Evaluation of the Extent of Treated Wastewater Utilization in Landscape Irrigation in New Cities

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ABSTRACT

Descriptive and quantitative statistical analysis methods were used to determine the extent of treated wastewater or non-refined water used in landscape irrigation in new cities as an alternative to drinking water utilization. The results of the study showed that about 65% of the sample, use drinking water and about 35% of the sample use treated wastewater in landscape irrigation. On other hand about 36%, 30%, 28% and 6% of the sample use sprinkler irrigation, mixed sprinkler and drip irrigation, traditional surface irrigation, and drip irrigation system in landscape irrigation, respectively. About 40% of the sample consume more than 20 cubic meters of water per week, where about 22%, 20% and 18% use more than 10-20 cubic meters, more than 5-10 cubic meters and 1 - 5 cubic meters per week to irrigate their landscape, respectively. There is a statistically significant relationship between the water quality used in landscape irrigation at home gardens and irrigation system, home garden area, and plant diversity in the garden. Whereas, the existence of a statistically significant relationship between water quality used, the number of landscape irrigation per week and the quantity of irrigation water used weekly were not proven. About 85% of the respondents prefer to use drinking water, where only 15% prefer to use treated wastewater for economic, psychological and health reasons.

Keywords: Landscape, Treated wastewater, Water quality, Chi-Square, Irrigation, New cities.

INTRODUCTION

Globally, freshwater water demands are increasing mainly due to population growth, increasing consumption and the demands of the industrial and agricultural sectors *(Massoud and Elfadel, 2002).* As the world population is expected to increase by 2 billion by 2050, the global food system will have to cope with this rise by doubling production to sustain the demand and improving living quality. Such intensification in agricultural systems and activities will stress fresh-water resources *(*Lahlou, *et al.,2021)*.

Egypt is one of the most vulnerable countries exposed to the effect of climate change which inversely reflects on water resources degradation (overuse, soil salinization, low irrigation efficiency, etc.). In addition, the increasing of water demand in agriculture as well as in the urban, industry and energy sectors *(Gaber, 2020)*. The water resources system in Egypt is classified as a semi-closed system. Its management relies on reuse of non-conventional water resources, the most important of which is treated wastewater *(Ahmed, 2017).*

Recently, the development of reclaimed domestic wastewater reuse projects has emerged as a potential non-conventional resource to satisfy the continuously increasing demand for water *(Massoud and Elfadel, 2002)*. Water reuse is an economical alternative in developing water resources because it can save more than half the cost of producing desalinated water *(*Eldeep et al., 2020). To reduce the pressure on freshwater resources and to preserve them for the providing of drinking water, it is important to consider how these resources are managed through policy developments *(Gaber, 2020)*. The reuse of treated wastewater could be one of the main alternative options to expand water resources, especially in dry areas, because it represents another source of renewable water *(Hashem and Xuebin, 2021)*. Though, treated wastewater is considered a good irrigation source for both arid and semi-arid areas *(*Eldeep et al., 2020).

In Egypt, about 5 billion m^3 of sewage water were collected every year. Therefore, the treated wastewater can add up to 5 billion m^3 to Egypt's water resources *(CAPMAS, 2020)*. In this respet several water-scarce countries worldwide, wastewater reuse is considered a long-established practice and very important. Potential wastewater reuse applications include agricultural and landscape irrigation, industrial reuse, urban applications such as street cleaning, and firefighting and ecological and recreational uses (*Hashem and Xuebin, 2021)*.

The wastewater treatment systems in Egypt are suffering from some problems as lack of public awareness, reliance on manual systems, lack of coordination between different water and wastewater authorities, over staffed unskilled labors, inadequate operation and maintenance plans, lack of accurate and reliable data, incomprehensive Master Plan, most of the facilities are over loaded, inefficient water and wastewater networks, small capacities of the treated wastewater treatment plant, lack of new technologies, financial crisis level, as well as absence of plans to preserve sector investment. Due to insufficient funds for operation and maintenance and technical know-how, many of the treatment plants are not able to meet the required standards *(Abdallah, 2014)*.

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Use of treated wastewater provides a reliable alternative source for irrigation in arid and semi-arid regions *(Elbana et al., 2014; Shetta,2016).* Treated wastewater effluents may be reused for different purposes such as landscape irrigation (parks, green areas, golf courses, etc), recreational activities, firefighting and groundwater recharge *(Massoud and Elfadel, 2002)*. The Egyptian code of the reuse of treated wastewater for agricultural purposes prohibited the usage of raw municipal wastewater (not treated) for agricultural use. Whereas, the treated wastewater has been classified into three categories (A, B, and C) according to the treatment level. The category B and C can be used for agriculture purposes in desert areas, whereas A can be used for landscape irrigation in urban areas *(Elbana et al., 2014)*.

Accordingly, the research problem can be summarized as the lack of enough studies to explain and clarified the effect of substitute potable water in irrigating landscape by treated wastewater and to How extend inhibited people in new cities can accept this water as well as government official. Solving this problem will reduce the heavy burden put in potable water for irrigating landscape. In addition, this will help improving wastewater treatment plant to improve this plant efficiency in quantity and quality.

Objective of the study:

- **The main objective:** was to determine the extent of treated wastewater or non-refined water in landscape irrigation in new cities as an alternative to drinking water utilization.
- **Sub- objectives:**

- Assessment of the current status of the reused drain water quantities for irrigation of tree forests.
- To estimate the average per capita, share of the quantities of refined water produced.
- To evaluate the relationship of the quality of landscape irrigation water used by respondents in the sample with some variables such as the number of irrigation times, the quantity of irrigation water used weekly, the garden area, the irrigation system and the plant diversity.
- To identify the obstacles and problems of using treated wastewater in landscape irrigation from the user's point of view.

MATERIAL AND METHODS

Methodology and data sources:

Descriptive and quantitative statistical analysis methods were used such as percentages, average, relative frequency and graphs. In addition, use of Chi–Square test to ensure that there is a statistically significant relationship between the quality of water used in landscape irrigation and some variables.

Two main sources of data were used. The first source is the published and unpublished secondary data issued by government agencies such as the central agency for public mobilization and statistics (CAPMAS) and the ministry of water resources and irrigation (MWRI). The second source is the preliminary data collected by the questionnaire, which designed to collect field data to serve the objectives of the study through personal interviews with citizens living in Katameya height, and Lake View compounds in the fifth settlement - New Cairo who have gardens in their homes, which selected randomly by simple random sampling method.

RESULTS AND DISCUSSION

The current situation of treated wastewater in Egypt:

Reuse of wastewater is one of the most important non-convential water sources in Egypt, as it represents about 65% of the non-traditional water resources and about 17% of the total available Egyptian water resources during the period 2015-2019, (CAPMAS, 2020).

Table 1 shows that the average quantities of used drain water for tree forests irrigation is estimated to 853.3 thousand cubic meters per day, and a standard deviation estimated to 104.9 thousand cubic meters per day during the period 2013-2018. It is also clear from the same table that the average of the served area used drain water is estimated to 10491.2 feddans and the standard deviation is estimated at about 1696.3 feddans within the same period.

On other hand, Table 2 shows the average quantity of pure water produced is estimated to about 9762.5 million cubic meters, with a standard deviation at about 945.5 million cubic meters during the period 2010-2020. As for the average per capita share of pure water produced is about 110.2 cubic meters annually, with a standard deviation at about 9.5 cubic meters annually during the same period.

Table 1. Quantities of drain water reused for tree forests irrigation between 2013-2018

Years	Quantity of used drain water ($1000m^3$/day)	Beneficial area (feddan)
2013	857	13701
2014	870	10838
2015	715	9423
2016	829	10346
2017	813	9487
2018	1036	9152
Average	853.3	10491.2
Standard Deviation	104.9	1696.3

Source: central agency of public mobilization and statistics, annual bulletin of irrigation and water resources statistics, several issues.

Table 2. Average per capita of pure water quantity produced between 2010-2020

years	Quantity of pure water produced (Million/m^3)	Population estimates (Million)	Average per capita pure water produced (m^3)
2010	10483	77.8	134.7
2011	8505	79.6	106.8
2012	8919	81.6	109.3
2013	9727	83.7	116.3
2014	8867	85.8	103.4
2015	8889	88	101.1
2016	9297	91.2	102.1
2017	9823	95.2	103.2
2018	10793	96.3	112.1
2019	11087	98.1	113
2020	10997	99.8	110
Average	9762.5	-	110.2
Standard Deviation	945.5	-	9.5

Source: central agency of public mobilization and statistics, annual bulletin of pure water and sanitation statistics, several issues.

The study sample:

Using the simple random sampling method, a hundred questionnaires were collected from citizens living in New Cairo city to identify the quality of water used in landscape irrigation in their gardens, as well as to estimate the relationship of the quality of used irrigation water with some variables such as the irrigation number, the quantity of irrigation water used weekly, the garden area, plant diversity in the garden and the type of irrigation system used to irrigate the landscape.

Fig.1 shows the water quality used for irrigating the landscape of the home garden, which explain that about 65% of the sample use drinking water to irrigate the home garden, where only 30% of the sample use treated wastewater. This asked for more attention and effort to increase treated wastewater in landscape irrigation. On other hand, Fig.2 presents the type of irrigation system used in landscape. It is found that about 36% of the sample use sprinkler irrigation system, about 30% use sprinkler irrigation system mixed with drip irrigation system, about 28% use traditional surface irrigation system and about 6% use drip irrigation system to irrigate their landscape.

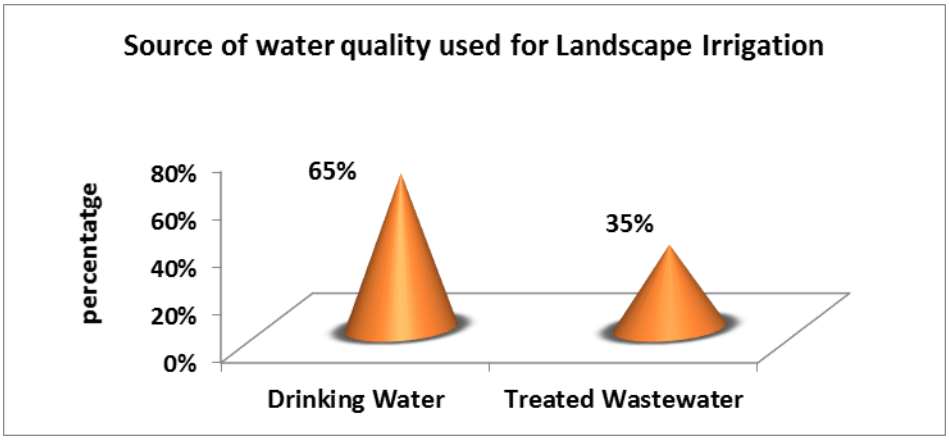

Fig.1. percentage of water quality used for landscape irrigation

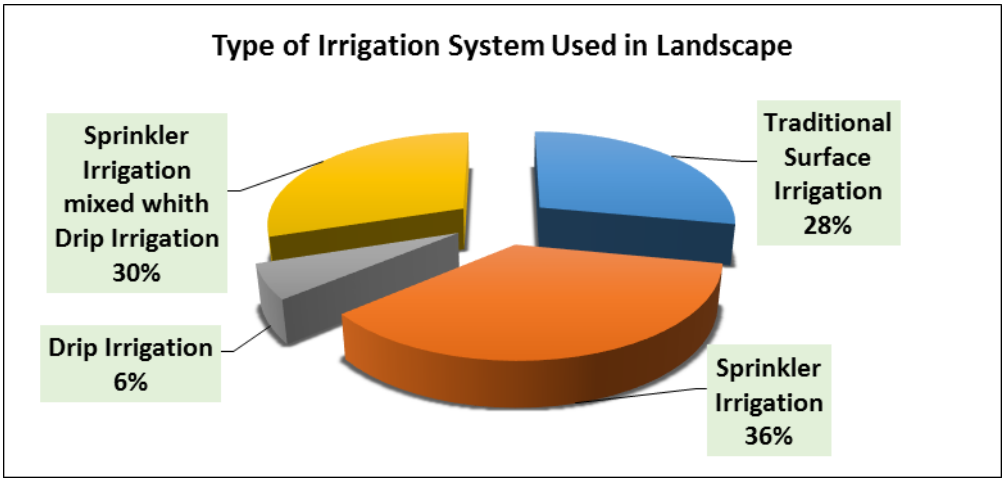

Fig.2. percentage of irrigation system type used in landscape

Fig.3 explain the garden state and its area at inhibited homes of the sample. About 19% of them have gardens estimated to 100-300 m^2, about 27% of them have gardens estimated to 300-500 m^2 and 54 % of them have gardens estimated more than 500 m^2.

As for the number of landscape irrigation per week, it found that about 27% of the sample irrigate their landscape seven times, 21% of them irrigate their landscape three times, 17 % of them irrigate their landscape twice a week, as shown in fig.4. From the above it can be concluded that there is high percent of inhabitant irrigate their landscape seven times which indicates how clean water is consumed by landscape irrigation and the need to save this amount and replace it by treated wastewater.

In other hand, quantity of water used for irrigating landscape, it was found that about 40% of the sample inhabitant use more than 20 m^3/week for irrigating their landscape, where 22%, 20% and 18% of the sample use about 10-20 m^3, 5-10 m^3 and 1-5 m^3 per week, respectively as indicated by fig.5.

Concerning the plant diversity at home garden, plant diversity was classified into three categories: good diversity (which includes grass areas, flowers and ornamental trees + fruit trees + vegetables), medium diversity (which includes grass areas, flowers and ornamental trees + fruit trees), and weak or poor diversity (includes Grass areas, flowers and ornamental trees).

Plant diversity at home garden of the sample was investigated at which 51% categorize to be good 32% as medium and 17% as poor plant diversity as shown in fig.6. This indicates why most respondents of the sample inhibited like to use drinking water for landscape irrigation.

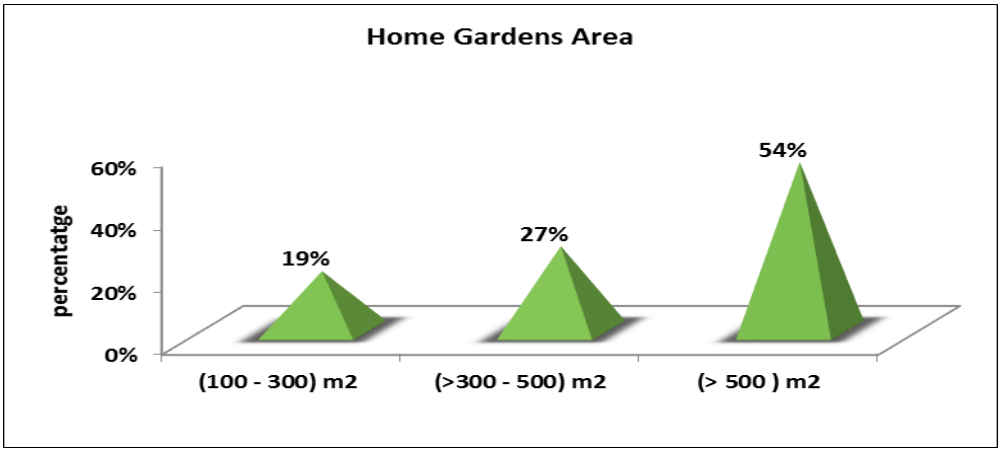

Fig.3. percentage of home gardens area

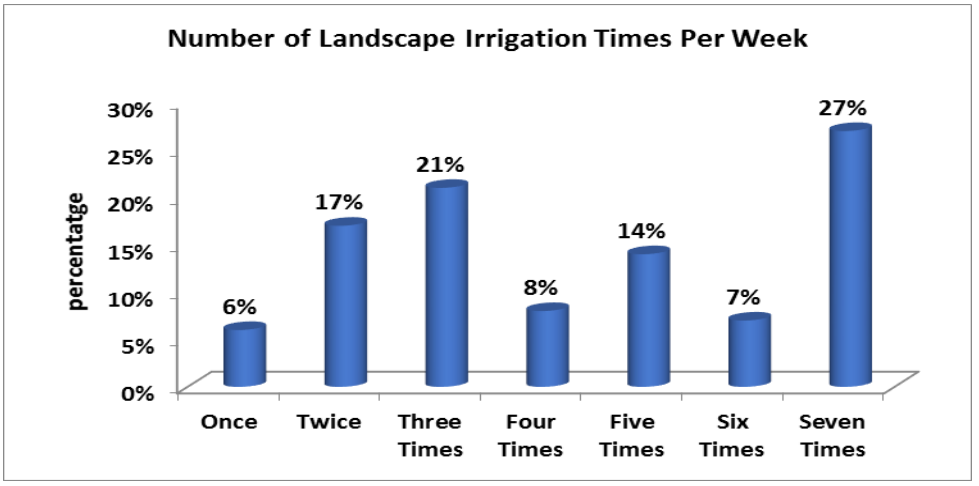

Fig.4. percentage of number of landscape irrigation times per week

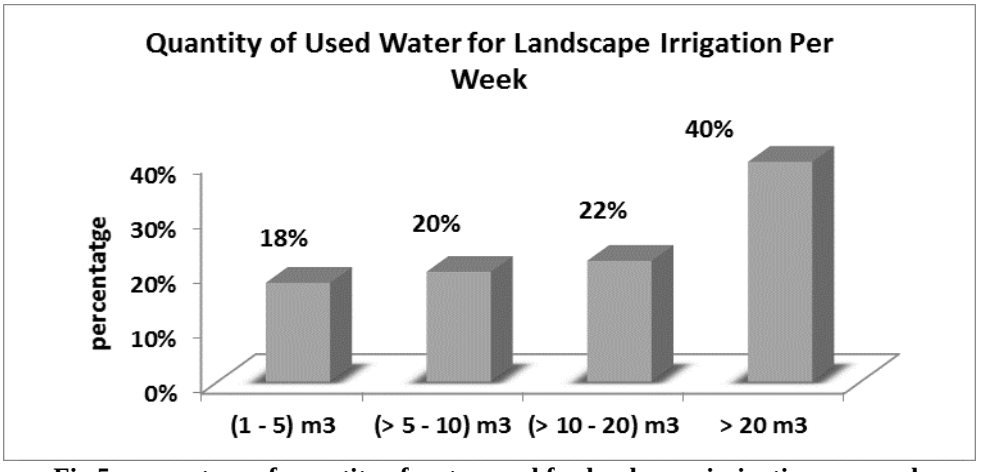

Fig.5. percentage of quantity of water used for landscape irrigation per week

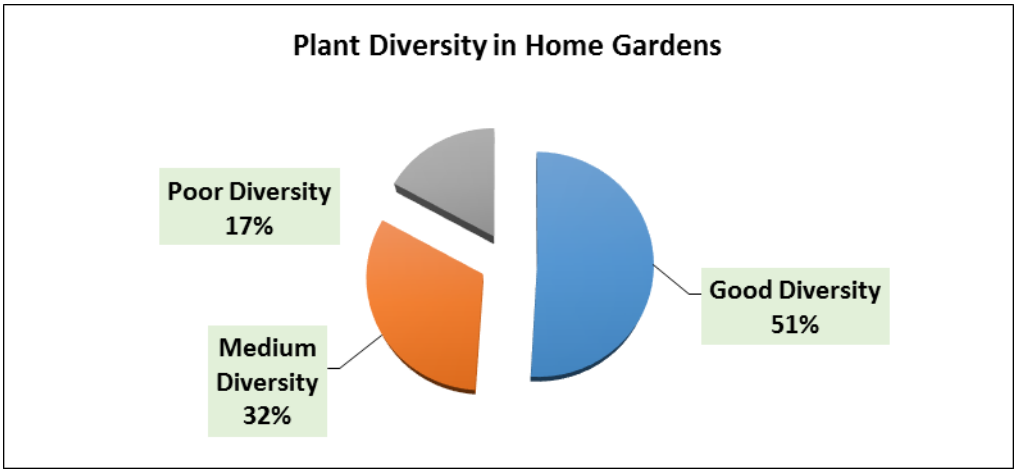

Fig.6. percentage of plant diversity in home gardens

Accordingly, a statistical analysis was implemented to test the significant relationship between water quality used for irrigating landscape and some variables as irrigation system, area of the garden, plant diversity, irrigation water quantity weekly and number of irrigation per week.

So, chi-square test was used where the result indicated that, there are significant relationship between water quality used for irrigating home garden and irrigation system, garden area and plant diversity, where no significant relationship with number of irrigation and quantity of irrigation water, as shown in Table 3.

Asking sample members about which type of water sources (drinking or treated water) to use for irrigating their landscape, their response was 85% prefer drinking water, where only 15% accept treated wastewater. Each category of them have their reasons as indicated in table 4 specially for treated wastewater. There reasons were classified as economic, psychological and health reasons.

With regard to the economic reasons, it included several reasons, which are: the unavailability of treated wastewater, the high costs of using treated wastewater, in contrast to low-cost drinking water, the irrigation network is damaged due to its blockage as a result of sediment formation inside it and fear of excess salt in the soil. The relative frequency of these reasons is estimated at 90%, 84%, 80% and 75% for each of them, respectively. As for the psychological reasons, they included feelings of malaise and disgust at being wastewater, the cleanliness of the treated wastewater and its undesirable odor. The relative frequency of it is estimated at 85% and 87%, respectively. As for the health reasons, they included fear of causing diseases or infection and concern that they might help spread insects and rodents, with a relative frequency estimated at about 85% and 80% for each, respectively.

Table 3. The relationship of water quality used in landscape irrigation and some field study variables

The **variables:**	**Pearson Chi-Square**	**Significance**
- Number of irrigation times per week	16.37	0.012*
- Quantity of irrigation water used per week	5.096	0.165*
- irrigation system type	17.68	0.001**
- The home garden area	11.05	0.004**
- Plant diversity in home gardens	23.59	0.000**

*is not significant. **is significant at significance level 5%.
Source: Chi-Square test results, IBM SPSS program V20.

Table 4. Obstacles and problems of using treated wastewater in landscape irrigation

Reasons for not using treated wastewater for irrigation:	**Relative Frequency (%)**
Economic reasons:	
- The unavailability of treated wastewater, unlike drinking water that is available and clean.	90
- The high costs of using treated wastewater, in contrast to low-cost drinking water.	84
- Damage to the irrigation network due to its blockage as a result of sediment formation inside it.	80
- Fear of excess salt in the soil.	75
psychological reasons:	
- Feeling upset and disgusted with being wastewater.	85
- Inadequate cleanliness of treated sewage water and its undesirable odor.	87
Health reasons:	
- Fear of causing disease or infection.	85
- Concern that it may cause the spread of insects and rodents.	80

Source: study sample data.

CONCLUSION

The water resources system in Egypt is classified as a semi-closed system. Its management relies on reuse of its non-conventional water resources, the most important of which is treated wastewater. The reuse of treated wastewater could be one of the main alternative options to expand water resources, especially in dry areas, because it represents another source of renewable water. So, the research aimed to determine the extent of treated wastewater or non-refined water used in landscape irrigation in new cities as a vital alternative to drinking water utilization. The results of the study showed that about 65% of the sample, use drinking water and about 35% of the sample use treated wastewater in landscape irrigation. It was confirmed that there is a statistically significant relationship between the water quality used in landscape irrigation at home gardens and irrigation system, home garden area, and plant diversity in the garden. Whereas, water quality used, the number of landscape irrigation per week and the quantity of irrigation water used weekly were not significant. About 85% of the respondents prefer to use drinking water, where only 15% prefer to use treated wastewater for economic, psychological and health reasons.

RECOMMENDATIONS

- Considering the reuse of treated wastewater in landscape irrigation as part of the integrated water management and planning.
- Conducting more studies and research to study the long-term positive and negative effects of the use of treated wastewater on the environment and health.
- Spread awareness and education among citizens through training and qualifying a technical cadre by holding training courses, lectures, survey tours and discussions, and also through the available media to encourage citizens using treated wastewater in landscape irrigation and save clean water.
- More efforts from concerned authorities have to be implemented to increase efficiency and number of sewage treatment stations.
- Reconsidering the licenses granted to real estate companies that determine the percentage of green areas and landscape and apply laws not to allow use of fresh water in landscape irrigation and encouraging them to set up wastewater treatment stations for use in landscape irrigation.

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الملخص العربي

تقييم مدى استخدام مياه الصرف الصحى المعالجة فى رى اللاند سكيب بالمدن الجديدة

رقيه كمال محمد أحمد ، طلعت أحمد أبو زيد

استخدمت الدراسة طرق التحليل الإحصائي الوصفي والكمي لتحديد مدى استخدام مياه الصرف الصحى المعالجة في ري اللاند سكيب في المدن الجديدة كبديل لاستخدام مياه الشرب. أظهرت نتائج الدراسة أن حوالي ٦٥٪ من العينة يستخدمون مياه الشرب وحوالي ٣٥٪ من العينة يستخدمون مياه الصرف الصحي المعالجة في ري اللاند سكيب. من ناحية أخرى، يستخدم حوالي ٣٦٪ و ٣٠٪ و ٢٨٪ و ٦٪ من العينة الري بالرش والري المختلط (الرش + التنقيط) والري السطحي التقليدي ونظام الري بالتنقيط في ري اللاند سكيب على التوالي. وأن حوالي ٤٠٪ من العينة تستهلك أكثر من ٢٠ متر مكعب من المياه أسبوعياً وحوالي ٢٢٪ و ٢٠٪ و ١٨٪ يستخدمون (أكثر من ١٠-٢٠ متر مكعب) و(أكثر من ٥-١٠ متر مكعب) و (١ - ٥ متر مكعب) أسبوعياً لري اللاند سكيب على التوالي. تم التأكيد على وجود علاقة ذات دلالة إحصائية بين نوعية المياه المستخدمة في ري اللاند سكيب في الحدائق المنزلية ونظام الري المستخدم ومساحة الحديقة المنزلية والتنوع النباتي في الحديقة، فى حين لم يثبت وجود علاقة ذات دلالة إحصائية بين نوعية المياه المستخدمة وعدد مرات ري اللاند سكيب في الأسبوع وكمية مياه الري المستخدمة أسبوعياً. كما تبين أن حوالي ٨٥٪ من العينة يفضلون استخدام مياه الشرب و ١٥٪ فقط يفضلون استخدام مياه الصرف الصحى المعالجة فى رى اللاند سكيب لأسباب اقتصادية ونفسية وصحية.

الكلمات المفتاحية: اللاند سكيب ، مياه الصرف الصحى المعالجة ، نوعية المياه ، مربع كاى ، الرى ، المدن الجديدة.