanka. Chemosphere. 58:1415–1420

Chandrajith, R., K. Mahatantila, H.A.H. Jayasena and H.J. Tobschall. 2008. Geochemical characteristics of sediments from a reservoir (tank) ecosystem in Sri Lanka. Paddy Water Environ. 6:363–371

Chatterjee, A., D. Das, B.K. Mandal, T.R. Chowdhury, G. Samanta, and D. Chakraborti. 1995. Arsenic in ground water in six districts of West Bengal, India: the biggest arsenic calamity in the world. Part 1. Arsenic species in drinking water and urine of the affected people. Analyst, 120: 643–650.

Chen, S.L., S.R. Dzeng, M.H. Yang, K.H. Chiu, G.M. Shieh, and C.M. Wai. 1994. Arsenic species in groundwaters of the blackfoot disease area, Taiwan. Environ. Sci. Technol. 28: 877- 881.

Chilvers, D.C. and P.J. Peterson. 1987. Global cycling of arsenic. In: Lead, Mercury, Cadmium and Arsenic in the Environment. (Eds. T.C. Hutchinson and K.M. Meema). Chichester, John Wiley & Sons, pp 279–303.

Das, D., A. Chatterjee, B.K. Mandal, G. Samanta, and D. Chakraborti. 1995. Arsenic in ground water in six districts of West Bengal, India: the biggest arsenic calamity in the world. Part 2. Arsenic concentration in drinking water, hair, nails, urine, skin-scale and liver tissue (biopsy) of the affected people. Analyst, 120: 917–924.

Das, D., G. Samanta, B.K. Mandal, T.R. Chowdhury, C.R. Chanda, P.P. Chowdhury, G.K. Basu and D. Chakraborti. 1996. Arsenic in groundwater in six districts of West Bengal, India. Environ Geochem Health, 18: 5–15.

Davenport, J.R. and K.I. Peryea. 1991. Phosphate fertilizer influences leaching of lead and arsenic in a soil contaminated with lead arsenate. Water, Air and Soil Pollution. 57/58: 101-110.

De Sastre, M.S.R., A. Varillas, and P. Kirschbaum. 1992. Arsenic content in water in the northwest area of Argentina,. Proc. of Seminar on Arsenic in the Environment and its Incidence on Health, Universidad de Chile (Santiago). pp 91–99.

Dhar, R.K., B.K. Biswas, G. Samanta, B.K. Mandal, D. Chakraborti, S. Roy, A. Fafar, A. Islam, G. Ara, S. Kabir, A.W. Khan, S.A. Ahmed and S.A. Hadi. 1997. Groundwater arsenic calamity in Bangladesh. Current Science. 73: 48–59.

FAO. 2007. Remediation of arsenic for agriculture sustainability, food security and health in Bangladesh. Working Paper – FAOWater, Food ad Agriculture Organization of United Nations. 28 pp.

FAO. 2005. International Code of Conduct on the Distribution and Use of Pesticides – Revised Edition. Food and Agriculture Organization of the United Nations, Rome. 36 pp.

FAO/WHO. 2011. Codex committee on contaminants in foods. Joint FAO/WHO food standards programme. Food and Agriculture Organization of the United Nations and the World Health Organization, Rome. 28 pp.

Fordyce F.M., T.M. Williams, A. Palittpapapon and P. Charoenchaisei. 1995. Hydrogeochemistry of arsenic in an area of chronic mining-related arsenism, Ron Phibun District. Keyworth, UK: British Geological Survey.

Duxbury, J.M., A.B. Mayer, J.G. Lauren, and N. Hassan. 2003. Food chain aspects of arsenic contamination in Bangladesh: Effects on quality and productivity of rice. J. Env. Sci. Health. 38: 61–69.

Garelick H., H. A. Jones, E. Dybowska and E. Valsami-Jones, 2008. Arsenic pollution sources. Rev. Environ. Contam. Toxicol., 197: 17-60.

Gazette No. 1190/24. 2001. The gazette of the Democratic Socialist Republic of Sri Lanka, Department of Government Printing, Colombo, Sri Lanka.

http://www.who.int/water_sanitation_ health/dwq/arsenic/en/ (accessed on 5th August 2011)

http://www.epa.gov/oppsrrd1/reregistration/ organic_arsenicals_fs.html (accessed on 31st August 2011)

http://www.fda.gov/Food/FoodIngredientsPackaging/FoodAdditives/FoodAdditiveListings/ucm091048.htm (accessed on 26th July 2011)

Indu, R., S. Krishnan, and T. Shah, 2007. Impacts of groundwater contamination with fluoride and arsenic: affliction severity, medical cost and wage loss in some villages in India. International Journal of Rural Management. 3: 69-93.

IPCS. 2011. Arsenic and arsenic compounds. In: Environmental Health Criteria 224. International Programme for Chemical Safety, World Health Organization, Geneva.

Jayawardene, C.D.R.A. 1987. Standards for food contaminants. Vidurava. 10: 9-13.

Kipling, M.D. 1977. Arsenic. In: The Chemical Environment (Eds. J. Lenihan and W.W. Fletcher). Glasgow, Blackie, pp 93–120.

Kurttio, P., H. Komulainen, E. Hakala, H. Kahelin, and J. Pekkanen. 1998. Urinary excretion of arsenic species after exposure to arsenic present in drinking water. Arch Environ Contam. Toxicol. 34: 297–305.

Lokuge, K.M., W. Smith, B. Caldwell, K. Dear and A.H. Milton. 2004. The effect of arsenic mitigation interventions on disease burden in Bangladesh. Environmental Health Perspectives. 112: 1172-1177.

Mandal, B.K., T.R. Chowdhury, G. Samanta, G.K. Basu, P.P. Chowdhury, C.R. Chanda, D. Lodh, N.K. Karan, R.K. Dhar, D.K. Tamili, D. Das, K.C. Saha and D. Chakraborti. 1996. Arsenic in groundwater in seven districts of West Bengal, India – The biggest arsenic calamity in the world. Current Science. 70: 976–986.

Mukherjee, A., M.K. Sengupta, M.A. Hossain, S. Ahamed, B. Das, B. Nayak, D. Lodh, M.M. Rahman, and D. Chakraborti. 2006. Arsenic contamination in ground-water: a global perspective with special emphasis on the Asian scenario. Special issue on arsenic. Journal of Health, Population, and Nutrition 24(2): 142–163.

Nahar, N. 2009. Impacts of arsenic contamination in groundwater: case study of some villages in Bangladesh. Environ. Dev. Sustain. 11: 571–588.

Nakayama, S.M.M, Y. Ikenaka, K. Hamada, K. Muzandu, K. Choongo, and H. Teraoka. 2011. Metal and metalloid contamination in roadside soil and wild rats. Environmental Pollution. 159: 175-181

Navaratne, A.N., A. M. Devasurendra, C. Magamage, C.B. Dissanayake, T. Abeyasekara and N.T.C. Athuruliya. 2009. Pesticide and pesticide residue analysis of drinking water in Girandurukotte area where chronic kidney disease is prevalent. Proceedings of the Peradeniya University Research Sessions, Sri Lanka. pp. 45-47.

Northoff, E. 2007. Arsenic threat in rice - Reducing arsenic levels in rice through improved irrigation practices (http://www.fao.org/newsroom/en/news/2007/1000734/index.html).

Onishi, H. 1969. Arsenic. In: Handbook of Geochemistry (Ed. K.H. Wedepohl), Vol. II-2. New York, Springer

Oremland, R.S. and J.F. Stolz. 2003. The ecology of arsenic. Science. 300: 939-944.

Senanayake, N., W.A.S. de Silva, and M.S.L. Salgado, 1972. arsenical polyneuropathy - a clinical study. Ceylon med. J., 17: 195-203.

Saifuddin Md. and Karim, Md. M. 2001. Groundwater arsenic contamination in Bangladesh: causes, effects and remediation. Proceedings of the 1st IEB international conference and 7th annual paper meet. Chittagong, Bangladesh. Institution of Engineers, Bangladesh.

Taleshi, M.S., J.S. Edmonds, W. Goessler, M. Jos, R. Chancho, G. Raber, K.B. Jensen and K.A. Francesconi. 2010. Arsenic-Containing Lipids Are Natural Constituents of Sashimi Tuna. Environ. Sci. Technol. 44:1478–1483

Tanaka, T. 1990. Arsenic in the natural environment. Part II: Arsenic concentrations in thermal waters from Japan. Appl. Organomet. Chem. 4: 197–203.

Valentine, J.L. 1994. Review of Health Assessments for US/Canada Populations Exposed to Arsenic in Drinking Water. In: Arsenic – Exposure and health - Chapter 14 (Eds. W.R. Chappell, C.O. Abernathy and C.R. Cothern) Northwood, UK, Science and Technology Letters, pp 139–152.

Vithanage, M., R. Chandrajith, A. Bandara, and R. Weerasooriya. 2006. Mechanistic modeling of arsenic retention on natural red earth in simulated environmental systems. J. Colloid Interface Sci. 254: 265–272

WHO. 2011. Evaluation of certain contaminants in food. Seventy-second Report of the Joint FAO/WHO Expert Committee on Food Additives. World Health Organization, Geneva. 105 pp.

Weerasooriya, R., H.J. Tobschall, H.K.D.K. Wijesekara, E.K.I.A.U.K. Arachchige, K.A.S. Pathirathne. 2003. On the mechanistic modeling of As (III) adsorption on gibbsite. Chemosphere 51:1001–1013

Welch A.H., M.S. Lico and J.L. Hughes. 1988. Arsenic in groundwater of the western United States. Ground Water. 26: 333–347.

Williams, P.N., A.H. Prince, A. Raab, S.A. Hossain, J. Feldmann, and A.A. Meharg. 2005. Variation in arsenic speciation and concentration in paddy rice related to dietary exposure. Environ. Sci. Technol. 39: 5531–5540.

Woolson, E.A. 1977. Fate of arsenicals in different environmental substrates. Environmental Health Perspectives. 19: 73-81

Woolson, E.A. 1977. Bioaccumulation of arsenicals. In: Arsenical Pesticides. (Ed. E.A. Woolson), American Chemical Society Symposium Series 7, Washington, D. C.

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