



INDIAN INSTITUTE OF TECHNOLOGY, ROPAR

B.Tech Project Report on
Treatment of Greywater and its Utilization for
Toilet Flushing

**Submitted in Partial Fulfillment for the B.Tech Second Year
Core Course on Human Geography and Societal Needs
(HS202)**

Group 24

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Certificate

This is to certify that the B. Tech project titled “**Treatment of Greywater and its Utilization**” prepared by Gagandeep Singh, Kirti Sharma, Sana Raffi, Uttam Saroj - the students of Group 24 is approved for submission for the course on Human Geography and Societal Needs (HS202) in the Department of Humanities and Social Sciences, Indian Institute of Technology, Ropar.

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Declaration

I hereby declare that the report entitled “Treatment of Greywater and its Utilization” submitted by me, for the partial fulfillment of the course on Human Geography and Societal Needs (HS 202) in the second year of the B. Tech programme in IIT, Ropar. The work carried out by us under the supervision of Dr. Kamal Kumar Choudhary (Department of Humanities and Social Sciences), Dr. Sreekumar Jayadevan (Department of Humanities and Social Sciences), Dr. Puneet Goyal (Department of Computer science and Engineering) and Dr. Jitendra Prasad (Department of Mechanical Engineering). We further declare that this written submission represents our ideas and other’s ideas or words have been included. We also have adequately cited and referenced the original sources in the case of other’s ideas or words. We have not misrepresented any idea/data/fact/source to the best of our knowledge. Therefore, we affirm that our group has adhered to all principles of academic honesty and integrity.

Place: Ropar

Date: 25-04-2022

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Last but not the least we would like to express our gratitude to some of our seniors who managed to give us some time to help us in finding some good resources to find the solution of the problem.

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List of Abbreviations

NBS	Natural Based Solution
MOWR	Ministry Of Water Resources
IUCN	International Union For Conservation Of Nature
MOWR	Ministry of Water Resources
BCM	Business Continuity Management
GW/WW	Greywater/ Waste Water
SBR	Sequencing Batch Reactor
MBR	Membrane Bioreactor
COD	Chemical Oxygen Demand
BOD	Biological Oxygen Demand
TN	Total Nitrogen
TSS	Total Suspended Solids
BCM	Billion Cubic Meters
WHO	World Health Organization
GDP	Gross Domestic Product
FC	Fecal Coliform
TP	Total Phosphorus
E.coli	Escherichia Coli
pH	Potential of Hydrogen

ABSTRACT

One of the major problems our country is facing is the access to clean water. Providing clean water resources to the needy proves to be impractical and uneconomical. A good amount of fresh water goes for toilet flushing purposes. Reusing the greywater for toilet flushing is one of the most suitable and efficient ways to save huge amounts of fresh water. Here the treatment of greywater is a challenge.

We propose a green roof, a nature based solution as the solution to treat the greywater coming from homes. This will tackle the water crisis issue to a huge extent by saving a large amount of freshwater in the homes.

In this study, we analyze the problems associated with the treatment of greywater. Then we also explain how our technology solves the problem of water shortage.

DEFINITION OF THE PROBLEM

1. Problem statement

Treatment of greywater in the houses and reusing it for toilet flushing.

2. Identification of the problem

India is suffering from the worst water crisis in its history and millions of lives and livelihoods are under threat. According to the WHO Global Health Observatory, currently 600 millions Indians face high to extreme water stress and about two lakh people die every year due to the inadequate access to safe water.

The situation will become worse in the coming decades. The country's demand is projected to be twice the available supply by 2030. This will lead to severe water scarcity for hundreds of millions of people and will further lead to near about 6% loss in the country's GDP. Water shortage can be due to a combination of population growth, economic development with extensive use of water in agriculture and industry, increasing standard of lifestyle, dietary changes and climate change.

According to the **National Commission for Integrated Water Resource development of MOWR report**, the water requirement by 2050 in high use scenarios is likely to be a milder 1180 BCM whereas present day availability is 695 BCM. The total availability of water possibly in the country is still lower than this projected demand at 1137 BCM. The water data systems in the country are limited in their efficiency, coverage and robustness. First the data is not often available at the adequate level of detail. For e.g. water use data for domestic and industrial sectors is available at only aggregate level. Second, where the data is available, it is often unreliable due to the use of outdated collection techniques and methodologies. For example, the groundwater data in India is based on an inadequate sample of ~55,000 wells out of a total ~12 million in the country.

Thus there is an immediate need to address the water crisis issue to some extent. A very promising solution to tackle the water shortage issue is to reuse the greywater. The GW is defined as household waste water made up of all domestic WW with the exception of toilet flushes. It includes the waste water produced in bath tubs, showers and laundry machines. GW can be divided into two types: light GW whose sources are bathrooms, showers, tubs, hand basins and sometimes laundry; dark GW which includes laundry facilities, dishwashers and kitchen sinks as well.

The reuse of treated GW can also produce economic benefits. Reusing greywater can be considered as a promising method for ensuring water security. But there are some major concerns which arise while reusing the greywater.

First of all, we wanted to know about the opinions of different people regarding this. So to understand the water issue from the people's perspective, our team conducted a survey. We went to ten different houses located in different areas to collect the data. We asked them several questions. From the survey, we understood that four out of ten houses were seasonally facing water shortage issues. We wanted to know their opinion regarding the reuse of treated GW.

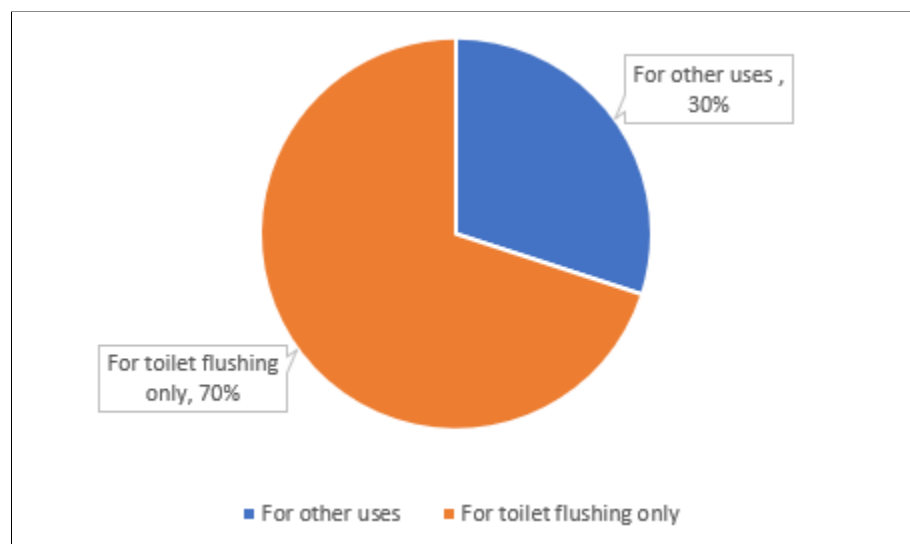


Chart 1: Survey Analysis

In Chart 1, we plotted the responses of different families. Almost 70% of the respondents were willing to reuse the treated greywater for the toilet flushing purposes. From here, we understood that an efficient model of reusing the treated GW needs to be developed so that water shortage issues can be addressed.

3. Detailed description of the identified problem

From the survey, we get the idea that most of the respondents were willing to reuse the treated GW for the toilet flushing and agreed to adopt some model that would be cost efficient. Now for treating the greywater, a deep study of research articles needed to be done. So we studied different research articles to understand the problem associated with the filtration of greywater.

GW reuse requires special attention in terms of pathogen proliferation and infection diffusion, especially when we are not maintaining and storing it properly. From the study of a research paper, we found that the quantity and quality of domestic GW depend on seasonal variations (means parameters like pH, acidity, COD etc. changes in different seasons), characteristics of users (means their number, age, habits, activities), composition of commercial cleaning products, etc. Normally, both bath and hand basin GW contains personal care products (e.g. soap, toothpaste, shampoo), human derived components (like shave residuals, hair, skin) and also traces of feces and urine. Laundry GW contains high concentrations of chemical products (e.g. soaps and oils) and non biodegradable fibers. Kitchen GW (from sinks and dishwashers) contains food, oils, fats and detergents. Especially when there are babies in houses, the wastewater coming from baths and laundry includes the feces and the food residuals. According to the definition, urine should not be included in the GW but the presence of high concentration of phosphorus and nitrogen indicates the presence of urine in the GW. These are the major concerns needed to be taken into account while developing a filtration technique for greywater reuse. Some studies show that the storage time also impacts the characteristics of GW. After 48 hours of storage, the quality of GW decreases drastically. Now after detailed identification of the problems associated with GW, our objective is to find a sustainable and nature

friendly solution that takes care of all the above problems and purifies the GW to that extent so that it can be used for toilet flushing.

4. Current developments in the domain

i) Greywater recycling for toilet use -

A study on greywater recycling solution for toilets done at a hostel for tribal students in Maharashtra shows significant improvement. The hostel was located at Chinchavali, 12 km from Panvel and 50 km from Mumbai. About 40 tribal students of age 10-16 along with 4 support staff reside in the hostel.

The Chinchavali area faces a water shortage problem every year. By December most of the sources of water get completely dried and they have to rely on expensive water tankers for the next six months until the monsoon season.

In the best scenario the hostel receives about 2500L per day of water supply. They have to use about 1050L for cooking and drinking, 650L for bathing and washing clothes, 350L for utensils cleaning and 450L for toilets.

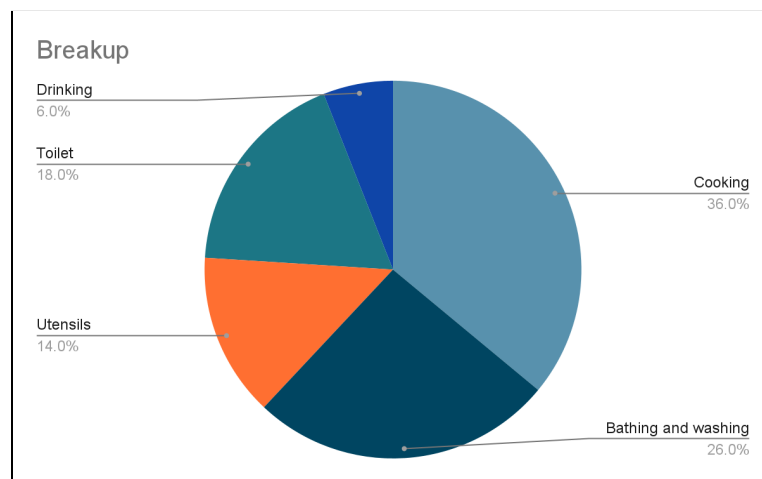


Chart 2: Breakup for water consumption

From the above breakup it is clear that sufficient water is not available for flushing the toilet waste even in the best scenario of water availability.

In the hostel, waste water from bathrooms and sinks discharges in the open which also leads to long term hazard from sewage accumulation.

From the above breakup they waste about **1000L of greywater** daily. So by collecting this water and using it for toilet flushing; those 18 percent of freshwater used for toilet needs can be saved. By doing this they are saving **18 percent (450L / day)** freshwater, getting double the amount of water for toilet flushing, and reducing the water drainage in the open. This greywater collecting project also pays back its installation cost by saving the water; they have to buy from the tankers.

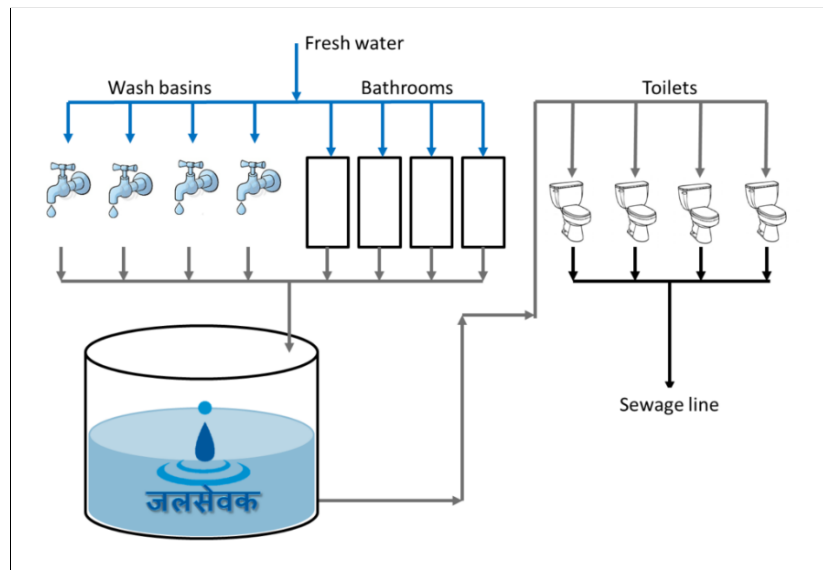


Fig 1: A schematic diagram showing a method used in the treatment of greywater

ii) Greywater filtration using carbon bed -

Another study was done for finding the current developments in this domain. In that home, the greywater is collected in a large tank then it is sent to another tank situated on the roof of the building, with the help of a small pump. The greywater first goes through a system of aeration then is passed through the activated carbon bed filter before storing in the tank on the roof. The water stored after carbon bed filtration and aeration is used in the toilets for flushing the toilet waste.

iii) Redirecting greywater into ground -

In this method of purification of greywater, One makes a pit and fills it with layers of concrete, sand and then dry leaves. The greywater discharging from the kitchen, bathroom, laundry etc gets collected in the pit and after getting filtered it goes into the ground. Some natural purifying plants (such

as- banana, kaina, syngonium, umbrella palm and spider lily) are also planted around the pit. They use the chemicals present in the greywater as their feed and make the water chemical free and it gets absorbed into the ground.

5. Need and significance of the resolving the problem

It is very well understood that the situation of water in India is worse. The reuse of treated GW does provide some hope. We did the detailed case studies to understand what gaps are there in the current system. In the first case study i.e. Maharashtra tribal hostel, where GW was being used for toilet flushing. Solution appears to be good in the short run. But there are many problems associated with that solution. They are not using any proper filtration technique to improve the water quality. We know that if the GW is not treated properly, then it will produce bad fumes in the environment. Long storage time will further intensify the problem. Even the presence of nitrogen and phosphorus in the treated GW will lead to the decline of the model in the long-run. We studied another case where the filtration technique used by the house owner is the carbon activated bed. This filtration method is very expensive. Dust particles can block it, there is risk of spontaneous combustion in the bed and moreover, its operational and maintenance cost is very high. These gaps show that there is a need to improve the current system. The filtration technique needs to be changed. Finding an environmentally friendly solution will help to solve the major water problem in India. Till now most of us are using fresh water for the toilet flushing purposes. With the adoption of this new filtration technique, we can save a huge amount of water for the future generation by using the treated greywater in toilet flushing. So there is a huge significance of finding a cost efficient filtration technique.

OBJECTIVES

To understand the scenario of greywater treatment in India and to have the detailed study of conventional methods that are already established. By understanding limitations in these methods we intend to find a sustainable, cost effective and environmentally friendly solution to treat the greywater to that extent so that it can be utilized for toilet flushing purposes.

TOOLS AND TECHNIQUES PERCEIVED TO BE EFFECTIVE FOR RESOLVING THE ISSUE

- **Study of Research Paper**

After analyzing the survey, it is observed that many people showed interest to use treated greywater for toilet flushing. This paved the way to study research papers and to understand the problem in details in order to suggest an effective solution to the problem. As per studies 75% of the domestic waste water consists of greywater. From the analysis of scientific literature, we find that with the reuse of greywater, water scarcity can be reduced to a great extent and this method can help us greatly in the summer season. At the same time it is showing that conventional greywater treatments are very expensive especially in advanced methods such as membrane bioreactor (MBR) and sequencing batch reactor (SBR). In this context, an alternative for conventional methods is the Nature-Based Solutions (NBS) for treating greywater.

According to IUCN (International Union for Conservation of Nature), Nature-Based Solutions (NBS) are defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits”. So, suggesting a NBS is a win-win situation for humans as well as for the ecosystem. The widely used NBS is the construction of wetland, but for the implementation of this method requires much area. This limitation of wetland leads us to find a unique and effective solution and we finally came up with another NBS called Green roof with the aim for the establishment of this method in urban areas.



Fig 2: Nature Based Solutions

DETAILED WORK PLAN

In the conventional greywater purification techniques, we have to face so many challenges especially regarding the establishment cost of advanced purification process and also the chemicals associated with it. With the introduction of Nature Based Solution (NBS) for greywater purification, we can reduce many constraints associated with conventional greywater purification processes. Here, we are explaining the detailed working of NBS - Green roofs. The main advantage of this method is nature friendly, implementation cost is less and low space requirement.

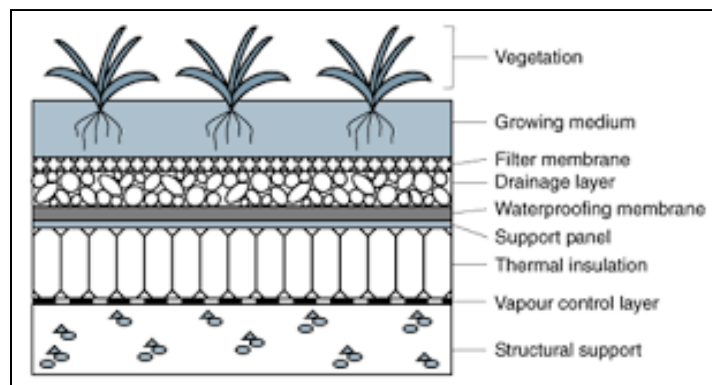


Fig 3: Sample model of green roofs

Green roofs are vegetated surface installed on a rooftop and generally made of modular systems consists of an insulation layer, a water proofing membrane and vegetation layer planted in a growing substrate. We will allow the grey water to pass through the planted pots filled with a combination of granular media such as vermiculite, sand, growstone, expanded clay, phytofoam, coir and perlite. Special care must be taken to choose the plant for greywater filtration. Plants such as Sempervivum, Carex glauca, Aromatic herbs etc, which require less area for root growth and high removal capacity of nutrients are good for the filtration process. The roots of these plants and the substrate arrangement can do different biological and physio-chemical process. When the greywater comes in contact with roots, substrate materials and biofilm will lead to different fundamental mechanisms of pollutant and pathogen removal through precipitation and adsorption as chemical process, sedimentation and filtration as physical process and microbiological degradation and nutrients uptake by plants as biological process. The efficiency of Green roofs depends on these factors. Basically, we can do multiple filtration processes through the construction of these Green roofs to get the purified water only for the flushing purpose.

INNOVATION OF THE PROPOSED INTERVENTIONS

With the implementation of NBS-Green roofs, we can improve the efficiency of greywater purification for toilet flushing as many biological and physio-chemical processes are taking place in green roof technique. When we compare it with conventional methods, the cost of establishment is very less which will help people from all the economic class to access the technique. Here we will analyze the effectiveness of Green roof method by considering some parameters such as pH, BODs, CODs etc, that will define the purity of water.

Parameters	Greywater	Efficiency
pH	5.90-8.34	-
TSS (mg/L)	53.80-655.00	92%
BODs	17.10-290.00	95%
CODs	43.90-681.00	88%
TN	17.00-28.82	82%
TP	0.01-3.84	58%
FC	50.00-120.00	97%
E.coli	-	-

Table1: Analysis of the efficiency of Green roof method of greywater processing

Parameters description:

- **Total Suspended Solids (TSS):-** This parameter describes the portion of fine particulate matter that remains in water. This measures the turbidity and also provides an actual weight of particulate matter for a given volume of sample. The high level of TSS will increase the temperature of water and decrease the dissolved oxygen levels.
- **Biological Oxygen Demand (BOD):-** This refers to the amount of oxygen consumed by bacteria and other microorganisms while they decompose organic matter under aerobic conditions. The BOD level of grey water is more.
- **Chemical Oxygen Demand (COD):-** This parameter refers to the amount of dissolved oxygen that must be present in water to oxidize chemical organic material. COD increases as the organic material increases.
- **Total Nitrogen (TN):-** Total nitrogen is the sum of nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen and organically bonded nitrogen. For purification sometimes we have to nitrification and denitrification according to the limit. Generally TN is more in grey water.

- **Total Phosphorus (TP):-** This refers to the dissolved and organic phosphorus. TP is comparatively high in grey water.
- **Fecal Coliform (FC):-** These are harmless microorganisms present in human intestine. Escherichia coli (E-coli) is a kind of FC bacteria. The presence of this quantity indicated that water has been contaminated with the fecal material of humans. In grey water chances are very less.

APPROACHES THAT COULD BE TAKEN TO IMPLEMENT INTERVENTION PLANS

In order to implement the technique, we have to undergo deep analysis and study of many things for the expected outcome.

1. Detailed study of the Govt. of India regulations and standards for the reuse of greywater. All the countries have different limits with respect to the source of greywater they are producing. We have to meet the boundary that set by our government to use the purified greywater by green roof method.
2. Frequent analysis of climate change in particular area for the implementation of this project. Variation of weather, strength of wind, intensity of sunlight, probability of heavy rainfall: these factors will affect the growth of plants in green roof. So, extra care must be taken for the sustainability green roof.
3. Appropriate selection of plants for the vegetation. Plants with qualities such as good nutrients absorbing power, require a small area for root growth and can survive all the tropical climate change is good for constructing green roof. Sempervivum, Carex glauca, Aromatic herbs:- these are some of the plants having these qualities.
4. Adequate awareness is required for the use of processed greywater for toilet flushing. Some people will show reluctance to use purified greywater because they don't have any idea about the merit of this methodology. So, the awareness about the processed greywater is necessary for the successful implementation of green roofs.

5. Effective piping arrangement and installation of the tank is necessary to control the flow of greywater and to collect the purified water for the purpose of toilet flushing.

POSSIBLE CONSTRAINTS AND BARRIERS TO IMPLEMENTATION

- Availability of plants which are suitable for the vegetation of green roofs. Inorder to establish green roof for large scale, sometimes it is difficult to get plants with expected qualities.
- During the summer season, there are chances where the plants get dried up and this will affect the proper functioning of vegetation. Moreover, there is a chance of strong evaporation of grey water, this will reduce the quantity of treated grey water and gradually this will affect the overall efficiency of our system.
- Minute chances are there in which the roots of the plants penetrate through the roof of the house/building. This will lead to the potential damage to the houses. So, good materials with proper insulation is required for this.
- Reluctance to use purified grey water as some people think there is still a possibility of contamination even after the treatment according to their cultural aspects.
- If the efficiency of the system is disturbed because of the inappropriate maintenance and operation of the green roof, this will lead to health issues because of the presence of microbes and pathogens.
- Extra cost is required for the new pipeline arrangement for grey water and for other water connections. For implementation of green roof, the entire piping arrangement has to be reestablished, and we also have to meet extra expenses for installing tank to collect grey water.

EXPERTISE AVAILABLE WITH EACH STUDENT

As a chemical engineering student, we are making use of chemical engineering to understand the problems associated with the treatment of greywater. We can understand the technical aspects related to the purification of greywater like TSS, BOD, COD, TS, TP etc. We can use our fluid mechanics knowledge to suggest the right diameter of pipes, right volume of tank that should be used and what type of pump required in order to maintain proper flow of fluid in the process of treatment of greywater.

EXPECTED OUTCOMES

From our analysis we figure out a few barriers and constraints regarding the implementation of the green roofs in the houses. We did a detailed study to address these issues and came up with some solutions. Proper insulation of roofs can prevent the penetration of plant roots. Moreover, the green roofs can provide shade, remove heat from the air and can reduce temperature of the roof surface and surrounding air. In addition to this, the installation of green roofs will provide fitness to local climatic conditions, aesthetic appearance and encourage biodiversity and ecosystem in the city.

In order to connect toilet flushing and green roofs, the piping arrangement can be changed. From these outcomes, we can say that the constraints involved in the implementation of green roofs can be minimized by the above mentioned points.

SUGGESTED PLAN OF ACTION FOR UTILIZATION OF OUTCOME EXPECTED FROM THE WORK

From the outcomes, we understand that for the proper insulation of roofs, a civil engineer is needed to be consulted for the proper guidance regarding the roofing material.

For changing the piping arrangement and to establish a connection between green roof and toilet flushing, a plumber is needed to be consulted and also to get the estimation of expenses related to it.

We intend to work on suggested plan of action to the best of our abilities and to complete this proposed work through the Capstone project.

CONCLUSION

The Engineering Problem identified during the course of this project was “Treatment of greywater and its utilization for the purpose of toilet flushing”. To address the water shortage issue, we develop a “green roof solution” for the treatment of the greywater.

We did a few case case studies to get a better understanding about the current developments in this domain. From there we found some gaps (like the use of conventional methods or the expensive filtration techniques) in the present system. To overcome these gaps, we propose NBS: green roof.

By implementing this solution, not only we are saving a huge amount of fresh water but also we are minimizing the sewage production and providing societal benefits of green spaces.

CONTRIBUTION OF EACH STUDENT

GAGANDEEP SINGH - Collection of data, Detailed description of problem, Survey

KIRTI - Collection of data, Study of research paper, Detailed description of problem

SANA - Study of research paper, Detailed work plan, Survey

UTTAM - Collection of data, Detailed work plan, Survey

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- <https://www.indiawaterportal.org/articles/feasibility-study-installing-greywater-recycling-solution-tribal-hostel>
- <https://youtu.be/UkKnK5VkwWQ>

QUESTIONNAIRES

- Which state/locality do you belong to?
- Do you have access to the clean water sources?
- Are you using any conventional method to purify the greywater?
- Is there any kind of reluctance to use the treated greywater?
- For what purposes do you want to use the treated greywater (Toilet flushing, Irrigation etc)?