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Seleniferous soils:

Spatial distribution, impact on plant, human and animal health, and its management

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The selenium (Se) concentration in soils is mainly determined by the selenium content of the parent rock, the topography and the climate, but introduction of seleniferous erosion material, poor drainage of soils, irrigation with selenium containing water, usage of phosphate fertilizer, influence of mining operations or volcanic eruptions and combustion of coal and petroleum can considerably enhance the soil selenium content. In agricultural crops, symptoms of selenium toxicity include loss of chlorophyll, whitening of leaves, stunting of plants etc. In wheat crop, whitening of leaves also include pinkish coloration in lower side of leaves. In humans, regular consumption of cereals grown in these soils results in the visible symptoms like cracked and discolored nails. Other symptoms include loss of body hairs, bleeding from the nails and gradual loss of health. The fodders grown on these soils may prove fatal for the domestic animals which can lead to mortality.

Key words: Animal health, Human, Plant, Seleniferous soils

SELENIUM (Se) occupies 70th position in order of abundance among naturally occurring elements. It combines directly and hydro-chemically with both metals and non-metals to form various organic and inorganic compounds. In natural environments, Se exists in the form of four inorganic species namely selenate $(SeO_4)^{2"}$, selenite $(SeO_3^{2"})$, elemental Se (Se^0) and selenide $(Se^{2"})$. The Se oxy-anions are among the trace elements common in soils which are soluble in water and especially the $(SeO_4)^2$ is prone to leaching. Generally, selenite has a higher affinity to adsorb onto soil particles compared to selenate. As a consequence, selenate is more mobile and easily available to plants especially under oxidizing, neutral to alkaline conditions. Elemental Se occurring under reducing conditions, is insoluble and exhibits no or very little toxicity. Selenide is a highly toxic gas, however, it is rapidly oxidized to non-toxic elemental Se in the presence of air. Although selenium (Se) does not act as an essential element in plant growth and development yet its existence in food and fodder is important for animal and human health. It is required as micronutrient for several physiological and biochemical processes mainly as a component of seleno proteins or amino-acids like selenomethionine and selenocysteine.

Distribution of seleniferous soils

Considerable enrichments of Se can be found in carbon shales (e”600 mg/kg), phosphatic rocks (d”300 mg/kg) or coal 6500 mg/kg). Selenium concentrations in soils are generally low with 0.01–2 mg/kg (average: 0.4 mg/kg) but soils with highly elevated Se concentrations (>2–5000 mg/kg), called seleniferous soils, are widely distributed throughout the world (USA: up to 28 mg/kg; Ireland: up to 1,200 $mgkg^{-1}$, China: up to 59 mg/kg). Several regions throughout the world like Australia, China, India and USA are known to suffer from Se intoxication due to consumption of food and forage grown on seleniferous soils. Pockets of seleniferous soils have also been identified in India especially in the North-eastern parts of Punjab and Haryana. In India, Selenium came into the scientific focus in the mid-seventies after an animal disease locally called ‘Degnala’ was found to be associated with high intake of Se in fodder grown on alkali soils of Haryana. Since last two decades, presence of high concentration of selenium and its toxicity to farm animals has been mainly reported for the North-eastern parts of Punjab, namely in Nawanshahr (renamed as Shaheed Bhagat Singh Nagar) and Hoshiarpur districts (Fig. 1). In India, both Se deficient (0.025–0.71 mg/kg) and seleniferous soils (1–20 mg/kg) have been recognized. In the Nawanshahr–Hoshiarpur region in Punjab, Se in the soil ranged from

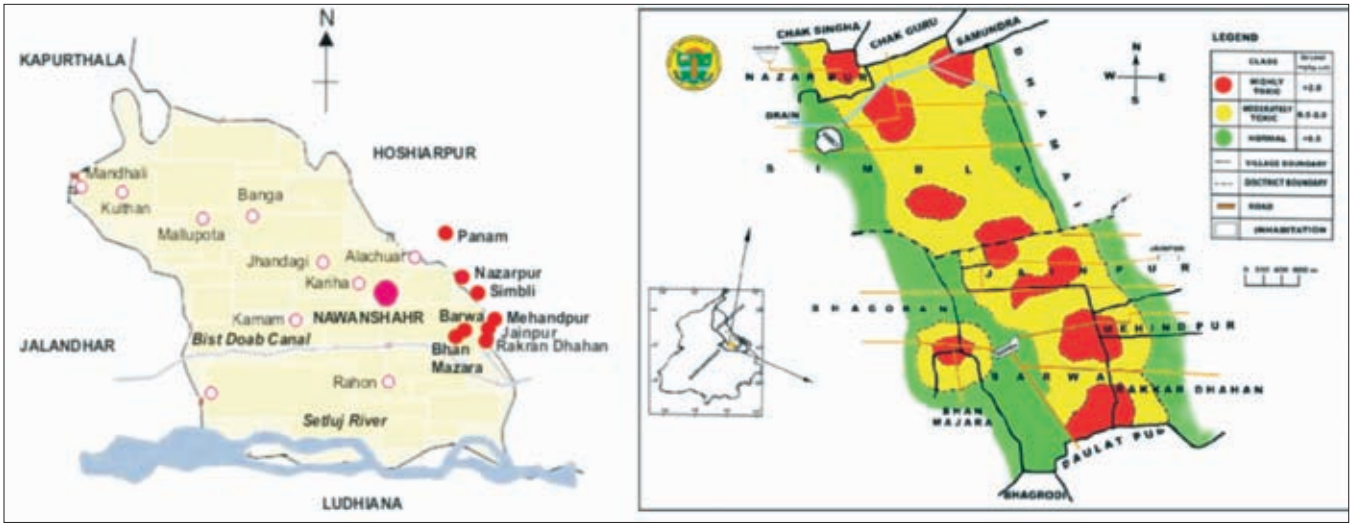


Fig. 1. Se affected region at boundary between Hoshiarpur and Nawanshahr (Courtesy: Bhalla *et al.* 2011)

0.25 to 4.55 mg/kg with a mean value of 3.63 mg/kg.

Reasons of high Se concentration

The Se concentration in soils is mainly determined by the Se content of the parent rock, the topography and the climate, but introduction of seleniferous erosion material, poor drainage of soils, irrigation with Se containing water, usage of phosphate fertilizer, mining operations, volcanic eruptions, combustion of coal and petroleum can considerably enhance the Se content in the soils. The mobility and bio-availability of Se depends on processes like adsorption, precipitation and transformation which are heavily influenced by the pH-value, redox conditions, amount of competing ions, Se-speciation, soil mineralogy, organic matter content, microbiology, plant species, etc. Process of natural weathering of Se-containing rocks and minerals, in conjunction with local irrigation practices, has led to the redistribution of Se, and Se containing salts to shallow aquifers, streams and wetland areas. Transport of Se-rich sediments from the Shiwalik hills along with flood water through seasonal streams and deposition in low lying areas over a period of time has led to the development of seleniferous soils in northwestern India. Transport of Se in appreciable quantities from soil through plants to animals and humans has resulted in serious health hazards. Utilization of Se-contaminated underground water for irrigation of crops may add up to 1,420 g/ha/year. Se year, thus further accentuating the problem of Se toxicity in this region. Where high concentrations of Se occur naturally in the soil, oxidized forms of Se are easily mobilized in underground and surface water.

Symptoms of selenium toxicity

Acceptable range for Se in forage plants by the EPA is 2 to 5 mg/kg. An acute long-term toxic effect of Se on animals is likely to occur when the Se concentration is above 5 mg/kg in forage. The recommended daily dietary allowance for selenium is 40 μg/d for persons above 14 years and the tolerable upper intake level (TUL) is 400 μg/d. Exceeding TUL can lead to chronic or acute selenosis. Consumption of food with selenium concentration less than 0.05 to 0.10 or more than 4-5 mg/kg (dry weight) may result in severe deficiency or toxicity in animals and humans.

Plants: Among agricultural crops, wheat plants show typical symptoms of selenium toxicity which can be described as snow-white or papery-white chlorosis with pink coloration at the lower surface of leaves. All the forage and cereal grain crops, when grown on such soils absorb selenium in levels toxic for animal and human consumption. Selenium content of wheat plants exhibiting varying degrees of toxicity symptoms ranges from 108 to 450 mg/kg (Fig. 2).

Humans: Regular consumption of cereals grown in these soils results in the visible symptoms like cracked and discolored nails (Fig. 3), loss of body hairs, bleeding from the nails and gradual loss of health.

Animals: The fodders grown on



Fig. 2. Symptoms of selenium toxicity in wheat crop (Courtesy: Bajaj *et al.* 2011.



Fig. 3 Symptoms of selenium toxicity in humans (Courtesy: *Bajaj et al*. 2011; www.thedoctorwillseeyounow.com)

these soils may prove fatal for the domestic animals which can lead to mortality. Acute selenium toxicosis is quite rare and occurs when a high dose of selenium is ingested over a short duration. Symptoms include abnormal movement and nervousness, dark watery diarrhoea, elevated temperature, weak and rapid pulse, laboured breathing, bloating and abdominal pain, pale, blue mucous membranes and dilated pupils. The symptoms may resemble those of rabies and so extra care should be taken not to contact the animal's saliva; and call your veterinarian. Death occurs within a few hours to days. There is no known treatment for acute selenium toxicosis. Subacute selenium toxicosis (called 'blind staggers') is usually seen in the spring when animals are craving green vegetation. Symptoms include staggering, wandering aimlessly and head pressing. Chronic selenium toxicosis (called 'alkalai disease') is caused by smaller amounts of selenium ingested through pasture, hay, or water, usually over a longer period of time. Symptoms may also include weight loss, hair loss (especially on mane and tail), and lameness. In severe cases the hoof wall may slough off (Fig. 4).

Management practices in high selenium soils

The potential for Se transfer from contaminated soils to plants can be minimized by application of gypsum and carefully selecting crops having low Se accumulation capacity. Cultivation of plants which accumulate high concentrations of Se could help in lowering the amount of Se in contaminated soils. Efficiency in Se removal by plants depends upon Se concentration in plant tissues and crop biomass. Certain native weed plants are known to accumulate Se in shoots up to several thousand mg per kg dry matter, but these do not accumulate enough biomass to remove large quantities of Se from soil. Some agricultural crops exhibit Se concentrations ranging from 50 to 5000 μg Se per kg dry matter and accumulate biomass up to 10, D ha. In comparison with other crops, plant species such as *Brassica* that requires high concentration of S will accumulate high concentrations of Se when grown on Se-rich soils. Agroforestry trees like *shisham* (*Dalbergia sissoo*), poplar (*Populus deltoides*) and eucalyptus (*Eucalyptus* hybrid) can remove 2385, 1845 and 1407 g Se/ha , respectively, in one growing season. Selenium removal further increased to 4207 g/ha under an agroforestry farming system of poplar–mentha (*Mentha viridis*) D wheat. Besides Se removal through harvested plant biomass, a small fraction of Se is being continuously lost into the atmosphere via biological volatilization. By this process, volatile Se compounds, e.g. dimethylselenide or dimethyldiselenide, are released into the atmosphere as non-toxic forms of Se. The efficacy of the phyto-remediation process is generally considered greater under controlled conditions than under field conditions. Field studies in a seleniferous region are, vital for developing reliable phytoremediation approaches for remediation of Se-contaminated soils. Following points include some measures that can be followed by farmers to minimize the harmful effect of high selenium concentration:

- Fodder/grain crops can be grown by applying gypsum @ 350 to 400 kg per acre in the alternate years. It helps in reducing absorption of selenium by agricultural crops up to 60-70%.
- Among the fodder crops in *rabi*,



Fig. 4. Symptoms of selenium toxicity in animals (Courtesy: http://horse.mlbcardvalue.com; http://poisonousplants.ansci.cornell.edu)

oats should be preferred instead of barseem.

- If barseem is grown on these soils, avoid feeding of the animals on first cutting.
- During *kharif*, fodder crops like maize, pearl millet and sorghum should be preferred.
- In case of multi-cut fodders, avoid feeding 1st/2nd cut to animals as it contains 2-3 times more selenium than the following cuts.

Continuous cultivation of *Brassica napus/Eruca sativa* should be preferred for lowering Se in affected soils.In area of high selenium concentration, tube-wells should be dug at a depth of about 400 ft (120 m). Maize-wheat cropping system should be preferred instead of rice-wheat. In agroforestry, trees like poplar, Eucalyptus and mulberry decrease the selenium content in soil through phyto-remediation. Selenium rich plants can be safely disposed off through incorporation in the non-seleniferous soils @ 80 q/ acre. Selenium rich materials should never be disposed off at the same site every year.

SUMMARY

Selenium (Se) does not act as an essential element in plant growth and development yet its existence in food and fodder is important for animal and human health. Soils with highly elevated Se concentrations (>2–5000 mg/kg) called seleniferous soils, are widely distributed throughout the world. Several regions throughout the world are known to suffer from Se intoxication due to consumption of food and forage grown on seleniferous soils. Pockets of seleniferous soils have also been identified in India especially in the North-eastern parts of Punjab and Haryana. The Se concentration in soils is mainly determined by the Se content of the parent rock, the topography and the climate, but several other factors can considerably enhance the soil Se content. In agricultural crops, symptoms of selenium toxicity include loss of chlorophyll, whitening of leaves, stunting of plants etc. In wheat crop, whitening of leaves also include pinkish coloration in lower-side of leaves. In humans, regular consumption of cereals grown in these soils results in the visible symptoms like cracked and discolored nails. Other symptoms include loss of body hairs, bleeding from the nails and gradual loss of health. The fodders grown on these soils may prove fatal for the domestic animals which can lead to mortality.

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Impact of Research of ICAR-CARI

DAC Technology for all- weather biogas production technologyexclusively from poultry excreta

Industrialization and intensification of poultry farming has led to generation of poultry wastes to the tune of 28 to 30 million metric tonnes per annum. These wastes are posing many environmental and health threats due to lack of proper utilization technologies/ disposal methods. Therefore, scientists of Central Avian Research Institute, Izatnagar, Bareilly developed a novel 'DAC' *technology* for all-weather biogas production exclusively from poultry excreta. This technology was tested on a pilot biogas plant comprising of anaerobic digester (200 lit) with various common components like inlet pipe, outlet pipe, gas collector, biogas compressor, gas cylinders etc. The poultry biogas burns like LPG with blue flame. The composition of poultry biogas revealed that the methane (%, V/V) was 60.02 which is equal to or better than biogas available from other methods and substrate.





This technology helps in conservation of water as used slurry of digester is reutilized again and again as dilutor for poultry excreta. Round the year i.e. both during summer and winter biogas production is possible from this technology. It is pertinent that, in India, most of the biogas plants become non-functional during winter due to lower ambient temperature. In 'DAC' technology 12-13 to 19-20 kg poultry excreta is required for production of about 1m^3 of biogas during summer and winter 1m^3, respectively. This quantity of biogas is sufficient for cooking 3-fold meals of an average family comprising 4 to 5 members. This can also be used as heat source at poultry farm. Spent slurry of poultry biogas has good manure value and germination potential and can be easily applied in agricultural fields for organic crop production without burning effect on plants which is a common problem with crude poultry excreta.

This technology may be helpful in self-sustainability of rural poultry farmers in their energy demand. The excreta of 5,000 layers birds has capacity to produce approximately 4,100 kg biogas per annum whose market value will be around ₹ 1.31 lakh, if cost of biogas is considered @ ₹ 32.00/ kg. There is potential to produce around 128 tonnes of manure from spent slurry. The value of this manure will stand around ₹ 2.56 lakh on urea, phosphate, potash and micronutrient equivalence basis. Therefore, this technology has great potential of value addition to the tune of 5-6 times from invaluable poultry excreta.

(Courtsey: Central Avian Research Institute)