Fertilizing value and health risk assessment related to wastewater reuse in irrigation
Case study in a Soudano-Sahelian city: Ouagadougou.
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ABSTRACT
The major aim of the study is to validate the use of wastewater as an alternative source of irrigation water and fertilizer, while assessing the sanitary quality of the vegetable products. More specific objectives are (i) to propose an adjusted treatment of effluent/fertilizer management (ii) and to evaluate potential risks associated with effluent irrigated crops consumption.

This paper presents the materials and method used and summarizes the results of each objective. The adjusted treatment applied on lettuce gave higher yields than those obtained with wastewater treatment. It also shows comparable yields with those of conventional treatment (i.e. fresh water and synthetic fertilizer). Experiments on carrot and eggplant however revealed that these crops, which have a longer growth period, need further investigation. The sanitary assessment indicated no adverse levels of heavy metals (Cd, Ni, Pb, Cr, and Cu) in the crops. The faecal contamination test performed with Escherichia coli analysis on the three crops indicated an absence of this bacterium on the edible part of eggplant and carrots that had been irrigated with wastewater, whereas lettuce presented some positives tests meaning that its consumption could involve a health risk.

Keywords: wastewater, soil, fertilizer, yield, heavy metals, faecal contamination

INTRODUCTION
Crop irrigation with wastewater is a widespread practice in developing country cities, especially in arid and semi-arid areas. This alternative source of water reduces fresh water demand and the cost of expensive commercial fertilizers necessary to reach optimal yields.

It is well known that wastewater contains nutrient elements like nitrogen, phosphorus, potassium and others micronutrients essential to plant growth. As such, some researchers have indicated that plants irrigated with wastewater have at least the same yields as those irrigated with fresh water and commercial fertilizers (Shende and Chakrabarti, 1987; Xanthoulis and Fonder, 2003). However, more recent studies demonstrated that long term irrigation with wastewater tends to reduce yields because of an imbalance in fertilizer (Wang and Huang, 2008).

Health impacts are mainly due to pathogens (bacteria, viruses, protozoa cysts and helminth eggs) and other organic and inorganic toxic substances which are likely to exceed health protection standards (WHO, 2006). Several studies (Dawson, 2005; Feenstra et al., 2000; Melloul et al., 2001) throughout the world have demonstrated a very close relation between the consumption of fruits and vegetables irrigated with raw wastewater and many foodborne diseases like gastroenteritis, cholera, chemical toxicity etc. However, other studies show that an appropriate treatment of these effluents allows safe irrigation even for eaten raw vegetables (Amahmid et al., 1999; Sheikh et al., 1981). This emphasizes the importance of the treatment in wastewater reuse.

This study took place in Ouagadougou, a typical West African city. Ouagadougou has 1.5 million inhabitants that are mostly young. The joblessness context involves a very high level of informal activities among which farming takes an important place. These urban farmers are set up randomly around water points. Many of

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them are settled along the open channels used for the drainage of the different domestic and industrial wastewaters throughout the city. Others farmers reuse secondary treated wastewater discharged downstream of the town sewage treatment plant. These effluents are used to irrigate vegetables among which some species, like lettuce or carrot, generally eaten raw.

The objectives of this study are (i) to propose an adjusted treatment of effluent/fertilizer management (ii) and to evaluate potential risk associated with effluent irrigated crops consumption.

MATERIALS AND METHODS

The study took two years, from 2006/2007 to 2007/2008 and was defined after a preliminary one year experiment (Sou et al., 2008). It was carried out at the International Institute for Water and Environmental Engineering (2IE) campus, at an experimental site situated downstream of a sewage treatment plant which treats domestic wastewater. Effluents from this plant were used to perform the experiments.

Three types of crops (lettuce, carrot, and eggplant) were tested with the following treatments: (i) treated wastewater (TW), (ii) fresh water with commercial fertilizers (FF) measured for optimum yields (iii) a mixed treated wastewater and fresh water irrigation (MWF). This last treatment represents the effluent/fertilizer management. It was based on wastewater dilution with fresh water poorly mineralized, in order to reduce highly concentrated nutrients contained in the effluents (generally nitrogen). If the dilution reduced other nutrients levels (like those of potassium or phosphorus) commercial fertilizers were added.

All the crops and the treatments applied were tested in three replicates. The plots, of 6 m² each, were disposed randomly according to the Split-plot design. The amount of irrigation water was calculated to compensate evapotranspiration in the area. The water was applied manually with a watering can according to the practice observed on the farming sites in the city. Pesticides were applied at the seedling stage and at each sign of insect attack.

At harvest time, the different crops yields were compared according to the applied treatments and the sanitary quality assessed with heavy metals concentration (Cd, Cu, Pb, Ni, Cr) and faecal contamination (Escherichia coli).

RESULTS

Characterization of the soil revealed loamy texture and very poor levels of nutrients. The irrigation wastewater was close to a neutral pH and its electrical conductivity is 600 µS cm⁻¹. The fertilizer's mean values were 25 mg l⁻¹ for easily assimilated nitrogen, 19 mg l⁻¹ for available phosphorus (PO₄) and 12 mg l⁻¹ for potassium (K). The microbiological quality is in accordance with World Health Organization (2006) standards for parasitic cysts and eggs. However, the number of faecal coliform was higher than the 1000 UFC 100 ml⁻¹ required for non-restrictive use in agriculture. The fresh water is very poor in nutrients content (mineral nitrogen, phosphorus and potassium were all lower than 5 mg l⁻¹). The pH was slightly under 7 and the electrical conductivity was ten fold lower than that of wastewater.

Figure 1 presents the crop yields (in t ha⁻¹) for the three treatments (TW, MWF and FF). TW treatment yields reduced between 2006-2007 and 2007-2008, meaning that irrigation with only wastewater led to yield reduction. This was particularly demonstrated with carrot and eggplant since their yields were reduced to about 50% between the two years.

The goal of the MWF treatment was to reach higher yields than those of TW treatment and comparable production with the FF treatment which is considered to be the optimal treatment. Lettuces MWF yields clearly reached this expectation. However eggplant and carrot results were somewhat questionable. The two crops have the same trends, which could be related to a growth period longer than that of lettuce.

The important conclusions for the effluent/fertilizer management objective are first that TW yields were always higher than those of FF, which indicate that the wastewater has important fertilizing capacity. The second conclusion is that this capacity can be enhanced with an adjusted effluent/fertilizer management, as shown on lettuce. The last conclusion is that the adjusted treatment made for carrot and eggplant did not improve the
yield as they were lower than those obtained just by applying wastewater. So the management process must be reviewed. Most likely, nitrogen provision during the growth period should provide a better fit for the crop period demand. It is possible that the dilution ratio between wastewater and fresh water (which was single for the entire growing period of one giving crop), should be variable according to the plant nitrogen demand.

According to sanitary quality, heavy metals results demonstrated that the crop’s consumption did not involve higher risk for consumers when the vegetables were irrigated with the wastewater, in comparison with fresh water irrigation. Microbial quality assessment indicated no *Escherichia coli* on edible part of carrot or eggplant irrigated with wastewater. Lettuce from wastewater treatment plots however exhibited presence of these bacteria, meaning that lettuce is likely to be contaminated by pathogens. Results on eggplant are not surprising as these vegetables are somewhat far from the ground and they receive an important part of the solar radiation which acts like a disinfectant. Carrots were expected to have the poorest microbiological quality. Therefore carrot root bacterial quality must be further investigated.

**CONCLUSION**

Wastewater reuse in irrigation is largely considered an inevitable option to compensate water shortage in developing countries, specifically in arid and semi-arid areas. Economic and agronomic advantages are sometimes promoted but several studies warn about health risks and environmental impacts.

The present study took place in Ouagadougou, a typical city in a sub-Saharan country where wastewater is frequently used in farming sites to irrigate vegetables. The study had two main objectives: (i) to propose an adjusted treatment of effluent/fertilizer management (ii) and to evaluate potential risk associated with effluent irrigated crops consumption. The study confirms that domestic wastewater is an important source of fertilizers, especially nitrogen. The effluent/fertilizer management proposed in the study consisted of adjusting the nutrients in the wastewater in order to provide high crop yield. This treatment, tested on lettuce, increased its yield compared to that obtained only with wastewater irrigation or a conventional treatment (fresh water and total doses of fertilizers). However the same treatment, performed on carrot and eggplant, did not
demonstrate better results; indicating that further investigations must be completed for crops with longer growing period. The sanitary assessment did not reveal higher risk of heavy metal (Cd, Cu, Pb, Ni, Cr) contamination associated with wastewater irrigated crops consumption. However, lettuce irrigated with wastewater is likely to contain some pathogen because *Escherichia coli* were found on the crop leaves. Surprising results concerning *Escherichia coli* absence on carrot root irrigated with wastewater also involve future investigation.

REFERENCES


