AN APPRAISAL OF MICROBIOLOGICAL INDICATORS FOR GREY WATER REUSE AS A PRIORITY ISSUE

GIRESUNLU E.[1] and BELER-BAYKAL B.[1]

[1] Istanbul Technical University, Department of Environmental Engineering
34469 Ayazaga, Istanbul, TURKEY
E-mail: giresunlue@itu.edu.tr; baykalb@itu.edu.tr

ABSTRACT

The search for alternative sources of water continues to be a challenge due to the growing problem of water stress/scarcity. Stream segregation offers an alternative source through the grey water stream which is water generated from washing/cleaning activities in households. Constituting about ¾ of the total volume, grey water has a lower pollution potential compared to domestic wastewater. The most important pollutant in grey water is considered to be organic matter, however microbiological safety is another issue that needs to receive attention. Total Coliform and Fecal Coliform concentrations of grey water are comparable to those in domestic wastewater and E.Coli concentrations are high too. Due to high concentrations of microbiological indicators, microbiological safety should be taken into account while reusing grey water. Australia is the only country with specific standards about reusing grey water, while other countries apply wastewater reuse standards for grey water as well. This work aims to provide a compilation of microbiological indicator concentrations in grey water in the literature and to present new data of microbiological analyses done with different grey water samples. An overview of standards about grey water reuse and wastewater reuse around the world are also provided. A comparison of those standards with microbiological indicators in grey water suggests the use of those parameters as one of priority importance.

Keywords: Water reuse; stream segregation; grey water and its characterization; microbiological indicators; water quality standards and guidelines.

1. Introduction

Increasing concern regarding water stress and scarcity has enhanced search for alternative water resources. One possible alternative is domestic wastewater, as it is indispensably generated wherever people live. On the other hand, segregation of different domestic wastewater streams enables the revaluation and reuse of those streams for different end uses. At this time, segregation of domestic wastewater is done in two ways as two (grey / black water) or three (grey / yellow / brown water, also called ECOSAN streams) component streams. Of those streams, grey water is wastewater generated from household cleaning and washing activities such as bathtubs/showers, wash basins, washing machines, sinks and dishwashers, while the other streams originate from the toilet bowl.

With its high volume of about 75% of conventional domestic wastewater, grey water is a valuable renewable water source that can be returned to almost any point in the water cycle after being treated. Moreover, treatment of grey water is expected to be easier as compared to conventional domestic wastewater, since grey water has a lower pollution potential. Birks & Hills (2007) state grey water itself can also be segregated in two streams as light (weak), grey water generated from bathtubs/showers and wash basins, and dark (strong), grey water coming from washing machines, sinks and dish washers. Light grey water has a lower pollution potential and lower concentrations in terms of organic matter as compared to dark grey water. The level of nutrient content in all fractions of grey water is low.

Grey water contains about 40% of all organic matter in conventional domestic wastewater (Beler Baykal, 2015). In the literature, the primary pollutant in grey water is considered to be organic matter, while the level of microbiological indicators is expected to be low as it is collected separately from the toilet wastewater (Werner *et al*, 2003; Langergraber and Muellegger, 2001), which carries the majority of pathogenic microorganisms. This seems to reflect in the choice of treatment systems as it is mostly based on organics in the literature and microbiological parameters are not emphasized as much.

Depending on being water scarce or water stressed, some countries have interest in domestic wastewater and grey water reuse as sources of water. Several countries have published standards and guidelines regarding water reuse and majority of present standards and guidelines take domestic wastewater reuse as basis. Grey water reuse is rarer around the world, as stream segregation is a new concept. There is no differentiation between treated domestic wastewater quality and treated grey water quality for reuse and separate guidelines for reuse of grey water does not exist, except for Australia and Germany.

Reuse standards and guidelines are mostly based on organics, suspended solids and microbiological quality. Turbidity is another parameter that is controlled for aesthetic reasons.

Considering the fact that, microbiological indicators are among important parameters to maintain public health, the aim of this work is to discuss the status of microbiological quality of grey water and its safe use together with an overview of grey water reuse standards and guidelines. Microbiological quality of different grey water streams in the literature are compiled together with the data generated in several institutions in Turkey and compared to grey water reuse standards and guidelines to analyze possible end uses.

2. Microbiological quality of grey water

Microbiological quality is one of the main concerns of any water reuse including conventional wastewater and grey water to secure public health, which makes microbiological indicators important for grey water reuse. Table 1 gives a brief summary of microbiological quality of grey water in the literature, in terms of minimum and maximum concentrations in terms of Total Coliforms, Fecal Coliforms and E.Coli. Microbiological indicator concentration intervals for conventional domestic wastewater are also given in Table 1 to enable a comparison between the quality of grey water and conventional domestic wastewater. A quick survey reveals that grey water has appreciable amounts of those microbiological indicators. Typically, Total and Fecal Coliforms are in the range of weak to intermediate domestic wastewater characteristics, however occasionally they may even reach those of strong domestic wastewater. This reveals that microbiological quality may be as critical as organic matter and should be carefully monitored and controlled.

Table 1: Microbiological quality of grey water (prepared based on Giresunlu, 2015) and conventional domestic wastewater (Metcalf and Eddy, 2003)

Type	Source	Total Coliform cfu/100 ml		Fecal Coliform cfu/100 ml		E.Coli cfu/100 ml	
		min	Max	min	max	min	max
Grey water	Light	$0.5*10^{3}$ [1]	$2.4*10^{7}$ [1]	$1.7*10^{2}$ [1]	$5.6*10^{5}$ [2]	$6.31*10^{2}$ [3]	$2.07*10^{6}$ [4]
	Mixed	$1.4*10^{4}$ [5]	$5.4*10^{8}$ [6]	$3.6*10^{3}$ [5]	$4.6*10^{8}$ [7]	$2*10^{5}$ [8]	
	Dark	$4.3*10^{5}$ [9]	$0.2*10^{8}$ [8]	$2.6*10^{5}$ [9]	$0.1*10^{7}$ [8]	$7*10^{5}$ [8]	
Con. domestic wastewater	Weak	10^{6} [10]	10^{8} [10]	10^{3} [10]	10^{5} [10]		
	Inter.	10^{7} [10]	10^{9} [10]	10^{4} [10]	10^{6} [10]		
	Strong	10^{8} [10]	10^{10} [10]	10^{5} [10]	10^{8} [10]		

[1] Christova-Boal *et al* (1996), [2] Friedler *et al* (2005), [3] Winward *et al* (2008), (4) Chaillou *et al* (2010), (5) Atasoy *et al* (2007), [6] Paulo *et al* (2009), [7] Dallas *et al* (2004), [8] Halalsheh *et al* (2008), [9] Bani-Melhem and Smith (2012), [10] Metcalf&Eddy (2003).

Table 2 shows the results of analyses carried out with different grey water samples originating from buildings with different functions in Turkey, where mean values are presented. Also the influent of a municipal wastewater treatment plant was analyzed for comparison.

Throughout the analyses, ready to use disposable nutrient pads were used and all samples were taken into sterilized bottles in order to prevent contamination. All samples were worked with three different dilutions and in duplicate. The results revealed that raw grey water has appreciable amount of Total and Fecal Coliforms as well as E.Coli, as shown in Table 2.

Grey water collected from the hotel and the student housing shows weak domestic wastewater quality, while the pollution potential of grey water collected from the university wash basins is lower as compared to weak conventional domestic wastewater. The results of this work coincide with the data in the literature, pointing at the fact that grey water may contain microbiological indicators at high concentrations. This is important in terms of maintaining public health, as reuse applications become more popular day by day. However, once treated properly, as shown in Table 2, it is safe to use grey water as no Total Coliforms, Fecal Coliforms and E.Coli were observed in the effluent of treatment plant during this monitoring program.

Table 2: Microbiological quality of raw grey water, domestic wastewater and treated grey water

Stream	Location	Source/ Specification	TC	FC	EC
			cfu/100 ml		
Raw grey water	Hotel	Wash basin/ Bath/ Shower	$8.9*10^8$ (1)	$2.16*10^8$ (1)	$1.96*10^5$ (1)
	University student housing	Wash basin/ Bath/ Shower	$1.79*10^7$ (2)	$3.20*10^6$ (2)	$2.6*10^6$ (2)
	University building	Wash basin	$2.69*10^3$ (2)	$8.70*10^2$ (2)	$0.1*10^3$ (2)
Conventional domestic wastewater	Municipal wastewater treatment plant	Conventional/ mixed	$1.15*10^9$ (2)	$2.00*10^6$ (2)	$9.4*10^6$ (2)
Treated grey water	Hotel	MBR effluent	0 (3)	0 (3)	0 (3)

(1) Ministry of Environment and Urban Planning (2015), (2) Giresunlu and Beler-Baykal (2014), (3) Giresunlu (2015). – TC: Total Coliform, FC: Fecal Coliform, EC: E.Coli

3. Standards and guidelines related to grey water reuse

There are many countries that encourage wastewater reuse, however standards specific to grey water reuse are available only in Australia. Australia seems to be the leading country about grey water management, while Germany is the leader of Europe. The only standards and guidelines specific for grey water reuse applications are available in Australia. Grey water reuse, in the form of service water combining grey water and rain water, is legal in Germany and standards for this application have been issued. Standards for both countries are given in Table 3.

Every state in Australia has its own grey water reuse standards and some of those are shown in Table 3. In Australia, treated grey water is generally used for irrigation, toilet flushing and cleaning purposes, and all end-use applications require different treated grey water quality. Generally, quality requirements are higher for applications that may possibly involve human contact with grey water such as surface irrigation and toilet flushing. On the other hand, grey water reuse applications where the possibility of human contact is lower, ie drip irrigation, subsurface irrigation, require lower quality. Treated grey water quality is generally controlled by BOD, TSS, pH and turbidity. Microbiological safety is ensured with monitoring of E.Coli in all Australian standards for grey water reuse. Chlorination is mandatory where human contact with treated grey water is possible.

Table 3 also lists service water standards in Berlin, Germany. Service water refers to non-potable water, which may come either from grey water, rain water, or a combination of both. Service water standards use Total Coliforms for microbiological quality, while the same indicator is used in WHO guidelines. As can be seen from Table 3, WHO guidelines suggest different Total Coliform levels depending upon final reuse. While toilet reservoirs receive the most

stringent values, those for food stuff and ornamental pools are acceptable at higher Total Coliform counts.
A survey of the literature shows that most of the countries do not have specific standards for grey water reuse and in those countries, standards available for wastewater reuse are applied for grey water also (Giresunlu, 2015). These standards have limitations for BOD, TSS, pH and turbidity as parameters, similar to those standards used in Australia, however these countries use Total Coliform for monitoring microbiological quality instead of E.Coli. Quality required for reuse of wastewater generally depends on final-use and increases as possibility of human contact increases, similar to grey water standards discussed above.

Table 3: Microbiological guidelines and standards for grey water reuse

	Total Coliform	Fecal Coliform	E.Coli	Reuse Application
		cfu/100 ml		
WHO, 2006(1)	10			Toilet reservoir
	200			Fruits and vegetables eaten raw
	1000			Ornamental pools, fruits and vegetables
Queensland, Australia(2)			1	Toilet reservoir, laundry, vehicle washing, cleaning
			1	Surface irrigation
			10	Drip irrigation
Victoria, Australia(3)		Not permitted		Toilet reservoir, laundry, surface irrigation
				Subsurface irrigation
Western Australia, Australia(4)			1	Toilet reservoir, laundry
			10	Irrigation
New South Wales, Australia(5)			10	Toilet reservoir, laundry
			30	Surface irrigation
Berlin, Germany(6)	10			Service water

(1) WHO, 2006. (2) Queensland Plumbing and Wastewater Code, 2011. (3) Victoria EPA, 2013. (4) Western Australia Department of Health 2010 (5) New South Wales Department of Energy, Utilities and Sustainability, 2008. (6) Nolde, 1996

Assigning standards which are in accord with final reuse practice makes a lot of sense, especially taking fit for purpose use of water approach into consideration. One of the most frequent reuse applications of grey water is toilet flushing, which is regularly done with water at drinking water quality, contradicting with this approach. For example for toilet flushing, bathing water quality could be acceptable with treated grey water, since chance of body contact while toilet flushing is not more than chance of body contact during swimming.

4. Conclusions

Organic matter seems to be the primary parameter of concern regarding grey water reuse in the literature so far. However Total Coliforms and Fecal Coliforms in grey water are comparable to those in conventional domestic wastewater and E.Coli concentrations are high too. A comparison of those indicators with standards and guidelines used for grey water reuse indicates that these parameters should not be overlooked. This points at the necessity to consider microbiological indicators as parameters of priority importance from the perspective of public health in addition to organics.

REFERENCES

1. Atasoy, E., Murat, S., Baban, A., Tiris, M. (2007), Membrane bioreactor (MBR) treatment of segregated household wastewater for reuse. Clean, 35(5), 465-472.
2. Beler Baykal, B. (2015), “Stream segregation in household use: A review of grey water as an alternative source of water and yellow water as an alternative source of fertilizers”, Water Quality Exposure and Health, 7(1), 27-37.
3. Chaillou, K., Gérente, C., Andrés, Y., Wolbert, D. (2010), “Bathroom greywater characterization and potential treatments for reuse”, Water Air Soil Pollution, 215, 31-42.
4. Christova-Boal, D., Eden, R.E., McFarlane, S. (1996), “An investigation into greywater reuse for urban residential properties”, Desalination, 106(1996), 391-397.

5. Dallas, S., Scheffe, B., Ho, G. (2004), "Reedbeds for greywater treatment – case study in Santa-Elena-Monteverde, Costa Rica, Central America", Ecological Engineering, 23(2004), 55-61.
6. Giresunlu, E., Beler Baykal, B. (2014), A preliminary investigation on pathogenic indicators in segregated domestic wastewater streams. 12th IWA Specialist Conference on Small Water and Wastewater Systems & 4th IWA Specialist Conference on Resource Oriented Sanitation, 2-4 November 2014, Muscat, Sultanate of Oman.
7. Giresunlu, E. (2015), "Characterization and Analysis of Weak Urban Grey Water", MSc Thesis, Istanbul Technical University Graduate School of Science Engineering and Technology, Turkey
8. Langergraber, G., Muellegger, E. (2005), "Ecological sanitation – a way to solve global sanitation problems?", Environment International, 31(2005), 433-444.
9. Lazarova, V., Hills, S., Birks, R. (2003), "Using recycled water for non-potable, urban uses: a review with particular reference to toilet flushing", Water Science and Technology: Water Supply, 3(4), 66-77.
10. Metcalf&Eddy (2003), Wastewater Engineering Treatment and Reuse (4th Edition), Mc Graw Hill, New York, NY, USA.
11. Ministry of Environment and Urban Planning website http://www.csb.gov.tr/db/tay/webmenu/webmenu13378.pdf
12. New South Wales Department of Energy, Utilities and Sustainability (2008), NSW Guidelines for Greywater Reuse in Sewered, Single Household Residential Premises.
13. Nolde, E. (1999), "Greywater reuse systems for toilet flushing in multi-storey buildings-over ten years experiences in Berlin", Urban Water, 1(4), 275-284.
14. Oruçtut, N. (2013), "Grey Water Management and Assessment of Grey Water Applications in Urban Areas", MSc Thesis (in Turkish), Istanbul Technical University Graduate School of Science Engineering and Technology, Turkey
15. Paulo, P.L., Begosso, L., Pansonato, N., Shrestha, R.R., Boncz, M.A. (2009), "Design and configuration criteria for wetland systems treating greywater", Water Science and Technology, 60(8), 2001-2007.
16. Pidou, M., Avery, L., Stephenson, T., Jeffrey, P., Parsons, S.A., Liu, S., Memon, F.A., Jefferson, B. (2008), "Chemical solutions for greywater recycling", Chemosphere, 71(1), 147-155.
17. Queensland Plumbing and Wastewater Code. (2011).
18. Victoria EPA, (2013), Guidelines for Environmental Practice, Code of Practice Onsite Wastewater Management.
19. Werner, C., Schlick, J., Mang, H. (2003), Reasons and principles of ecological sanitation. 2nd International Symposium on Ecological Sanitation, 7-11 April 2003, Lubeck, Germany.
20. Western Australia Department of Health (2010), Code of Practice for the Reuse of Greywater in Western Australia 2010.
21. WHO, 2006. "Overview of greywater management health considerations".
22. Winward, G.P., Avery, L.M., Frazer-Williams, R., Pidou, M., Jeffrey, P., Stephenson, T., Jefferson, B. (2008), A study of the microbial quality of grey water and an evaluation of treatment technologies for reuse. Ecological Engineering 32, 187-197.