

AGROFORESTRY AS DISPOSAL OPTION FOR DOMESTIC AND INDUSTRIAL EFFLUENTS

AGROFORESTERIE COMME OPTION D'ÉLIMINATION DES EFFLUENTS DOMESTIQUES ET INDUSTRIELS

Gurbachan Singh¹

ABSTRACT

Large volume of domestic and industrial effluents are produced daily and is dumped in-situ/ ex-situ and/ or released in village ponds, open abandoned spaces in cities, sewage systems and canals etc. Such effluents are many times loaded with heavy metals and other toxic cations and anions. Sewage water without treatment around cities is used for peri –urban agriculture, particularly for cultivation of vegetables and fodder. The heavy metals associated (Plate 1) with sewage water irrigation either gets accumulated in the soil, leached into the ground water and / or accumulate in root zone soil/ plant system. Several cases of heavy metal accumulation in vegetables and fodder and their subsequent cycling in food chain (soil – plant – animal – human – atmosphere) in peri – urban areas have been raised by environmentalists and civil society organizations. In Several parts of India heavy metal accumulation such as arsenic, cadmium, selenium, fluoride etc. is detected in the soil and affecting the human and livestock populations Sustainable water recycling and waste water reuse are important now a days considering water scarcity and increased water consumption through human activities. Trees based land use system where end product is not associated with the human and animal food / feed system for livestock seems an option of great promise for disposal and credit worthy option for safe disposal of industrial effluents. There seems strong case to reserve some abandoned / wasteland in or near big cities to be planted with trees to create green belt using industrial effluents. Research to identify a list of trees tolerant to specific and multiple heavy metal stresses and different submergence regimes following different planting geometry, planting technique and management practices seems need of the hour. The three-phase strategy mentioned below for safe use of water will be discussed in this paper.

Planning for separation of domestic waste water from industrial effluents loaded with heavy metals and toxins needs to be strategized. The domestic waste water mainly comprising of human and livestock excreta can be used in agriculture by mixing with fresh water. However, close monitoring of such water on yearly basis will be needed to check nitrate leaching in soil, ground water and edible portion of the crops. Close watch on micro-organisms build-up in general and *E- coli* in particular has to be exercised.

In cases where domestic sewerage and industrial effluents are draining at one point, such water should not be used to irrigate edible crops. A part of such sewerage effluent can be used for raising green belts using high transpiration trees such as eucalyptus, dalbergia, bamboo, pongamia, casuarinas, silver oak etc. In this case, trees are raised on bunds of about one meter height and one meter width. The sewerage effluents are disposed in the furrows between tree rows. It may also be useful for rehabilitation of unused waste land areas in periphery of big cities and also along roads, railway tracks and canals. However, careful monitoring of soil, ground water and air pollution will be required to incorporate timely corrections. The most effective and practical way to deal with waste water is to establish waste water treatment plants.

Keywords: Waste water, Agroforestry, Domestic waste water, Industrial effluents, Heavy metals, Human health.

1 Gurbachan Singh Foundation for Research, Education and Development (GSFRED), Karnal-132001, India, Former Director, CSSRI, Karnal, E-mail: dr.gurbachan@gmail.com, Website: www.gsfred.org

RESUME

Un grand volume d'effluents domestiques et industriels se produit quotidiennement et est déversé sur place ou ailleurs, ou rejeté dans les étangs de village, les espaces ouverts abandonnés dans les villes, les systèmes d'égouts et les canaux, etc. Ces effluents sont souvent chargés de métaux lourds et d'autres cations et anions toxiques. Aux abords des villes, les eaux d'égout sans traitement sont utilisées pour l'agriculture périurbaine, en particulier pour la culture de légumes et de fourrage. Les métaux lourds associés (plaque 1) à l'irrigation des eaux d'égout s'accumulent dans le sol, lessivent dans les nappes phréatiques et / ou s'accumulent dans la zone racinaire du système sol/plante. Des écologistes et des organisations de la société civile ont signalé plusieurs cas d'accumulation de métaux lourds dans les légumes et le fourrage, ainsi que leur recyclage ultérieur dans la chaîne alimentaire (sol – plante – animal – humain – atmosphère) en zone périurbaine. Dans plusieurs régions de l'Inde, une accumulation de métaux lourds tels que l'arsenic, le cadmium, le sélénium, le fluorure, etc., est détectée dans le sol et affecte le bétail et la population humaine. Le recyclage durable de l'eau et la réutilisation des eaux usées sont désormais importants compte tenu de la pénurie d'eau et de l'augmentation de la consommation d'eau due aux activités humaines. Le système d'usage des sols basé sur les arbres, où le produit définitif n'est pas associé au système alimentaire humain / fourrager pour le bétail, semble une option très prometteuse et digne de crédit pour l'élimination sûre des effluents industriels. Il semble tout à fait pertinent de réserver certains terrains en friche ou abandonnés, situés dans ou près de grandes villes, de planter d'arbres afin de créer des ceintures vertes irriguées par des effluents industriels. Il est urgent de mener des recherches pour identifier des arbres tolérants à des stress spécifiques ou multiples liés aux métaux lourds ainsi qu'à divers régimes de submersion, tout en étudiant les géométries de plantation, les techniques de plantation et les pratiques de gestion appropriées. Cet article présentera une stratégie en trois phases pour une utilisation sûre de ces eaux.

Il est nécessaire d'élaborer une stratégie pour séparer les eaux usées domestiques des effluents industriels chargés de métaux lourds et de substances toxiques. Les eaux usées domestiques, composées principalement d'excréments humains et du bétail, peuvent être utilisées dans l'agriculture en étant mélangées avec l'eau douce. Cependant, une surveillance annuelle étroite de ces eaux sera nécessaire pour vérifier le lessivage des nitrates dans le sol, les eaux souterraines et la partie comestible des cultures. Une surveillance étroite de l'accumulation des micro-organismes en général et de l'*E-coli* en particulier doit être exercée.

Dans les cas où les égouts domestiques et les effluents industriels sont évacués en un point, cette eau ne doit pas être utilisée pour irriguer les cultures comestibles. Une partie de ces effluents d'égouts peut être utilisée pour créer des ceintures vertes en utilisant des arbres à haute transpiration tels que l'eucalyptus, le dalbergia, le bambou, la pongamia, les casuarinas, le chêne argenté, etc. Dans ce cas, les arbres sont élevés sur des digues d'environ un mètre de hauteur et un mètre de largeur. Les effluents des égouts sont déversés dans les sillons entre les rayons d'arbres. Il peut également être utile pour la réhabilitation des terrains en friche inutilisés en périphérie des grandes villes et aussi le long des routes, des voies ferrées et des canaux. Cependant, une surveillance attentive de la pollution des sols, des eaux souterraines et de l'air sera nécessaire pour intégrer des mesures correctives appropriées en temps utile.

La mise en place des stations d'épuration sera le moyen le plus efficace et le plus pratique de traiter les eaux usées.

Mots-clés : Eaux usées; Agroforesterie; Eaux usées domestiques; Effluents industriels; Métaux lourds; Santé humaine.

Introduction

Increasing supplies of water to meet the expanding demand of non-agricultural sectors are resulting in generation of huge volumes of wastewater in commensuration with rapidly increasing population, urbanization, improved living standards and changing dietary habits. In general, urban drainage and

disposal systems are common and the wastewaters consist of effluents from residential, institutional, commercial, industrial establishments and urban run-off water arising from rains or storms. Most of these waters are loaded with contaminants. Those require suitable treatment before use in agriculture. About 20 million hectares of agricultural land is irrigated with treated and untreated wastewater throughout world (Raschid-Sally and Jayakody, 2008). Use of untreated wastewater directly or polluted water from rivers and streams poses potential risks of pathogens and toxic chemicals contamination of crops, public health and environment in the form of soil and groundwater pollution (Drechsel and Evans 2010). As an alternative, irrigation of tree species grown for fuel and timber with wastewater seems promising approach, which can help in overcoming health hazards associated with sewage farming (Thawale et al., 2006). Developing and executing the green belts around the cities with forest trees under wastewater irrigation can further revive the ecological balance and improve environmental quality by self-treatment of wastewater through land application and forest irrigation.

Tree plantations are often expected to use water at higher rates than the shorter vegetation. This is because of greater aerodynamic roughness of tree plantations, clothesline effect in tree rows and deeper rooting system for accessing water down to several meters of soil. Thus, the systems of agroforestry, which have come to be known as HRTS (high rate transpiration systems) are the land application systems based upon the transpiration capacity of tree species those promote the treatment of wastewater through renovating capability of living soil filter enabling recycling and reuse of wastewater and conservation of nutrient energy into biomass and thereby bringing multiple benefits to society such as fuel wood, environmental sanitation and eco-restoration. Various aspects of disposal of domestic and industrial waste water through agroforestry interventions are discussed in this paper

Use of Poor-Quality Water in Agriculture

India with its 4.2 per cent share of global water resources is supporting 16.7 per cent of global population. Nearly 85 per cent of India's freshwater resources are being utilized in agriculture and the balance, 15 per cent, in domestic and industrial sector. Quantity and quality of groundwater are most important factors of high productivity and production. In general, the areas demarcated by water scarcity are also usually underlain by poor quality groundwater resources. The maximum area over saline and brackish groundwater in India occurs in the arid and semi-arid regions of Rajasthan, Haryana, Delhi, Punjab and Uttar Pradesh. Because of the scarcity of good-quality water and increasing pumping cost, brackish groundwater is being increasingly utilized for irrigated agriculture.

Because of extensive pumping of the groundwater, areas which were underlain with good-quality aquifers are being contaminated in several parts of the country. Indiscriminate use of poor-quality waters in the absence of proper soil-water-crop-livestock management practices poses a serious threat to soil, animal, human and environment health. Build-up of salinity, sodicity and heavy metals problems in soils with increased use of poor-quality water not only reduces crop productivity but many times effects become so severe that lands even go out of cultivation.

Promising Grasses and Trees for use of Poor Quality Waters

Several grass species have mechanism to tolerate high salt concentration in the root zone soil. Some of these highly tolerant grasses either exclude the absorption of salts from the soil and/or deposit the absorbed/translocated salts at point within the plant system which do not allow them to interfere in metabolic processes. Such grasses have been identified and a list according to their level of salt tolerance is given in Table I. Grasses like *Leptochloa fusca* has the potential to yield high biomass even at pH level of 10.4 and more. *Bricharia mutica* is another salt tolerant grass, which can be grown even under prolonged waterlogged and salty conditions

Several experiments have been conducted at CSSRI, Karnal and elsewhere to study the performance of these grasses in association with salt tolerant trees like *Prosopis juliflora* and *Acacia nilotica* in a unified agroforestry system (Singh et al., 1988; Singh, 1995). A field study conducted at Gudha Experimental Farm for 6 years indicated that *Leptochloa fusca* has the potential to yield about 20 metric

tons ha⁻¹ of green biomass per annum when planted with *Prosopis juliflora* in a soil of 10.4 pH. A number of medicinal and aromatic crops have been screened for salinity and sodicity tolerance in India. Crops Like Isabgol (*Plantago ovata*) and *Matricaria* can be successfully cultivated in soils having pH of 9.5 and EC between 8 and 10 dS m⁻¹. Similarly, dill (*A. graveolens*), a spice crop and *Salvadora*, a non-edible oil tree can be grown in salt-affected vertisols very successfully. Industrial species like *Euphorbia* and *Mulathi* (*Glycyrrhiza glabra*) also have good scope for cultivation in salty environments.

Table I. List of promising grasses according to their level of tolerance to soil pH

pH	Grass/forage crop	Botanical name
10.4	Karnal grass Rhodes grass Gatton panic Bermuda/Dub grass	Leptochloa fusca Chloris gayana Panicum maximum Cynodon dactylon
10.0	Para grass	Brachiaria mutica
9.6	Blue panic	Panicum antidotale
9.2	Hybrid Napier Setaria grass	Pennisetum purpureum Setaria anceps
8.8	Anjan grass Guinea grass Deenanath grass	Cenchrus ciliaris Panicum maximum Pennisetum pedicellatum

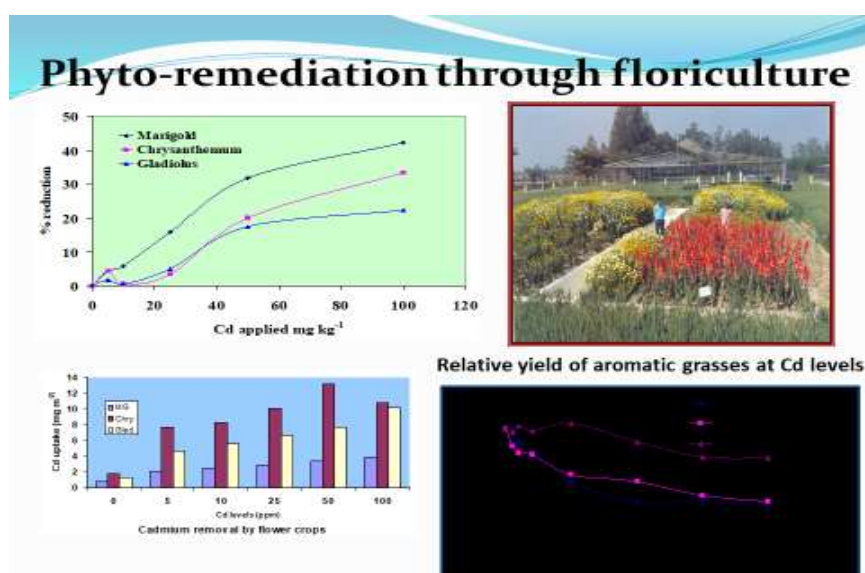
The pH value at which 50 per cent or less than 50 per cent yield reductions occurred.

Phytoremediation

Phytoremediation is an emerging technology using selected plants to clean up the contaminated environment from hazardous contaminant to improve the environment quality. Heavy metals, the most potential contaminants in wastewater, cannot be degraded biologically but only transformed from one oxidation state to another or form organic complexes. Amongst the 300 accessions of 30 plant species, Brassica (juncea, napus, rapa) exhibited moderately enhanced Zn and Cd accumulation (Ebbs et al. 1997). The fern *Pteris vittata* was reported capable of accumulation of Arsenic to the extent of only 0.7 mg g⁻¹ dry weight of plant and aquatic *Azolla caroliniana* and terrestrial *Populus nigra* could accumulate 0.2 mg Arsenic g⁻¹ dry weight of plant root plants (Tangahu et al. (2011).

Though some species have shown hyperaccumulation of different metals; as Brassica campestris, B. carinata, B. juncea lead and B. nigra > 100 mg lead g⁻¹ dry weight; and B. napus, B. oleracea and Helianthus annuus > 50 mg Pb g⁻¹ dry weight; and B. juncea >1 mg Hg g⁻¹ dry weight but with every chance of food chain contamination. However, if cultivated for fuel wood with trees as component of agroforestry can serve purpose of phytoremediation. Similarly, Lal et al. (2008) observed that cut-flowers such as marigold (*Tagetes erecta*), chrysanthemum (*C. indicum*) and gladiolus (*Gladiolus grandiflorus*) have promise in Cadmium contaminated environment (Figure-1) while Jasmine sambac, Jasmine grandiflora and Polyanthus tuberosa are the other ornamental and cut flower species suitable for urban greening and avenue culture with wastewater irrigation (Augustine 2002).

Lal et al. (2013) further observed that lemon grass (*Cymbopogon flexuosus*) could be successfully grown using primary treated municipal wastewater for achieving higher productivity without contamination of the end product – the essential oil. Lemon grass could also accumulate heavy metals such as Cadmium, Chromium, Nickel and Lead from wastewater used for irrigation containing these metals acting as phytoremedial agent. More than 400 plant species have been identified as metal hyper-accumulators (Reeves 2003, Lone et al. 2008), which include either high biomass plants such as willow (*Salix* spp.) or those that have low biomass but high hyper-accumulating characteristics such as species of *Thlaspi* and *Arabidopsis*.



(Figure 1)

Urban Plantations for Wastewater Disposal

Waste water is used for irrigation to agricultural crops and forest plantations since centuries. Untreated sewage was used to irrigate; *Acacia salicina*, *Eucalyptus camaldulensis* and *Tamarix aphylla* (Armitage 1985); mixed hardwood stand consisting mainly of oaks (*Quercus* spp.), red pine (*Pinus resinosa*) and white spruce (*Picea glauca*) (Braatz 1996) in Australia; and neem (*Azadirachta indica*) and date palm (*Phoenix dactylifera*) in UAE, forestry plantations for urban greening. In Murray Darling Basin (Australia), area under wastewater irrigated tree plantations increased from 500 to 1500 ha in > 60 variable size effluent sites (CSIRO 1995). Most of these studies were aimed on handling the disposal of wastewater problem, however, to utilize the nutrient potential of wastewater, economic gains are also considered in recent plantations. For example, in Egypt, Omran et al. (1998) observed better growth of orange trees. The availability of sufficient quantity of nutrition in wastewater induced luxuriant growth of the most of these plantations. Tabari et al. (2011) observed in afforested *Pinus eldarica* (15 years old) stands that trees showed better growth in the field irrigating using municipal water than in plots irrigated with well water, as indicated by the increased diameter at breast height (DBH), basal area and standing volume of trees in wastewater irrigated fields.

Heavy Metals Recycling Potential

To tackle the limitations of conventional wastewater treatment systems avoid food chain contamination due to use in agriculture; alternate low cost, eco-friendly methods need to be evolved for safer disposal and desired level of treatment (Figure II). Phyto-remediation, a cost-effective 'green' technology, mainly relies on nutrients, salts and metals-accumulating plants to remove polluting metals from soil or water. In comparison to food arable crops, wastewater irrigation in plantations is relatively safer, cost-efficient and environmentally sounds way to treat and dispose wastewater. On wastewater irrigated soils, *Acacia nilotica*, *Dalbergia sissoo*, *Acacia modesta* accumulated relatively higher heavy metals than several bushes and grass species. Heavy metal accumulation in these species varied as per the composition of wastewater in the order of Fe > Zn > Cr > Pb > Ni > Cd > As. All the species exhibited higher heavy metal composition in the root as compared to shoot (Irshad et al. 2015). Beneficial effects of organic load in wastewater and sludge on tree growth processes has been found to far outweigh any adverse impacts of the added metals. Several tree species grown on sludge-amended spoil had the highest concentrations of Cd, Cu, Ni and Zn in root tissues. Wood and bark are important sinks for biologically available metals, with additional sink tissue being formed each growing season. Massive root systems

of trees upon establishment bind the soil thus promote soil stabilization. Moreover, addition of litter to the surface quickly leads to an organic cover over the contaminated soil. In addition, transpiration by the trees reduces downward and lateral flow of water in the soil, thus reduces the amounts of heavy metals transferred to ground- and surface water.



(Figure II)

Nutrient Removal Through Treatment of Waste Water

A major concern with wastewater irrigation is the fate of excess than plantation sequestration potential of nitrogen (N) and phosphorus (P) in the environment as these cause pollution of surface and groundwater (Duncan et al. 1998). While P will not usually be a problem in short to medium term, particularly on soils with high P adsorption capacity, there is always potential risk for leaching of N (as nitrate) to groundwater. Fast growing trees initially accumulate significant amounts of N, but the net N requirement declines after canopy closure stage of plantation when recycling sets in via decomposition of litter and internal translocation. Therefore, removal of N and other nutrients by plantation can be maximized by growing trees in short rotations. However, short rotations (<6 years) may compromise water use, and also limit the potential products to biomass for fuel rather than higher value wood. Across *Eucalyptus* species, above-ground elemental uptake (mainly N, P, K) by coppiced or original trees generally increase in proportion to biomass accumulation with > half of N being in foliage. Duncan et al. (1998) observed that under high N (15 mg L^{-1}) strength wastewater irrigation, maximum amount of N was sequestered in the potentially harvestable biomass of 3 year short rotations; while longer rotations (12 years) could achieve a similar balance of inputs through assimilation of N equivalent to supply from only lower (5 mg L^{-1}) strength effluents. Another serious issue associated with wastewater irrigation is the management of metallic pollution. The tree species for urban greening should be selected on the basis of nature of elements present in wastewater to be used. *Acacia*, *Mimosa*, *Anadenantera* and *Salix* are efficient in absorbing Cadmium; *Eucalyptus* and mangroves are efficient in Lead accumulation; *Genipa americana* is efficient in Chromium absorption; and *Salix viminalis* can remove up to 20% Cadmium and 5% Zn. Sewage treatment plants are established in large cities only and as such there are no or a very few wastewater treatment facilities available in small and medium urban settlements of most of third world countries. Apparently for these areas, decentralized natural treatment systems such as urban plantations with green areas and constructed wet lands could prove cost effective and environment friendly alternative wastewater treatment.

Wastewater Treatment with Urban Plantations and Environmental Security

The ponds, rivers and wetlands with plantations as part of natural treatment of wastewater also serve for recreation, wildlife habitat, aesthetics and educational use. Wetlands, the most biologically diverse ecosystems, a resource for tertiary wastewater treatment increase habitats for flora and fauna in and along the waterways. The biological functions and physical aeration occurring in the wastewater during

the passage of wastewater in the waterways remove many of the toxic effluents from the wastewater (ICLEI 1995). These plantations with wetlands in urban park systems are the low cost wastewater treatment facilities for low-income cities. There are several alternatives to wastewater treatment and disposal that can be incorporated in green areas. As such wastewater can be used to irrigate urban and suburban agriculture and forests, horticultural projects (flowers for export), city landscaping and parks, and tree farms. All of these options provide for a safe and productive means of wastewater disposal (Braatz 1993). Controlled recycling wastewater into urban plantations and green areas parks or forested, farmed and degraded lands may also be more economical than finding ways to dispose of it somewhere else. Urban plantations and green areas provide some direct and other indirect benefits related to improvement of environment and quality of life. In addition to direct benefits as fuelwood, food, fodder, and poles; these improve air, water and land resources and also safer outlet for disposal of urban wastes which help in improvement of health, recreation, environmental education, aesthetics, and enhancement of landscape, especially for urban poor. Plantations also help in controlling erosion, urban water supplies and habitats for wildlife. Urban plantations and green areas should be designed on the basis of needs and desires of local populations so that these can serve maximum possible benefits. Overall the term urban agro-forestry including urban greening using plantations involves the management of urban and peri-urban plantation in a planned, integrated and systematic manner to achieve the maximum environmental, social and economic well-being of the urban society. Tree plantations offer additional advantage of mitigating predicted increase in atmospheric carbon concentration through their potential to carbon absorb more efficiently. During the process of photosynthesis, the atmospheric CO₂ is utilized by the leaves to produce photosynthetic pathway compounds, which get stored either in the roots or bole. The carbon absorption by tree plantations in a given area varies with plantation age corresponding to variations in growth as well as plantation density. Carbon absorption is also expected to increase with better tree growth caused by essential plant nutrients supplied through sewage irrigation. Minhas et al. (2015) recorded that rate of increments in stock volumes of wastewater irrigated *Eucalyptus tereticornis* plantations increased with plantation density and age; and for densities <2000 stems ha⁻¹, it peaked during the 6th year of growth as compared to earlier in higher densities.

References

- Armitage FB (1985). Irrigated forestry in arid and semi-arid lands: a synthesis. Ontario, Canada, IDRC.
- Augustine DS (2002). Eco-friendly management of solid and liquid wastes of farm, urban and industries. Lecture notes of training at TNAU, Coimbatore. Pp 213.
- Braatz K (1996) The use of municipal waste water for forest and tree irrigation-Unasylva 185: pp 9
- Braatz S (1993). Urban forestry in developing countries: status and issues. In: Kollin C. Minnesota (ed) Proceedings of the Sixth National Urban Forest Conference, American Forests.
- CSIRO (1995). Effluent irrigated plantations: design and management. CSIRO Technical Paper No. 2 1995. Canberra.
- Drechsel P, Evans AEV (2010) Wastewater use in irrigated agriculture. Irrig Drainage Sys 24: 1-3
- Duncan M, Baker T, Wall G (1998) Wastewater irrigated tree plantations: Productivity and sustainability. Paper presented in 61st Annual Water Industry Engineers and Operators' Conference Civic Centre-Shepparton, September 2-3, 1998, pp 18-26
- Ebbs SD, Lasat MM, Brady DJ, Cornish J, Gordon R, Kochian IV (1997) Phytoextraction of cadmium and zinc from a contaminated soil. J Environ Qual 26(5): 1424-1430
- ICLEI (1995) Multi-Functional Park Design and Management. Case Study 27. International Council for Local Environmental Initiatives (ICLEI), Durban, South Africa.
- Irshad M, Ahmad S, Pervez A, Inoue M (2015). Phytoaccumulation of heavy metals in natural plants thriving on wastewater effluent at Hattar industrial estate, Pakistan. International Journal of Phytoremediation 17:154-158.
- Lal K, Minhas PS, Shipra, Yadav RK (2008). Extraction of cadmium and tolerance of three annual cut flowers on Cd- contaminated soils. Biores Technol 99: 1006-11.
- Lal K, Yadav RK, Kaur R, Bundela DS, Khan MI, Chaudhary M, Meena RL, Dar SR, Singh G (2013) Productivity, essential oil yield, and heavy metal accumulation in lemon grass (*Cymbopogon flexuosus*) under varied wastewater-groundwater irrigation. Indus Crops & Products 45: 270-278.

- Minhas PS, Yadav RK, Lal K, Chaturvedi RK (2015). Effect of long-term irrigation with wastewater on growth, biomass production and water use by Eucalyptus (Eucalyptus tereticornis Sm.) planted at variable stocking density. Agric Water Manage 152: 151–160.
- Waly TM, Abd-Elmaim EM, El-Nashir BMB (1998) Effect of sewage irrigation on yield, tree components and heavy metals accumulation in Naval Orange trees. Biol Wastes 23: 7-24
- Reeves RD (2003) Tropical hyperaccumulators of metals and their potential for phytoextraction. Plant Soil 249(1): 57-65
- Lone MI, He Z-li, Stoffella PJ, Yang X-e (2008) Phytoremediation of heavy metal polluted soils and water: Progresses and perspectives. Review. J Zhejiang Univ Science B 9(3): 210-220
- Singh Gurbachan, I.P Abrol and S.S. Cheema. (1988) Agroforestry on alkali soil: Effect of planting methods and amendments on initial growth, biomass accumulation and chemical composition of mesquite (*Prosopis juliflora*) (SW,DC) with interspace planted with and without Karnal grass (*Diplachna fusca* linn. P beauv.). Agroforestry System, 29: 61-75. A112. 8.20
- Singh Gurbachan. (1995) An agroforestry practice for the development of salt lands using *Prosopis Juliflora* and *Leptochloa fusca*. Agroforestry System, 29: 61-75. A112. 8.20
- Thawale PR, Juwarkar AA, Singh SK (2006). Resource conservation through land treatment of municipal wastewater. Curr Sci 90: 704-711.
- Tabari M, Salehi A, Mohammadi J (2011) Impact of municipal waste water on growth and nutrition of afforested *Pinus eldarica* stands. In: Sebastin F, Einschlag G (eds) Waste Water- Evaluation and Management, pp 303-312 (www.intechopen.com/books)