# SAFE VEGETABLE PRODUCTION WITH WASTEWATER IN DEVELOPING COUNTRIES: DEMYSTIFYING THE NEGATIVE NOTIONS

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## Abstract

**The unplanned shift from rural to urban cities in developing countries have continually put burden on planners, policy makers and the residents. The productive use of wastewater has increased alongside increased rural-urban shift, as millions of small-scale farmers in urban and peri-urban areas of developing countries increasingly depend on wastewater sources to irrigate high-value edible crops for urban markets. Despite the good motive, undesirable constituents in wastewater can harm human health and the environment. The heavy metals such as Lead, Chromium, Zinc, Nickel and Cadmium have been detected in vegetables and may get biomagnified in food chain if the contaminated irrigated products are continually consumed. This can be fatal in the long run. There has been brewing unspoken skeptism regarding the vegetable products derived through this avenue. Apart from the consumers, government agencies in horticultural industries and those involved in quality standard regulations have, through design or default, failed to offer support to farmers' initiative and resolve to safely utilize wastewater for vegetable production. In this paper we review the key initiatives and compelling reasons that motivate farmers to utilize the wastewater; health risks not withstanding. The review dissects an array of crop choice interventions that lead to soil health mitigation with minimal human health implications. We single out and place emphasis on vegetable crops with hyperaccumulator traits for the purpose of soil remediation, but with a higher biomass as this leads to metal dilution within the plant. We also give a distilled analysis on the policy and social-cultural implications in regard to wastewater use and further appreciate the challenges the policy makers face in attempt to implement the blueprint on wastewater use.**

**Key words**; Crop choice, Health risk, Hyperaccumulators, Policy interventions, Vegetable, wastewater

## Introduction

According to United Nations Population Funds (UNFPA, 2007) projects, the world's urban population outnumbered its rural population for the first time in 2007. Urban growth is projected to increase significantly in the coming decades. Accompanying this urbanization process is a phenomenon referred to as the "urbanization of poverty" (Ravallion, 2001), where the population growth is combined with a gradual shift in the locus of poverty from rural to urban areas. The proportion of the poor living in cities is expected to increase from 0·30 in 2000 to 0·40 by 2020 and 0·50 by 2035 (UNFPA, 2007). Moreover, in most developing countries, urbanization has become virtually synonymous with slum growth where the slum population had almost doubled within 15 years (UNFPA, 2007). Most cities in developing countries encounter great difficulty in creating sufficient employment opportunities and to provide adequate basic services for the rapidly growing population.

This leads to high unemployment and very poor living conditions in the slum areas. Most urban poor rely on the informal sector and unstable intermittent jobs for their survival. Some of them resort to practicing Urban and Peri-Urban Agriculture (UPA), which is, in most cases informal.

Urban and Peri-Urban Agriculture can contribute to enhancing urban food security and healthy nutrition of the urban poor. Urban households that are involved in some sort of farming or gardening are more food secure, have a better and more diverse diet, and eat more vegetables than non-farming households (Zezza and Tasciotti, 2008). Production of food by poor urban households can supply 0·20–0·60 of their total food consumption (especially in green vegetables, medicinal and aromatic herbs, eggs, milk and meat from small animals; Smit *et al*., 1996). The surplus is normally sold and has become a source of income. Work by van Veenhuizen and Danso (2007) concluded that monthly net income figures from such peri-urban producers usually range between US$30 and US$70 per month, but can increase to US$200 or more. In the same countries, the minimum monthly wage was in the range of US$20–40, indicating that urban vegetable production is a profitable business compared to other urban jobs. To sustain UPA, wastewater use has been proposed to play a key role in this sector. The wastewater results from discharge from industrial process, sewage from households, rain water passing through slums loaded with raw human wastes etc. In some countries the wastewater is treated or partially treated but in most developing countries this conspicuously lacks.

The use of urban wastewater in agriculture is not new in human civilization. In the recent past, there has been renewed attention in this “centuries-old practice” as stated by Scott *et al.* (2004). These authors further observed an increasing trend in scarcity of freshwater resources in many Arid and Semi-Arid regions. Driven by rapid urbanization and growing wastewater volumes, wastewater is widely used as a low-cost alternative to conventional irrigation water and supports livelihoods and generates considerable value in urban and peri-urban agriculture despite the health and environmental risks associated with this practice (Qadir *et al.*, 2010). Though pervasive as these authors allude, this practice is largely unregulated in low-income countries, and the costs and benefits are poorly understood.

As urban populations in developing countries increase, and residents seek better living standards, larger amounts of freshwater are diverted to domestic, commercial, and industrial sectors, which generate greater volumes of wastewater (Lazarova and Bahri, 2005; Qadir *et al*., 2007; Asano *et al*., 2007). The industrial sectors in developing countries commonly discharge wastewater with little or no treatment into natural water bodies, which can become highly polluted; for instance Arsenic, Lead and Cadmium were high in Jessore village in Bangladesh (Alam, 2003). The discharge of the raw discharge and industrial pollutants put serious burden on city planners, policy makers, health workers, environmentalists and residents in finding amicable solutions. For realistic, effective, and sustainable management approaches, Scott *et al* (2004) argue that there is crucial need to understand the context-specific tradeoffs between the health of producers and consumers of wastewater-irrigated produce as well as the quality of soils and water. This paper gives a brief review of farmer-preference of wastewater, soil and plant-based interventions that need to be addressed to enhance wastewater use. Moreover, the review delves on drive, challenges and prospects of the livelihoods dependent on wastewater resource.

## Why farmers prefer wastewater despite the risks? The big question

It has been shown that wastewater use can contribute to improved livelihoods at the household level (Raschid-Sally *et al*., 2005), particularly through recycling of water for irrigation and specifically with additional direct benefits of nutrients for plant use (Janssen *et al*., 2005). This noble approach of agricultural use of domestic wastewater, if well designed and managed, has the potential to address the problems of local water shortages, improved soil fertility and can also be viewed as part of a treatment system to reduce environmental pollution (Jime´nez, 2005). The handling of wastewater to reduce the pollutants can be direct through initiatives of municipalities (e.g. use of chlorine or UV radiation) that kill pathogens or indirectly by informed choice of hyperaccumulator crops that can extract heavy metals from water or soils along the water channels and partially by passing the wastewater through oxidation ponds (an oxidation pond is such a pond that contains partially treated wastewater which is then left to allow the growth of algae and bacteria which decompose the rest of waste).

Generally, farmers in urban and peri-urban areas of nearly all developing countries who are in need of water for irrigation often have no other choice than to use of wastewater. They even deliberately use undiluted wastewater (a case where the government has taken intervention to partially treat the wastewater) as it provides nutrients or is more reliable or cheaper than other water sources (Keraita and Drechsel, 2004; Scott *et al*., 2004). This kind of unprecedented response creates daunting challenge to policy makers in trying to formulate policy on treatment or partial treatment of wastewater in their planning framework for wastewater use or re-use. In Faisalabad for instance, report indicates that farmers refuse to use treated wastewater from oxidation ponds because the lower nutrient values require additional fertilizer inputs (Qadir *et al.,* 2008). Comparative studies between wastewater and non-wastewater farmers have shown that the former make more income not only from savings in fertilizer but additionally the reliable wastewater supply allows them to grow short-cycle cash crops (van der Hoek 2004; van der Hoek *et al*., 2002; Ensink *et al*., 2004; Karanja *et al.*, 2010).

Wastewater may be used directly or after mixing with sewage channeled into natural drainage systems, from where the polluted water is used for farming (Qadir *et al.,* 2010). Most commonly, a year-round vegetable production is practiced, for which farmers have a good market. In many places in the world, this form of production has great importance as a source of income and livelihood for many people. Huibers and Raschid-Sally (2005) observed that farmers usually have no land rights and make use of available urban land belonging to property owners or the state, until they are thrown out. Consequently, there is no irrigation infrastructure and no means for regulation and control. Watering of the plants is done by simple means, for example using buckets or watering cans. This practice leads both to health risks to the irrigators who are in close contact with the polluted water, and there is also high risk of crop contamination. Interestingly crop contamination may also occur during the crop handling after harvest (Amoah *et al*., 2007), and this applies irrespective of whether the crop is produced with wastewater or other source of water.

## Concerns on human and environmental health risks associated with wastewater use

Despite farmers' good reasoning and the advantages accruing from wastewater use, this practice can severely harm human health and the environment (Qadir *et al*., 2007). This is mainly from not only the associated pathogens, but also heavy metals and other undesirable constituents depending on the source. Furthermore, farmers, consumers, and some government agencies in many countries are not fully aware of the potential impacts of irrigation with wastewater (Qadir *et al*., 2010). According to these authors, the absence of financial and technical resources in many developing countries makes comprehensive wastewater collection and treatment a challenge that needs a long-term future strategic planning. It is therefore required that in the short term, risk management and interim assessment and solutions be implemented to prevent adverse environmental and health impacts from wastewater irrigation. This kind of thinking is favoured by other documented reports (IWMI, 2006; WHO, 2006). Further emphasis is that wastewater used for irrigation has often been proven to contain microbiological contaminants exceeding the WHO guidelines (WHO, 2006). For instance; Kibera farm along the banks of Nairobi river in Kenya had mean faecal coliform count/100 ml of $4.8x10^8$ (Karanja *et al*, 2010) which was higher than WHO recommended values of $10^3$/100 ml; the value recommended for use in unrestricted irrigated agriculture (WHO 2006). A market survey by the International Water Management Institute (IWMI) in Kumasi, Ghana showed that vegetables were contaminated with faecal coliforms and enteropathogens such as *Salmonella* and *Shigella* organisms (Keraita *et al*., 2003). A similar scenario was reported in Nairobi (Karanja *et al*., 2010). Among the inorganic contaminants, heavy metals are important due to their non-degradable nature leading to bioaccumulation through tropic level which may have deleterious biological effects. Even at low concentrations, elements such as nickel (Ni), cadmium (Cd), chromium (Cr) and lead (Pb) are harmful to plants and humans (Emongor, 2007). Compared to heavy metals in soil, various crop parts accumulated more heavy metal loads. The potential metal load for uptake depends on soil conditions and concentrations.

## Soil-based interventions

Heavy metal contamination caused by natural processes or by human activities is one of the most serious ecotoxicological problems. Long term irrigation can induce changes in the quality of soil as trace element inputs are sustained over long periods. There are various reports (Barman *et al*., 2000; Singh *et al*., 2004), that show that when wastewater is used for the irrigation of edible plants for prolonged period, soil health is affected. It is therefore becoming a matter of concern to environmentalists since the presence of pollutants, particularly; toxic metals apparently accumulate in soils. Thus, introducing these pollutants into the plants growing therein through roots, which are translocated to foliage and even to edibles fruit parts (Zayed *et al*., 1998; Barman *et al*., 2000; Fytianos *et al*., 2001) easily take place in such environments. Heavy metal ions like Fe, Cu, Zn, Mn etc. at appropriate concentrations are required for structural and catalytic components of proteins and enzymes as cofactors, essential for normal growth and development of plants. However, supra-optimal concentrations of these micronutrients and other heavy metals in plants operate as stress factors (Steffens, 1990; Van Assche and Clijsters, 1990; Singh and Sinha, 2004; Singh *et al*., 2004). It has been well documented that excessive supply of certain heavy metals such as Cu, Zn or Mn interferes with Fe metabolism and may induce physiological changes that resemble Fe deficiency syndrome. Some metals such as Chromium have many industrial uses and unregulated application has led to the contamination of soil, sediments, surface and ground water (Barnhart, 1997; Kotas and Stasicka, 2000; Singh *et al*., 2004), which causes severe environmental problems due to extreme toxicity to living organisms. Similar to other metals, Cr in trace amounts is beneficial to humans, animals, plants and microorganisms (Nielsen, 1998). However, at higher concentrations, it is detrimental to health and it is regarded as priority pollutant by United States Environmental Protection Agency (USEPA) due to its carcinogenicity and mutagenicity (Cohen *et al*., 1993, Cieslak-Golonka, 1995). When plants and foodstuffs laden with such metals are consumed by humans and animals, they pose a serious health through biomagnification in food chains resulting into catastrophic episodes such muscle spasms (Nriagu, 1988). Thus soil-based interventions that do not involve production of edible plants are important, particularly in the case of inorganic contaminants, such as heavy metals derived from industries. These usually accumulate in the upper part of the soil due to strong adsorption and precipitation phenomena (Qadir *et al.*, 2010).

Long-term use of industrial and/or municipal wastewater in irrigation is known to make significant contribution to the trace elements load (Cd, Cu, Zn, Cr, Ni, Pb, and Mn) in surface soils (Mapanda *et al*. 2005). Excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination but also affect food quality and safety (Muchuweti *et al*., 2006; Sharma *et al*., 2007).

**Table 1**. Tissue heavy metals and bio-concentration factors (BCF) of selected vegetables.

| Vegetables | Scientific name | Family name | Arsenic conc$^{n}$ (mg g$^{-1}$) | Relative Pb conc$^{n}$ | BCF (x10$^{-1}$ |
|---|---|---|---|---|---|
| Potato | *Solanum tuberosum* | Solanaceae | NR | NR | 6 |
| Brinja | *Solanum melongena* | Solanaceae | NR | NR | 14 |
| Ash gourd | *Benicasa hispida* | Cucurbitaceae | NR | NR | 6 |
| Snake gourd | *Trichosanthes anguina* | Cucurbitaceae | 0.489 | (+-) | 34 |
| Squash | *Lagenaria siceraria* | Cucurbitaceae | 0.306 | ++ | NR |
| Green papaya | *Carica papaya* | Malvaceae | 0.389 | (+-) | 3 |
| Taro | *Colocasia esculanta* | Araceae | 0.440 | ++ | NR |
| Eddoe | *Colocasia schott* | Araceae | NR | ++ | NR |
| Ghotkol | *Typhanium trilobatum* | Araceae | 0.446 | ++ | 34 |
| Okra | *Abelmoschus esculentus* | Malvaceae | NR | NR | 1 |

Modified from Alam *et al*, (2003)

**Note:** As- Arsenic; Pb- Lead and BCF; Bio-concentration factor; NR- Not recorded; +; high and (+-); low; conc$^{n}$ ; concentration

Some trace elements are essential (e.g. Zinc) in plant and Chromium in animal nutrition respectively, but some plants growing in the nearby zone of industrial areas have been reported to display increased concentration of such heavy metals in supra-optimal levels; serving as biomonitors of pollution loads in soil environment (Mingorance *et al*., 2007). There are differential plant minerals uptakes among and within plant species, leading to differential accumulations among species (Table 1) and the differences are further evident from one mineral element to the other as well as in the bioconcentration factors –BCF (the ratio of the amount of mineral in plant tissue to that in environment; in this case soil). The BCF is a good indicator of plant's role in bioremediation through heavy metal hyperaccumulation, which can be proposed for phytoremediation of the polluted soils.

## Crop-based interventions

Information on the pattern and distribution of heavy metals, their uptake and translocation in plants from the sites of deposition in natural fields receiving industrial effluents can be quite crucial for long-term planning. This would be helpful in selection of suitable bio-accumulator plant species to remediate contaminated sites with the aim of minimizing the concentration of these metals in the highly polluted soils (Barman and Bhargava 1997; Barman *et al*., 1999). Alam *et al* (2003) screened vegetables for heavy metal contamination with Arsenic (As) and Lead (Pb) and part of their documentation is summarized in Table 1. Their results revealed a differential accumulation of metals among different species, with Cucurbitaceae family showing a generally higher bio-concentration factor (Table 1). Other reports show the process of metal uptake and accumulation by different plants to vary according to the concentration of available metals in soils, solubility sequences and the plant species growing on these soils (Chaney, 1973; Andersson, 1977; Pahlsson, 1989). These plants can play a critical role as metal accumulators in environmental clean-up operations and hence are good candidates for bioremediation. However, they can pose heath risks to consumers. Evidently, most of the work in this line have often overlooked the entry point of the metal aerosols from industries that fall directly onto the leaves and not necessarily taken up from the roots, and hence there is need to separate the sources. This oversight has partly led to the erroneous conclusion that most of the leafy vegetables accumulate more heavy metals than other vegetables (e.g. root, fruit). A more controlled experiment with wastewater or soils irrigated with wastewater for sometime may be used in a greenhouse can serve as ideal control.

Compared to heavy metal in soils, various crop parts accumulated more heavy metal loads. In the study by Nabulo *et al*. (2008), it was shown that *Brassica oleracea* acephala (kales) with high leaf to root ratio metal concentration compared to African nightshade (*Solanum villosum*) exhibited higher efficiency in concentrating the heavy metals from both soil and atmosphere, implying that kale was more predisposed to metal toxicity than black nightshade. The hyperaccumalator plants may pose health risks to consumers. Hence the need to settle for trade-off between bioremediation and health concerns. Two techniques have previously been developed in the field of phytoextraction (Lombi *et al*., 2001). The first, referred to as continuous phytoextraction, uses naturally occurring hyperaccumulator plants with exceptionally high metal-accumulating capacities and the second also known as chemically enhanced phytoextraction involves the use of high biomass crops (such as *Brassica juncea* (L.) Czern.), which are able to take up large amounts of metals by enhancing the mobility of metals in the soil through application of chemical, chelates e.g. EDTA or citric acid. This option ensures that more metals are equally extracted (due to high biomass). It is expected to be less harmful to end-user because the large biomass leads to dilution of the metal in plant tissues. The first strategy would be more suitable if it involves the partitioning of metals to non- edible parts (breeding for such strategic partitioning is possible). The current review holds view that second technique is more favourable. This option (shown in Fig. 1) ensures that more metals are extracted due to high biomass; as on right side of Fig.1 (A) but less harm to end-user, since the large biomass leads to dilution. While on the left side, Fig.1B, the concentration is considerably higher. Therefore, on a per unit mass basis; 500 g of first scenario (Fig.1 A), for instance, may have similar concentration to 50g of vegetable in second scenario (Fig. 1B); meaning that if a consumer ingests 100g of each source, there would be less harm in first case. Such differential tissue concentrations of metals in plants are demonstrated in Table 1. It is evident from the table that different species have varying potential to uptake or tolerate different metals.

Accumulation of metals in root from soil and subsequent translocation to other parts of plant like stem, leaves and fruits is important for the selection of plant specially crops and vegetables. Plant accumulating least quantity of metals in the edible parts, with the concentration within the permissible limit than the other varieties or species can be selected for the cultivation on the field having high level of metal contamination (Barman and Bhargava, 1997). In contrast, plants accumulating high concentration of heavy metals from contaminated soil can be used for detoxification/ phytoremediation of metals from soil or growing medium (Sarma, 2011). The two strategies can both be effectively used; where more extraction takes place (Sarma, 2011) but with minimum concentration (lower permissible limits) in the tissues (see Fig.1). Though, not entirely same mechanism, the scheme agrees well with work of Barman and Bhargava (1997).

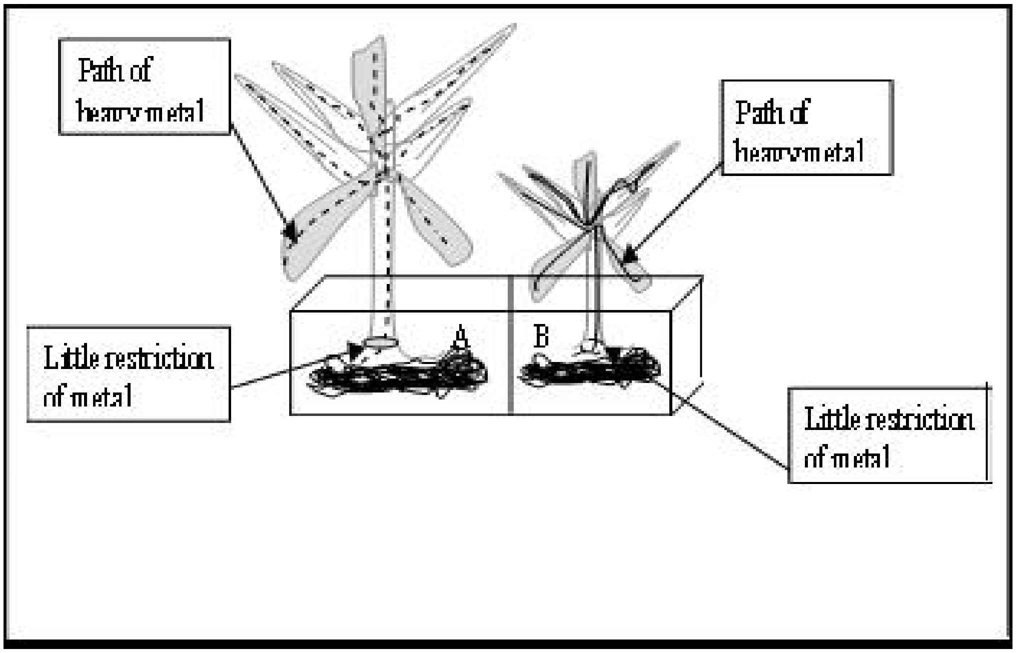

**Figure 1**: Heavy metal hyperaccumalator plants models with (A) having higher biomass and hence less concentration (B) has low biomass and high metal concentration.

### The drive, challenges and prospects: Considerations for policy makers

According to Huibers and Raschid-Sally (2005), wastewater irrigation schemes represent an example of planned and institutionalized use of wastewater in the downstream rural areas of big cities. This wastewater is rarely treated at secondary level, and in many cases the quality of the effluent is below standard because of poor performance of the treatment system (WHO 2006). Under these schemes, an effort is made for an optimal recycling of both water and nutrients. Huiber and Raschid-Sally (2005) argue that since these schemes are formal, government rules on crop choice and management are strict and much more controlled than in the other situations as we have tried to schematically present in Fig. 2.

The involvement of authority in wastewater treatment more than often restricts farmers from growing the crops of their choice suitable to the market, or they are forced to apply expensive management systems. Theoretically, as observed by Qadir *et al* (2007), farmers could compensate income loss due to crop restrictions by the lower water price they would normally pay and by saving on fertilizers. However, in practice farmers have insufficient insight into the nutrient composition in the water they use and keep applying chemical fertilizer as well (this is scenario where is wastewater is fully or partially treated). This brings unnecessary costs to the farmer, while the resulting over-fertilization is a source of further pollution (Qadir *et al*., 2010). At present, to our knowledge, there are no microbiological irrigation water quality standards that acknowledge the concept of an acceptable level of health risk for irrigators and the wider community, other than zero risk.

In the absence of other norms, the WHO microbiological quality guidelines for the design of wastewater treatment plants, where the effluent is intended to be used for irrigation, are used extensively to evaluate the health risks arising from the use of polluted water sources for irrigation (WHO, 1989). Many developing countries are clearly below this threshold. In Ghana, for example, only 7 out of 44 smaller treatment plants are functional and probably none meets the designed effluent standards (Obuobie *et al*., 2006). Whereas this is pertinent, the public officials must consider potential impacts on the poor when designing policies and programs since stringent adherence to the requirement may deter the informal farmers to access the wastewater resources profitably. And this is therefore one amongst the numerous challenges that affect peri-urban informal farmers relying on wastewater.

The other greatest challenge might be ensuring that low-income residents of peri-urban and rural areas who rely on polluted streams or wastewater for crop production are not deprived of their livelihoods. Many poor farmers have been using these water sources for years without formal water rights and a study shows that banning the use of polluted water was estimated to affect about 12,700 households or 90,000 people living around the city of Kumasi by late 90s, depending on dry-season irrigation (Cornish and Lawrence, 2001). Such predicaments faced by farmers in Kumasi and Accra are very similar to those of their counterparts in Nairobi, particularly in Ruai and Maili Saba (Cornish and Kielen 2004; Karanja *et al*., 2010). The other challenge is the accumulation of heavy metals and microbial contamination of crops, particularly vegetables produced by such system.

Information on the pattern and distribution of heavy metals, accumulation and translocation in the edible plants from the sites of deposition in agricultural field receiving industrial wastewater would be helpful for the selection of suitable plant species that can be used as accumulator plant to minimize the concentration of these metals in the highly polluted soils (Salt *et al*., 1995; Rai *et al*., 1996; McGrath, 1998; Sinha *et al*., 2002). The kind of the information needed to be shared by all stakeholders is proposed in the current review as indicated in Fig. 2.

As has been mentioned here, the metal accumulation in the various parts of the plant depends upon availability and species of metals in soil, solubility, their translocation potential and the type of plant species. The bioavailability of trace metals in soils also governed predominantly by various soil properties (pH, redox potential, cation exchange capacity and organic matter) (Karanja *et al*., 2010). And this is of significance to technical advisors (e.g. agricultural officers) to ensure such soil properties are amended to alleviate inducing availability in the soil media for subsequent uptake by crops.

The other important concern to be observed in sustainable wastewater use is the inclusion of user and consumer health protection concerns, through interventions at farm level, post harvest measures, public policies to motivate better management of wastewater. This can be through ensuring that the farmers wear gloves, are frequently medically examined and research come up with a detergent that farmers use to clean the vegetables under supervision of experts before being ferried to market. Vinegar can be a good option.

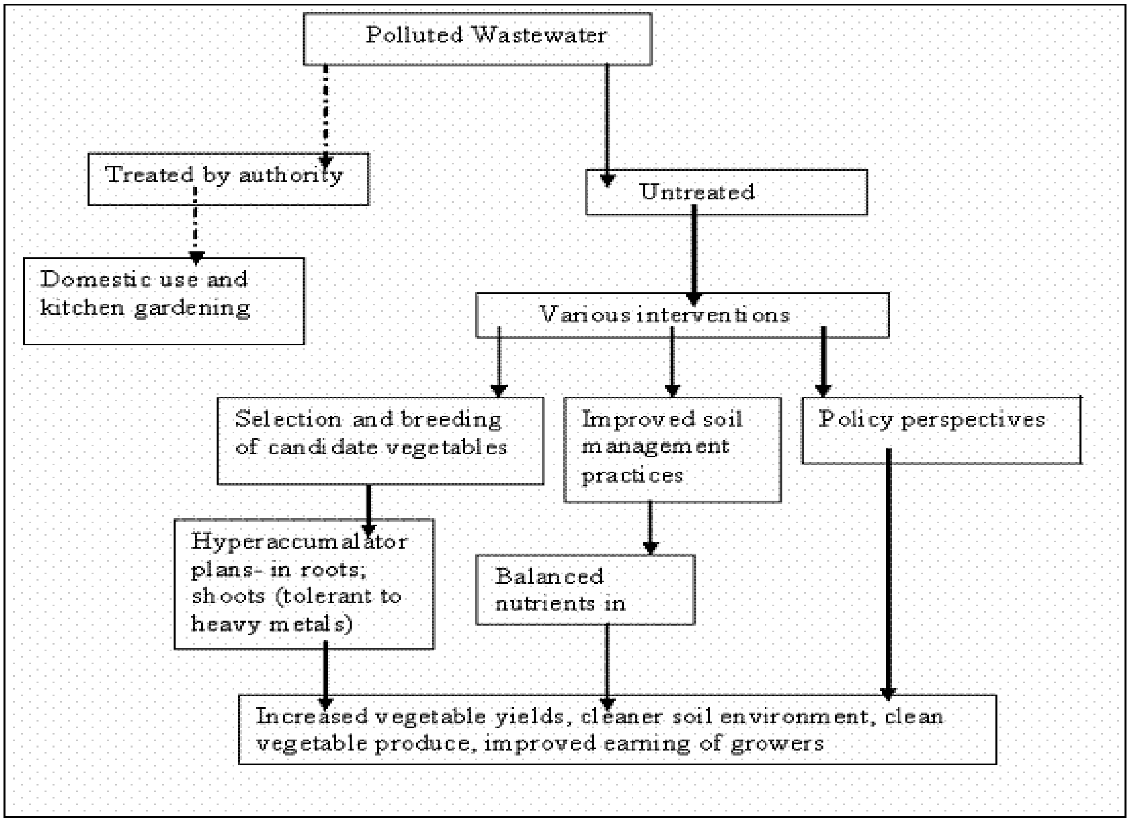

**Figure 2**: Conceptual framework showing wastewater treatment and utilization initiatives by different stake holders.

So far the results of most researchers have ignored other routes of metal pollutants into plant tissues. We speculate that there may be substantial amount that get to plants as aerial droplets and this need to be separated from plant uptake from soil. To separate this, a greenhouse experiment using contaminated soils or using wastewater may be crucial. The irrigation system will ultimately be proposed with an aim of reducing aerial plant contamination. In natural environment, it may be tricky during rainy season since the wastes may be splashed onto the crops from soil surface. But this too has an implication since the rain water essentially dilutes the wastewater (which may be viewed as partial treatment). Future experiments may need to consider these factors in order to come up with a comprehensive and inclusive report to safeguard farmers' use of wastewater.

The success of wastewater unfortunately should not be viewed purely from benefits accruing from the business. Indeed there are other social and cultural connotations associated with the use of this water source. The socio-cultural acceptability of produce and handling of wastewater varies from region to region. The health effects of wastewater production and the social and economic consequences of farmers, agricultural labourers and their household members and consumers of wastewater-irrigated produce have been studied in different areas (Shuval *et al*., 1986; van der Hoek *et al*., 2002; Ennsink *et al*., 2003; Ensink *et al*., 2004). Many of the health studies, however, lack what Mara and Cairncross called for in their well-known "Guidelines for the Safe Use of Wastewater in Agriculture and Aquaculture" (WHO, 1989), that is, 'a thorough assessment of the local socio-cultural context'.

Research conducted in urban, peri-urban and rural areas near Hyderabad city, India, shows that such socio-economic characteristics as caste, class, ethnicity, gender and land tenure influence the type of wastewater-dependent livelihood activities in which each person engages (Buechler *et al.*, 2002). The research concluded that sale of vegetables in the wastewater-irrigated urban and peri-urban areas was controlled by women and the venture improved their ability to gain access to a wider variety of vegetables for themselves and for their household members and for market. Therefore, according to Buechner *et al.* (2002), recommendations based on biophysical studies that include a switch in crops from leafy vegetables to tree crops might have ramifications for women's income-generating capabilities and food-security status. This is because the introduced crops may be male-dominated, hence edging out women and children in the arena of wastewater use.

## Conclusion

From the foregoing, it is clear that there is varied and overwhelming information in respect to wastewater use. The use of wastewater has great potential of transforming poor urban and peri-urban agricultural activities and livelihood of the informal irrigators. However, before such potential is realized, there is urgent need of various players to work together. These actors include agronomists, plant nutritionists, policy makers, irrigation engineers, vegetable produce regulators, health workers, environmentalists, farmers and consumers among others. There is need for research in terms of crop choice, soil interventions, diseases and pathogen to be conducted within agreeable policy framework. For instance, the current Kenya constitution recognizes need for environmental protection as well as irrigation of marginal areas but is silent on wastewater use. There is need to engage policy makers to recognize the business since it is easier to regulate when all players are involved directly on the ground and the risks of health due to poor handling such as use of raw sewage can avoided as some degree of treatment can be realized.

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