A Review of Urban Water Reuse- Limits, Benefits and Risks in Nepal

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Abstract: ***The reuse of water for agricultural irrigation is often viewed as a positive means of recycling water due to the potential large volumes of water that can be used. The volume of wastewater generated by domestic, industrial sources has increased with population, urbanization, improved living conditions, and economic development. The productive use of wastewater has also increased, as millions of farmers in urban areas of developing countries depend on wastewater to irrigate high-value edible crops for urban markets. Undesirable elements in wastewater can harm human health and the nature. Hence, wastewater irrigation is an issue of concern to public agencies responsible for maintaining public health and environmental sustainability. Due to various reasons, many developing countries are still unable to implement comprehensive wastewater treatment programs. Wastewater reuse in Nepal is also a widespread but poorly documented practice. Therefore shortly, risk management and sustainable use of waste water are needed to be focused for preventing adverse impacts caused by them. There are several opportunities for improving wastewater management via norms, institutional dialogues and financial mechanisms, which would reduce the risks of wastewater. Effluent standards combined with incentives or enforcement can motivate improvements in water management by all the sectors discharging wastewater from point sources. Strengthening institutional capacity and establishing links between water delivery and sanitation sectors through inter-institutional coordination leads to more efficient management of wastewater and risk reduction. This work was done to explore the environmental limits of urban water reuse for different sectors. Different standards and limits defined for different industries for the wastewater were obtained from the literature review.***

Keywords: Wastewater, reuse, benefits and risks, Nepal.

1. Introduction

Wastewater originates predominantly from water usage by residences, commercial and industrial establishments, together with groundwater, surface water and storm water. Consequently, wastewater flow fluctuates with variations in water usage, which is affected by factors like climate, community size, living standards, dependability and quality of water supply, water conservation requirements or practices, and the extent of meter services, in addition to the degree of industrialization, cost of water and supply pressure.

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 [1-3].

No reliable data is available on the total volume of wastewater production from different sources and in the urban and rural areas of Nepal. In the absence of needed information, the daily volume of wastewater production is estimated based on average daily consumption of water per capita, which is taken 75 liters per capita per day in the urban areas and 40 liters per capita per day in the rural areas and 85% of this ending up as domestic wastewater [4]. Based on this consideration the total wastewater production in the country is estimated to be 296 million liters per day (MLD) [5].

Increasing productivities in crop management and the continuing increases in crop yields has increased demands on water resources for irrigation purposes. Wastewater is reused for irrigation purposes in many countries around the world on all of the populated continents [6]. In many regions of the world, increasing demand of water has placed severe strains on existing resources with resulting environmental impacts. An example is in Perth, Australia where the major drinking water aquifer is being depleted by a combination of uses as a public drinking water source, horticultural irrigation and the positioning of pine plantations of large area of the mound [7]. Saudi Arabia is another example of a country which demonstrated impacts on natural water resources due to increasing demands on groundwater by the agricultural sector [8]. Large decreases in groundwater levels (up to 200 m in some places) have been observed due to over extraction. In a number of countries, for example Australia, this has been compounded by prolonged periods of drought or seasons of low rainfall. In addition, predicted climate impacts from global warming also point to further stresses on water resources, thus reducing the amount of water available for both irrigation and the environment. A review of literature for the situation in Nepal has shown that wastewater irrigation is not well documented in spite of it being widespread [9].

Nepal is one of the Least Development Country, as defined by the United Nations in terms of its low national income, less developed human capacity and a high degree of economic vulnerability [10]. The impact of climate change has already been observed in Nepal in the form of increase in the average annual temperature at a rate of 0.04^0C to 0.06^0C and high rate of glacier melting and retreat [11]. This has resulted floods and droughts. The scarcity of water is increasing at present and has affected the life.

There are ranges of mechanisms that can be used to reduce the pressure on fresh water resources for irrigation use. One possible mechanism is the recycling of wastewater and drainage water that can be used in the place of other fresh water sources for irrigation. Types of wastewater used for recycling include treated and untreated sewage effluent [12-14], storm water runoff [13, 15] domestic grey water [16], and industrial wastewater [13, 17]. For the purposes of this paper all of these water types are considered effluents, which have the capacity to be reused. These different water types, however, can vary in quality and in the contaminants that could be potentially present. The quality and contaminants present will also impact on the level of treatment required, which in turn impacts on the economic viability of reusing the various wastewater [18].

In many arid and semi-arid countries water is becoming an increasingly scarce resource. Beginning of the twenty-first century, agriculture is using a global average of 70% of all water withdrawals from rivers, lakes, and aquifers. The FAO anticipates a net expansion of irrigated land of some 45 million ha in 93 developing countries (for a total of 242 million ha in 2030) and projects that agricultural water withdrawals will increase by some 14% from 2000 to 2030 to meet future food production needs [19]. Therefore, any sources of water which might be used economically and effectively should be considered to promote further development [20].

The use of wastewater for irrigation of agricultural land is a worldwide practice. It is especially common in developing countries, where water treatment costs cannot yet be afforded [21]. In developed and developing countries alike, the disposal of wastewater from urban and rural areas can pose a serious threat to the environment. This may become a problem if wastewater is disposed of improperly. Thus, the proper treatment and sanitary disposal of wastewater should be a high priority in urban and rural development programs [22]. Use of wastewater for agricultural sites offers an economic alternative to disposal into surface waters enhancing nutrient cycling, although pollutants may accumulate in the soils and cause a potential risk to soil quality and productivity in the long term [21]. Irrigation is relatively flexible with respect to water-quality requirements. The effect of wastewater application on the environment varies with soil type, wastewater characteristics, and the vegetation of the irrigated soil [23].

The objective of this study is to explore the environmental limits of release of industrial wastewater and risks and benefits of reuse of wastewater. In this paper, i studied monographs and papers on the environmental limit values for wastewater (industrial effluent) discharged into surface waters, benefits and risks of use of wastewater and policies and legislations in Nepal by using Google as a search engine.

2. Policies and Legislations

The legislations and regulatory provisions encompassing the issues relating to wastewater management and safeguarding of water bodies include: Environmental Protection Act (1996), Local Self-Governance Act (1999), Industrial Enterprises Act(1993), National Wetland Policy Act (2003), National Sanitation Act (1994), Pesticide Act (1992), Solid Waste Management and Resource Mobilization Act (1988) and Water Resources Act (1992).

3. Benefits of urban waste water

Wastewater and agriculture are two sectors where the economic and environmental benefits of joint water management have been demonstrated through case studies around the world. It has been shown that the nutrients embodied in wastewater can increase yields as much or more than a combination of tap water and chemical fertilizer [24-27]. The reliable access to wastewater irrigation can improve farm productivity in water-constrained systems [28- 30]. Diverting wastewater effluent to agriculture also reduces the discharge of nutrients to surface waters, may reduce demand for freshwater, and potentially decreases the costs of wastewater treatment by eliminating the need for nutrient removal [31]. However, more than 80% of wastewater and fecal sludge generated globally is indiscriminately discharged without treatment [32]. Aside from unplanned reuse in regions where farmers irrigate with waste-contaminated sources, planned reuse in agriculture is limited in comparison to its potential. Agriculture accounts for 70% of freshwater withdrawals but wastewater-fed irrigation accounts for only 1% of agricultural water use [33-34].

Wastewater may be applied in agriculture, industry and automobile. Wastewater can be adopted to meet the water demand in different fields and contribute to the conservation of freshwater resources.

3.1 Agricultural irrigation

Wastewater from different sources can be used for irrigation. However, the wastewater needs to be improved and made eco-friendly. The limit for the water quality for irrigation is presented in Table 1. It is important for improving the quality and quantity of production. Thus, more efficient use of agricultural water through wastewater reuse is essential for sustainable water management. Potential benefits of wastewater reuse for agriculture include the following:

i. Conservation and more rational allocation of freshwater resources, particularly in areas under water stress
ii. Avoidance of surface water pollution
iii. Reduced requirements for artificial fertilizers and associated reduction in industrial discharge and energy expenditure
iv. Soil conservation through humus build-up and prevention of land erosion
v. Contribution to better nutrition and food security for many households [35]

Table 1: Nepal water quality guidelines for irrigation water

Parameter name	Target Water Quality Range
Microbiological constituents	
Coliforms (faecal)	<1 count/100ml
Physical constituents	
pH	6.5-8.5
Suspended Solids	<50 mg/l
Electrical Conductivity	<40 mS/m
Chemical constituents	
Aluminium	<5 mg/l
Arsenic	<0.1 mg/l
Beryllium	<0.1 mg/l
Boron	<0.5 mg/l

Cadmium	<0.01 mg/l
Chloride	<100 mg/l
Chromium	<0.1 mg/l
Cobalt	<0.05 mg/l
Copper	<0.2 mg/l
Fluoride	<2 mg/l
Iron	<5 mg/l
Lead	<0.2 mg/l
Lithium	<2.5 mg/l
Manganese	<0.02 mg/l
Molybdenum	<0.01 mg/l
Nickel	<0.2 mg/l
Nitrogen (Inorganic)	<5 mg/l
Selenium	<0.02 mg/l
Sodium Adsorption Ratio (SAR)	<2 mg/l
Sodium	<70 mg/l
Total Dissolved Solids (as EC)	<40 mg/l
Uranium	<0.01 mg/l
Vanadium	<0.1 mg/l
Zinc	<1 mg/l

Source: Department of Irrigation, Ground Water Project (Nepal Gazette (Number 10, 16 June 2008))

3.2 Industries

Wastewater can be reused in industries and factories for different purposes. Industrial water reuse has the following specific benefits, in addition to the general environmental benefits discussed in earlier sections:

i. Potential reduction in production costs from the recovery of raw materials in the wastewater and reduced water usage
ii. Heat recovery
iii. Potential reduction in costs associated with wastewater treatment and discharge.

3.3 Automobiles

Water can be used in automobiles for different purpose. Waste water can be reused after necessary treatment for the purpose of cleaning the vehicles and cooling the parts.

4. Risks of urban waste water

Uses of wastewater before and after treatment have several risks. The health of the people is affected by the use of wastewater. Agricultural field workers and their families, crop handlers, consumers of crops, meat and milk and people living near the areas irrigated with wastewater will be affected by the use of wastewater. Cholera, typhoid and diarrhoea will spread among the people.

Potential concerns for industrial water reuse include scaling, corrosion, biological growth, and fouling, which may impact industrial process integrity and efficacy, as well as product quality. Salt concentrations can be affected by various factors, including process operating temperatures, sources of wastewater, and areas from which wastewater is collected (e.g. coastal areas may have higher concentrations).

5. Urban water treatment requirements

5.1 Reduction of Pathogens through Wastewater Treatment

The purpose of the wastewater treatment is to protect the consumer from pathogens and from impurities in the water that may be harmful to human health. This can be achieved with treatments such as coagulation, sedimentation, filtration and advanced treatments, to remove pathogens [36]. Processes are grouped together to provide various levels of treatment known as preliminary, primary, advanced primary, secondary (without or with nutrient removal), and advanced (or tertiary) treatment. Pathogens may be inactivated or destroyed through biological, chemical and physical treatments. Inactivation is a period of time during which the pathogen is rendered harmless or incapable of causing an infection. If the inactivation method is long enough, the pathogen dies. When the inactivation period is not long enough, the pathogen may become active and may cause infection. Pathogens within wastewater treatment systems may be inactivated or destroyed by exposure to the following biological, chemical, or physical conditions.

5.2 Removal of Parasites through Stabilization Ponds

Primary sedimentation cannot be relied on for effective removal of pathogenic protozoan and helminths from wastewater. Some additional removal may be obtained by conventional biological treatment, but the reported results are not uniform. Oxidation ponds usually provide detention periods of 5 to 30 days and should provide better conditions for the sedimentation of protozoan and helminths than conventional primary sedimentation plants with detention times of 2 or 3 hours or secondary treatment systems with total detention of 8 to 12 hours.

5.3 Removal of Parasites by secondary and tertiary treatment

Egg removal from wastewater appears to be in the range of 20-90 percent, with higher reductions when the effect of secondary sedimentation is included. The activated sludge process itself has little effect on protozoal cysts and helminth eggs, but substantial proportions of eggs will be removed in the secondary settling tank (activated sludge plants have been reported to remove 80-100 percent of helminth eggs). Overall, the results that have been obtained with conventional treatment vary. Even though tertiary treatment processes (sand filtration; membrane separations; granulated carbon adsorption; powdered activated carbon; ion exchange) are used for further reduction of suspended solids rather than pathogen removal, some of them do have good pathogen-removal characteristics. Coagulation could achieve some pathogen removal. Slow sand filters is effective in removing protozoa, helmith eggs and viruses, and are highly recommended where there is a lack of trained operators and land is available. Land treatment by percolation may have similar results if properly designed and operated, and if groundwater contamination is not expected.

Maturation lagoons receiving effluents from aerobic ponds will remove parasites on the same principle as of waste stabilization ponds. If two or more maturation ponds are used, with perhaps 5 days of retention in each, high removal of protozoan cysts and helminth eggs can be achieved. Effluent chlorination is not efficient in eliminating protozoan cysts because they are more resistant than either excreted viruses or bacteria. Most helminth eggs are totally unharmed by effluent chlorination.

5.4 Advanced Wastewater treatment

Advanced wastewater treatment, sometimes referred to as tertiary treatment, and is generally defined as anything beyond secondary treatment. These methods are applied when a high quality of reclaimed water is required such as for the irrigation of urban landscaping and food crops that are eaten raw.

Tertiary or advanced treatment systems are used to improve the physico-chemical quality of biological secondary effluents. Several unit operations and unit processes, such as coagulation-flocculation-settling-sand filtration, nitrification and denitrification, carbon adsorption, ion exchange and electro-dialysis, can be added to follow secondary treatment in order to obtain high quality effluents. None of these units are recommended for use in developing countries like Nepal when treating wastewater for reuse, due to the high capital and operational costs involved and the need for highly skilled personnel for operation and maintenance.

If the objective is to improve effluents of biological plants (particularly in terms of bacteria and helminths), for the irrigation of crops or for aquaculture, a more appropriate option is to add one or two ponds as a tertiary treatment. If land is not available for that purpose, horizontal or vertical-flow roughing filtration units (which have been used for pre-treatment of turbid waters prior to slow-sand filtration) may be considered. These units, which are low cost and occupy a relatively small area, have been shown to be very effective for the treatment of secondary effluents and remove a considerable proportion of intestinal nematodes.

6. Industrial wastewater

Industries contributed 20%to Nepal's Gross Domestic Product with Carpet, Readymade Garments and Leather contributing 65% to total exports. Six percent of total wastewater generated was estimated to be from industry, mostly carpet dyeing and washing wastewater [37] which is acidic and usually highly colored. These effluents may also contain heavy metals. Effluents from wool processing and dyeing industry, tested at Nepal Bureau of Standards and Meteorology Laboratory indicated that they do not comply with the Nepal standard 229 Part 2 for effluents from the wool processing industry. There were three main industrial areas accommodating about 16% of the industrial units and the rest were scattered across the valley. Only one of the industrial areas was served with a wastewater treatment plant [38]. No information was available on the quality of the treated effluent. Domestic and industrial wastewater were collected in the same network [9].

7. Standards applied in Nepal

There are different standards for environmental limits of wastewater (industrial effluents) discharged into surface water. Ministry of Population and Environment, Government of Nepal has formulated Environment Conservation Regulations (ECR), 1997 and with the rule of 15 the following Generic Standard are defined for the national standards as in Table 2.

Table 2: Environmental limit values for wastewater (industrial effluent) discharged into surface waters

Parameter	Minimum and maximum limit
Total Suspended Solids (TSS), mg/L	30-200
Particulate size of total suspended particles	Shall pass 850-micron Sieve
pH	5.5 to 9.0
Temperature	Shall not exceed 40 degree C in any of the stream within 15 meters downstream from the effluent outlet
Biochemical oxygen demand for 5 days at 20^{o}C, mg/L	30-100
Oils and grease, mg/L, Max	10
Phenolic compounds, mg/L, Max	1.0
Cyanides (as CN), mg/L, Max	0.2
Sulphides (as S), mg/L, Max	2.0
Radioactive materials Alpha emitters, c/ml, Max Beta emitters, c/ml, Max	 10^{-7} 10^{-8}
Insecticides	Absent
Total residual chlorine, mg/L	1
Fluorides (as F), mg/L, Max	2.0
Arsenic (as As), mg/L, Max	0.2
Cadmium (as Cd), mg/L, Max	2.0
Hexavalent chromium (as Cr), mg/L, Max	0.1
Copper (as Cu), mg/L, Max	3.0
Lead (as Pb), mg/L, Max	0.1
Mercury (as Hg), mg/L, Max	0.01
Nickel (as Ni), mg/L, Max	3.0
Selenium (as Se) , mg/L, Max	0.05
Zinc (as Zn) , mg/L, Max	5
Ammonical nitrogen, mg/L, Max	50
Chemical Oxygen Demand, mg/L, Max	250
Silver, mg/L, Max	0.1

Environment Conservation Regulations, 1997 has endorsed the following standards for different industries operating in Nepal as in Table 3-7.

Leather industries are the major cause for the high influx of chromium to the biosphere [39].The huge quantity of chromium salts discharge into tannery waste has raised several ecological concerns.

Table 3: Environmental limits for leather industry

Parameter	Minimum and maximum limit
Colour and odour	Absent
Total dissolved solids, mg/L, Max	2100
Suspended solids, mg/L, Max	100
Biochemical oxygen demand (5 days at 200 C) mg/L, Max	100
Chlorides as (Cl) mg/L, Max	600
Hexavalent chromium (as Cr) mg/L, Max	0.1
Total chromium (as Cr) mg/L, Max	2.0
Sulphide (as S) mg/L, Max	2.0
Sodium %, Max	60
Chemical oxygen demand mg/L, Max	250
pH Value	6.0-9.0

Wool industries

The crude waste, if discharged into the stream, causes rapid depletion of dissolved oxygen of the stream, the condition aggravates due to the settlement of the suspended substances and subsequent decomposition of the deposited sludge in anaerobic condition. The alkalinity and the toxic substances like sulphides and chromium affects the aquatic life; and also interferes with the biological treatment process; some of the dyes are also fund toxic. The color often renders the water unfit for use for some industrial purposes in the downstream side. The presence of sulphides makes the waste corrosive particularly to concrete structure.

Table 4: Environmental limits For wool industries

Parameter	Minimum and maximum limit
Suspended Solids, mg/L	100
Biochemical Oxygen Demand (5 days at 200 C), mg/L	100
Oil and grease, mg/L	10
Chemical Oxygen Demand, mg/L	250
Total Chromium (as Cr), mg/L	2
Sulphide (as S), mg/L	2
Phenolic compounds (as C6H5OH), mg/L	5
pH Value	5.5-9.0
Temperature ^{0}C	40

A large amount of water is used for cleaning operations in brewing industry. The wastewater contains solid wastes like spent grains, yeast and spent hops [40].

Table 5: Environmental limits Fermentation industries

Parameter	Minimum and maximum limit
pH	5.5 to 9.0
TSS, mg/l, max	100
BOD 5 days at 200 C mg/l, max	60

The wastewater released from the ghee and oil industries contains chemicals, plastics pieces, germs, hair and dust particles. Therefore, wastewater should be treated well as per the limits provided below and released into the atmosphere.

Table 6: Environmental limits Ghee and oil industries

Parameter	Minimum and maximum limit
BOD 5 days at 200 C mg/L, max	100
COD, mg/l, Max	250
pH 6-9	
Oil and Grease, mg/l, Max	10
Nickel, mg/l, Max	3

The wastewater from paper and pulp industries contains wood debris and soluble wood materials similarly pulp bleaching generates toxic substances as it utilizes chlorine for brightening the pulp. Various toxic chemicals such as resin acids, unsaturated fatty acids, diterpene alcohols, juvaniones, chlorinated resin acids and others are generated in the pulp and paper making process. The range of environmental limits as [41] is presented in the Table 7.

Table 7: Environmental limits Paper and pulp industries

Parameter	Minimum and maximum limit
pH	5.5 to 9.0
Suspended Solids, mg/l	100
BOD 5 days at 200 C mg/l, max	100

Source: Ministry of Population and Environment, Government of Nepal, 2010

Nepal Government has endorsed the Generic Standard/Tolerance Limits for different industrial effluents discharged into Inland surface water as in Table 8-11

Oils, dust and chemicals may be leaked from the dairy industry which can pollute the water. This water should be treated and make environment friendly. The range of environmental limits is presented in the Table 8.

Table 8: Environmental limits Dairy Industry

Parameter	Minimum and maximum limit
TSS, mg/l	150
pH	5.5-8.5
BOD 5 days at 200 C mg/l, max	100
COD, mg/l, Max	250
Oils and grease, mg/l, max	10

Sugar mills use large amount of lubricating oil and grease. Waste oil and grease from spills and leaks constitute the wastewater. The tolerable range for the release waste is presented in the Table 9.

Table 9: Environmental limits Sugar Industry

Parameter	Minimum and maximum limit
TSS, mg/l	100
pH	5.5-9
BOD 5 days at 200 C mg/l, max	100
COD, mg/l, Max	250

Textile Industry

The textile industry is one of those industries that consume considerable amounts of water in the manufacturing process. The water is primarily employed in the dyeing and finishing operations in which the cloths are dyed and processed to finished products. In a typical dyeing and finishing mill, about 100 litres of water are consumed on the average for every ton of cloths processed [42]. The water employed in the dyeing and finishing processes eventually ends up as wastewater which needs to be treated before final discharge.

Normal textile dyeing and finishing operations are such that the dyestuffs used in a mill can vary from day to day and sometimes even several times a day mainly because of the batch wise nature of the dyeing process. Frequent changes of dye stuff employed in the dyeing processes cause considerable variation in the wastewater characteristics, particularly the pH, colour and wastewater chemical oxygen demand (COD) concentration [43].

Wastewater effluent from the secondary wastewater treatment plant of a dyeing and finishing mill is chemically treated for possible reuse. The treatment system consists of electrochemical, chemical coagulation and ion exchange processes [44].

Table 10: Environmental limits Cotton and Textile Industry

Parameter	Minimum and maximum limit
TSS, mg/l	100
pH	6-9
BOD 5 days at 200 C mg/l, max	100
COD, mg/l, Max	250

The saponification of fats and oils and neutralization of fatty acids releases water that contains fats, oils, acids and glycerine. [45] The range of environmental limits is presented in the Table 11.

Table 11: Environmental limits Soap Industry

Parameter	Minimum and maximum limit
TSS, mg/l	200
pH	5.5-9
BOD 5 days at 200 C mg/l, max	100
COD, mg/l, Max	250
Oils and grease, mg/l, max	10

Source: Nepal Gazette, 30 April 2001 and 23 June 2003

8. Conclusion and Discussion

Wastewater use in agriculture, automobile and industries is not regulated and national standards or guidelines, and related planning regulations are non-existent. Interaction through a formal mechanism, among the key stakeholders who can influence the course of wastewater agriculture in Nepal, is suggested to effect beneficial changes.

The use of recycled water for the irrigation of crops has benefits in using a resource that would otherwise be discarded and wasted. Using recycled water also reduces the pressures on the environment by reducing the use of environmental waters. There are factors that need to be considered, including the presence of pathogens and chemical pollutants as well as salinity and impacts on soil structure. These can all be controlled through treatment and effective farm management practices. Current research and development will also improve and increase the use of recycled water for irrigation purposes as well as increasing public assurance.

9. Acknowledgement

The author takes this opportunity to thank the Central Bureau of Statistics (CBS), Nepal for providing the secondary data and literature. The author acknowledges the remarks and the suggestion on the manuscript and would like to thank anonymous reviewer(s).

References

[1] V. Lazarova, A. Bahri, Water Reuse for Irrigation: Agriculture, Landscapes, and Turf Grass, CRC Press, Boca Raton, USA, 2005.

[2] M. Qadir, D. Wichelns, L. Raschid-Sally, P.S. Minhas, P. Drechsel, A. Bahri, P. McCornick, Agricultural use of marginal-quality water - opportunities and challenges. In: Molden, D. (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture, Earthscan, London, UK, 2007.

[3] T. Asano, F. Burton, H. Leverenz, R. Tsuchihashi, G. Tchobanoglous, Water Reuse: Issues, Technologies, and Applications (McGraw-Hill). Metcalf & Eddy Inc., 2007.

[4] UNEP, Nepal: State of the Environment 2001, United Nations Environment Program (UNEP) and International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal, 2001.

[5] B.L. Nyachhyon, Service Enhancement and Development of Sanitary Sewerage System in Urban and Semi-Urban Settings of Nepal, Economic Policy Network, Policy Paper No. 23. Ministry of Finance, Government of Nepal and Asian Development Bank, 2006.

[6] USEPA, U.S. EPA, Offices of Water and Wastewater and compliance (Ed.) Guidelines for water reuse. U.S. EPA, Washington, 1992.

[7] WA State Water Strategy, “Securing our water future: A state water strategy for Western Australia”, Western Australian Government, February 2003. [Online]. Available: http://www.ourwaterfuture.com.au/community/statewaterstrategy.asp [Accessed: Sept. 12, 2013].

[8] A.A. Bushnak, Future strategy for water resources management in Saudi Arabia, In: Proceeding of A Future Vision for the Saudi Economy Symposium, Riyadh, 12–23 October, 2003, p. 37, 2002.

[9] T. Rutkowski, L. Raschid-Sally and S. Buechler, “Wastewater irrigation in the developing world- Two case studies from the Kathmandu Valley in Nepal,” Agricultural water management 88 83–91, 2007.

[10] UNOHRLLS, “Least Developed Countries. UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States”. [Online]. Available: http://www.unohrlls.org/en/home/. [Accessed on 20 June 2011].

[11] S. Marahatta, B.S. Dongol, G.B. Gurung, Temporal and Spatial Variablity of Climate Change Over Nepal (1976-2005), Kathmandu: Practical Action Nepal, 2009.

[12] M.M. Shereif, M. Easa El-S, M.I. El-Samra, K.H. Mancy, “A demonstration of wastewater treatment for reuse applications in fish production and irrigation in Suez, Egypt,” Water Sci. Technol. 32, 137–144, 1995.

[13] T. Asano, M. Maeda, M. Takaki, “Wastewater reclamation and reuse in Japan: overview and implementation examples,” Water Sci. Technol. 34, 219–226, 1996.

[14] J. Haarhoff, and B. Van der Merwe, “Twenty-five years of wastewater reclamation in Windhoek, Namibia,” Water Sci. Technol. 33, 25–35, 1996.

[15] P.J. Dillon, P. Pavelic, N.Z. Gerges, D. Armstrong, A.J. Emmett, Artificial recharge of groundwater In: Proceeding of the Second International Symposium Artificial Recharge of Ground Water, pp. 426-435, 1994.

[16] J.M. Anderson, “Current water recycling initiatives in Australia: scenarios for the 21st century,” Water Sci. Technol. 33, 37–43, 1996.

[17] P. Guillaume, D. Xanthoulis, “Irrigation of vegetable crops as a means of recycling wastewater: applied to Hesbaye Frost,” Water Sci. Technol. 33, 317–326, 1996.

[18] S. Toze, “Reuse of effluent water—benefits and risks,” Agricultural Water Management, 80 (2006) 147–159, 2006.

[19] FAO, “Agriculture, Food and Water,” FAO. Rome, 2003.

[20] I. Angin, A.V. Yaganoglu, M. Turan, “Effects of long-term wastewater irrigation on soil properties,” J. of Sust. Agric. 26(3): 31-42, 2005.

[21] J.K. Friedel, T. Langer, C. Siebe, K. Stahr, “Effects of long-term wastewater irrigation on soil organic matter,

soil microbial biomass and its activities in central Mexico,"Biol. Fertil. Soils 31: 414-421, 2000.
[22] H.I. Shuval, 'Wastewater irrigation in developing countries," Summary of World Bank Technical Paper No: 51, Washington, DC, 1990.
[23] G.N. Magesan, J.C. Williamson, G.P. Sparling, L.A. Schipper, and A.Rh. Lloyd-Jones, "Hydraulic conductivity in soils irrigated with wastewaters of different strengths: Field and laboratory studies," Aust. J. Soil Res. 37: 391-402, 1999.
[24] M.J. Mohammad, M. Ayadi, "Forage yield and nutrient uptake as influenced by secondary treated wastewater," Journal of Plant Nutrition 27 (2), 351–365, 2005.
[25] A. Lopez, A. Pollice, A. Lonigro, S. Masi, A.M. Palese, G.L. Cirelli, A. Toscano, R. Passino, "Agricultural wastewater reuse in southern Italy" Desalination: Integrated Concepts in Water Recycling 187 (1–3), 323–334, 2006.
[26] WHO, "WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. In: Wastewater Use in Agriculture," vol. II. World Health Organization 222, 2006.
[27] M. Kiziloglu, M. Turan, U. Sahin, I. Angin, O. Anapali, M. Okuroglu, "Effects of wastewater irrigation on soil and cabbage-plant (brassica olerecea var. capitate cv. yalova-1) chemical properties," Journal of Plant Nutrition and Soil Science 170 (1), 166–172, 2007.
[28] A. Bradford, R. Brook, C. Hunshal, "Wastewater irrigation in Hubli-Dharwad, India: implication for health and livelihoods," Environment and Urbanization 15, 157–172, 2003.
[29] F. Huibers, and J. Van Lier, "Use of wastewater in agriculture: the water chain approach," Irrigation and Drainage 54 (S1), S3–S9, 2005.
[30] L. Raschid-Sally, R. Carr, S. Buechler, "Managing wastewater agriculture to improve livelihoods and environmental quality in poor countries," Irrigation and Drainage 54, S11–S22, 2005.
[31] H. Rosenqvist, P. Aronsson, K. Hasselgren, K. Perttu, "Economics of using municipal wastewater irrigation of willow coppice crops," Biomass and Bioenergy 12 (1), 1–8, 1997.
[32] J. Bos, H. Gijzen, H. Hilderink, M. Moussa, L. Niessen, "Quick Scan Health Benefits and Costs of Water Supply and Sanitation. Netherlands Environmental Assessment Agency," National Institute for Public Health and the Environment, Netherlands, p. 45, 2004.
[33] B. Jimenez, and T. Asano, "Water reclamation and reuse around the world. In: Jimenez, B., Asano, T. (Eds.)," Water Reuse: An International Survey: Common Practices and Current Needs in the World, IWA Publishing, London, pp. 3–26, 2008.
[34] World Water Assessment Program, "The United Nations World Water Development Report 3," Water in a Changing World. UNESCO and Earthscan, Paris and London, 2009.
[35] World Health Organization, "Health Guideline for the Use of Wastewater in Agriculture and Aquaculture," (WHO Technical Report Series, No.778), Geneva, Switzerland, 1989.
[36] MEDAWARE, "Development of Tools and Guidelines for the Promotion of the Sustainable Urban Wastewater Treatment and Reuse in the Agricultural Production in the Mediterranean Countries, Technical Guidelines on Wastewater Utilisation. European Commission, Euro-Mediterranean Partnership, 2005.
[37] H.M. Green, "The Effects of Carpet Dye on the Bagmati River," MSc Thesis, Civil and Environmental Engineering Department, Massachusetts Institute of Technology, Cambridge, MA, USA, 2003.
[38] Metcalf & Eddy, Inc., CEMAT Consultants Ltd, "Urban Water Supply Reforms in the Kathmandu Valley," Completion Report, ADB TA Number 2998–NEP, 2000.
[39] G. Rajendra and H. D. Lekhak, "Scientific World," 4, 102-108, 2006.
[40] A.A. Olajire, "The brewing industry and environmental challenges," Journal of Cleaner Production, doi:10.1016/j.jclepro.2012.03.003, 2012.
[41] MOPE, "Environmental Standards," Ministry of Population and Environment, Government of Nepal, 2010.
[42] Internal Technical Report, "Far Eastern Textile Company," Panchiao, Taiwan, 1994.
[43] C.F. Gurnham (Ed.), "Industrial Waste Control," Academic Press, New York, 1965.
[44] S.H. Lin, and M.L. Chen, "Treatment of Textile Wastewater by Chemical methods for reuse," Wat. Res. Vol. 31. No. 4. Pp. 868-876, 1996.
[45] Nepal Gazette, "Government of Nepal" Vol. 47, 1999.

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