Waste Management Model for Shri Mata Vaishno Devi Katra Pilgrimage Holy Town, Jammu, India

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***Abstract*- Jammu, also known as "City of Temples" is blessed to have Mata Vaishno Devi's holy cave in its Katra town. Mata Vaishno Devi holy pilgrimage is one of the major and most important pilgrimage destinations in Jammu. Katra town draws an enormous amount of devotees from the entire world. Mostly these places are small towns with very less domicile population who experience a huge number of floating population in different months of the year which puts a virtuous amount of pressure on the local natural resources which further results as dilapidation of the ecological settings. This paper debates that substantial deviations in balance occurrence and atmosphere of such visits reproduce different problems on the environs of sanctified locations. Using a case study of the holy town of Katra, a famous Mata Vaishno Devi Hindu pilgrimage at Katra in Jammu tries to search instrumental connections among various issues which gives character to form the environment in the pilgrimage destinations.**

***Index terms*- Pilgrimage tourism, Waste management, Strategic framework, Waste disposal system, Amelioration strategies**

INTRODUCTION

Worldwide Pilgrimage or Religious tourism has extreme significance. It is considered as a growth engine. Besides giving mental psychological peace of mind to the devotees at the same time it also provides huge employment and also boosts the economic activities of the people. Pilgrimage tourism not only increases international trade, at the same time it upgrades and creates bonding both within the country and outside too. At present globally Pilgrimage Tourism is an important socio- economic venture. It helps everyone in learning and understanding different cultures, languages, styles etc of other countries and encourages national integration too. This tourism has both dark and bright imprints on the different pilgrimage destinations. These impressions may be physically, socially, culturally and economically etc. "Atithi Devo Bhava" the Sanskrit expression which renders as "Guest is God" is considered as the main concept behind a strong approach adopted to encourage Pilgrimage tourism globally by government of India.

Since early ages, India has been the hotspot for religions and has even been credited to be the birthplace of many major religions including Hinduism and Buddhism. For ages, India has been covered by the pall of mythology and the mystique that comes with it. It is the home to a large number of Temples, Churches, Mosques, Gurudwaras, among other places of worship. The places with legends attached to them have even gained prominence as religious 'yatras' that devotees conduct each year. This devotion has become an essential aspect of traditional homes as well.

In Hinduism, a number of 'Tirtha yatras' are said to be a way to attain salvation. However, this sentiment isn't just in Hinduism as multiple other religions and their devotees conduct these pilgrimages to attain the blessings of their god and ask for forgiveness for any sins.

The enchanting journey of Shri Mata Vaishno Devi leads you to the shrine where Mata Vaishno Devi had spent some time while witnessing various spiritual disciplines and penances. The conclusion of this journey took place at the Holy cave where Mata Vaishno Devi amalgamated her body mass with the

mystical form of her makers, the three Spiritual topmost powers. This Place is visited by people from all the beliefs. Ecological disturbance, environmental degradation and adverse effects on the local population is the result of a continuously increasing number of devotees to the Holy Shrine at Katra also known as the base camp for this pilgrimage.

Quality of air and its pollution significantly affects the hygienic and respectable living of humans, animals, or plants live in it. Despite the fact that the air is an unfavourable environment for microorganisms to grow, it is merely a place which temporarily occupies and move in. The air is very often called "transport environment" because microorganisms may be present and often can be transported over considerable distances. Microorganisms move in the air via wind movement, which takes them away from various habitats and surroundings (soil, water, waste, plant surfaces, animals, and other), or is introduced during the processes of sneezing, coughing, or sewage aeration .

VAISHNO DEVI TEMPLE

Mata Vaishno Devi Temple is the most visited religious site in India, right after Tirumala Venkateswara Temple. The shrine is dedicated to Mata Rani or Vaishnavi, who is the manifestation of the Mother Goddess. Located in Katra, Udhampur, pilgrims undertake a tiresome tough mountainous walk to the Trikuta Hill which has an altitude of over five thousand feet. This hill can be referred to as the start point for the uphill journey to the main destination on top of hill where holy shrine is located. The distance to the shrine is over 13 km, where there is sadly no provision for modern transport, except for a helipad. Pilgrims, especially old people often take the help of horses for the uphill climb.

The Aarti ritual, is a two-hour act of reverence for the Goddess Vaishnavi performed twice a day. During this time, the shrine echoes with the holy sounds of chants, devotional songs and mantras accompanied by uttering 108 names of Goddess Durga. Three forms of Goddess Vaishnavi are worshipped in this shrine: Mahal Kali, Mahal Lakshmi, and Mahal Saraswati. It is believed that anybody who comes to seek her blessings has never gone back upset or dissatisfied. As part of these spiritual feelings Maa Vaishno Devi sanctifies Jammu with happiness and opulence.

NEED OF STUDY

The demand for supporting infrastructure is naturally created by the pilgrims. Urbanization of these small natural original rural setups can be noticed and felt to cater the much required demands of this pilgrimage tourism. These small holy towns starts transforming their main character of pure serene environment into high pollution, change in their carrying capacity and inadequate waste management to fulfill the demands of increase of these religious tourists.

Who is responsible? Policies for healthier inhabitants because of absence of resources and authority to perform. Neither the local inhabitants are worried for this unpleasant change as they are themselves enjoying their own commercial setups nor these religious organisations who are openly enjoying from the devotees donations. Both the beneficiaries are not donating towards refining the environment. The places are turning dangerous for pilgrims in peak seasons. Unsightly development, refuse and an ever-increasing number of pilgrims take their toll in distracting one and diminishing the sacred ambience.

Could the experiences be made, more meaningful for devotees?

INTRODUCTION TO STUDY AREA

Katra small town known for Holy Shrine of Mata Vaishno Devi is 42 kms from the city of Jammu in the foothills of Trikuta mountains lies in Reasi district in the union territory of Jammu and Kashmir. One has to come to Jammu first to visit Mata Vaishno Devi Shrine at Katra.

SELECTION CRITERIA

Connected by State Highway NH-1C which further connects Reasi as well. Since there is no other developed tourist place in nearby area and no other important pilgrimage place also so all the pilgrims have no other alternative to visit or spend their holy time except for Katra town. Keeping this in mind and after analyzing the topography, connectivity and future development factors the region in large was selected.

ROUTES

The real journey begins from Katra from where pilgrims start their journey on foot to Mata Vaishno Devi. It leads to 13.5 km trek from Katra. Many times devotees walk barefoot on the entire route which consists of steep staircases and covered tiles paths upto main holy Bhawan where deity is located from the starting point of journey Katra. One is an old route and other is a new route which starts from halfway i.e. Adhkunwari and ends up at Bhawan i.e. the last point.

The old route is used by the ponies and also by the pilgrims but being very steep in profile is used less by the pilgrims. Generally, the new second route which starts from Adhkuwari is used by pilgrims and by the battery-operated vehicles as well.

New 7 kms full pedestrian marg known as Tarakote Marg starts from Balini bridge passes Tarakot and ends at Adhkuwari; on the way it passes atop a hillock overlooking Katra settlement in district Reasi of J&K.

The third route which is via Helicopter starts from Katra base camp and ends at Sanjhi Chatt, from where the pilgrims can walk and can hire pony till Bhawan to complete the holy trip.

POPULATION DATA:

Residential Population Evolution and Records:

In 1911 only 168 families used to dwell in a small pilgrimage settlement known as Katra. This growth of population increased to 3315 in 1971 and 8083 in 2001A.D. respectively.

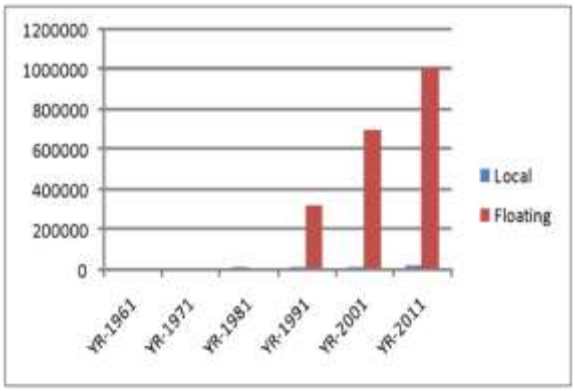
With the escalation of devotee's population the domestic inhabitants grew with a decadal escalation of 116.80% during 1961-71 decade.

Under the provision of J&K State Municipal Act, J&K State government notified the settlement of Katra by making it as urban town with the constitution of Notified Area Committee.

In 1986 after the formation of Shri Mata Vaishno Devi Shrine Board, Katra has witnessed the escalation in both residential population and huge increase in floating population.

Floating Population:

There consists of two categories of residents, migrated population which falls under service division and service providers which are in town for 4-6 months.



Tab no 1.1: Comparison between floating population and local population

Source: Shri Mata Vaishno Devi Shrine Board Katra

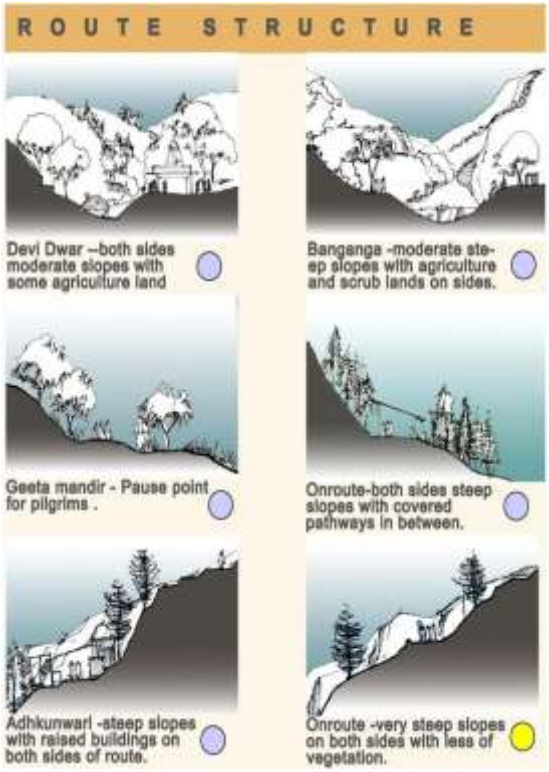
Migrated Population

The migrated population is mostly the employed population. The population approaches Katra town for livelihood in the numerous commercial divisions etc.

No such statistics is available for the migrated population for Katra town and neighboring hamlets.

Quality of life of business community is increasing but vice-versa of natives.

ROUTE STRUCTURE



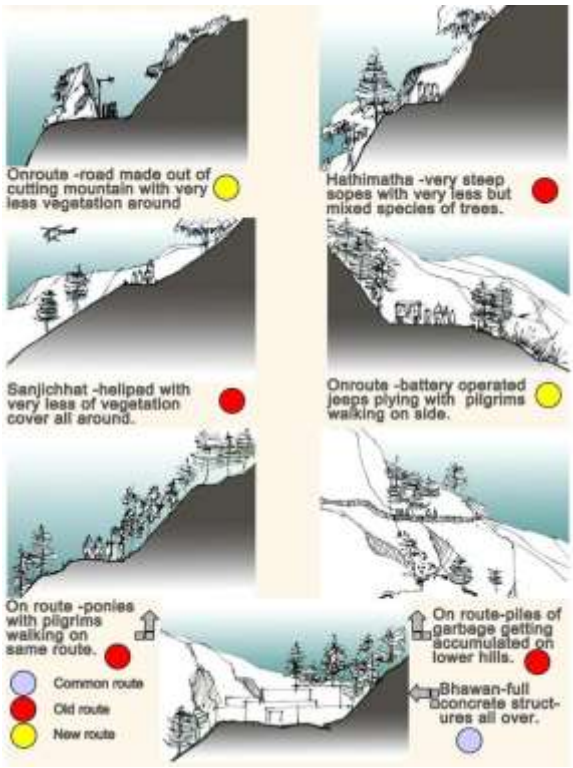


Fig no 1.1: Conceptual sketch by author on the different positions of holy route from Katra to Holy Bhawan.
Source: On the personal analysis and based on certain readings by the Author.

CHANGE OF LANDUSE

From the below data, it can be seen that for the period 1971-81 the average annual growth in local population was of 3.8 % and for the period 1981-91, 3.1 % and suddenly after 1986 --the period after the formation of Shri Vaishno Devi Shrine Board, Katra, there is an increase in the percentage of the local population. Due to this increase in the population both in local and floating agriculture land started getting converted to commercial lands as sudden hotel industry started coming up without any rules and regulations.

The trend in the population of local people of Katra as per the census figures is provided below:

Year	Estimated Population (local people)	Estimated population (Floating)
1961	2702 nos	------
1971	5240 nos	------
1981	7246 nos	------
1986	8373 nos	1395832 nos
1991	9500 nos	3115447 nos
1995	10750 nos	4011627 nos
2000	12000 nos	5217715 nos
2005	14000 nos	6251998 nos
2009	16000 nos	8234896 nos

Tab.no.1.2 Table showing local and floating population of Katra of few years.
Source: Shri Mata Vaishno Devi Shrine Board, Katra

The distribution of the floating population is as follows:

1. In Katra (stationed in Hotels, Tourist Complexes, Dharamshalas) :60%
2. En-route to shrine : 15%
3. In the Shrine area : 25%

Katra has developed in an unplanned manner with varying population densities.
The population density varies from 2. 48 to 7.33 sqm/person in areas lying between the north of Katra and Jammu road and 7.33 to 34.34 sqm/person in areas lying between south of Katra and Jammu road.

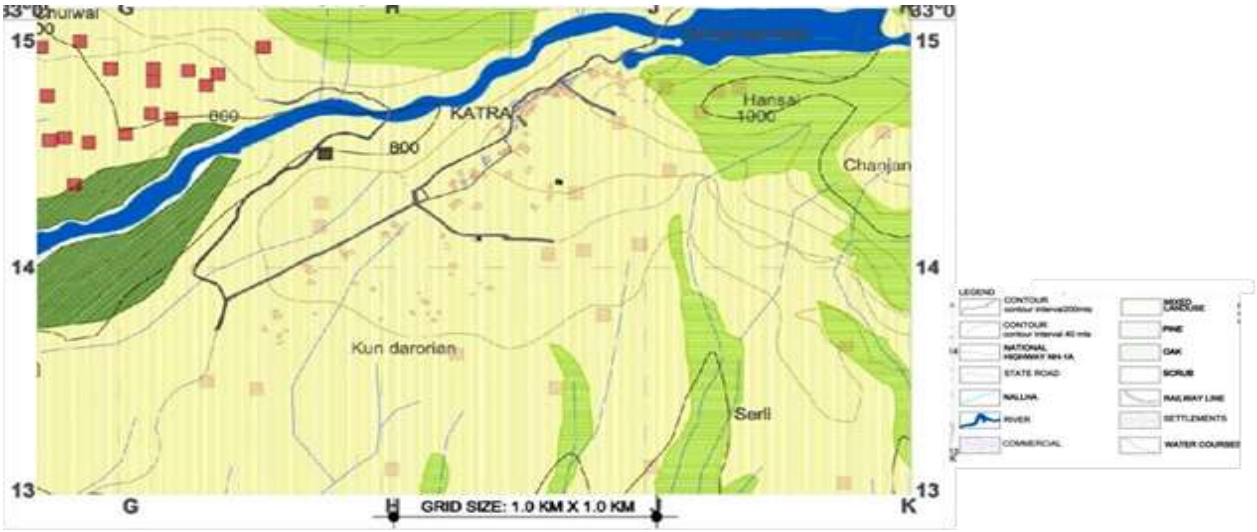


Fig. no 1.2 Map showing the landuse of 1980 of the region
Map showing more of agricultural land and few residential and very less commercial infrastructure.
Source: On the personal analysis and based on certain readings by the Author

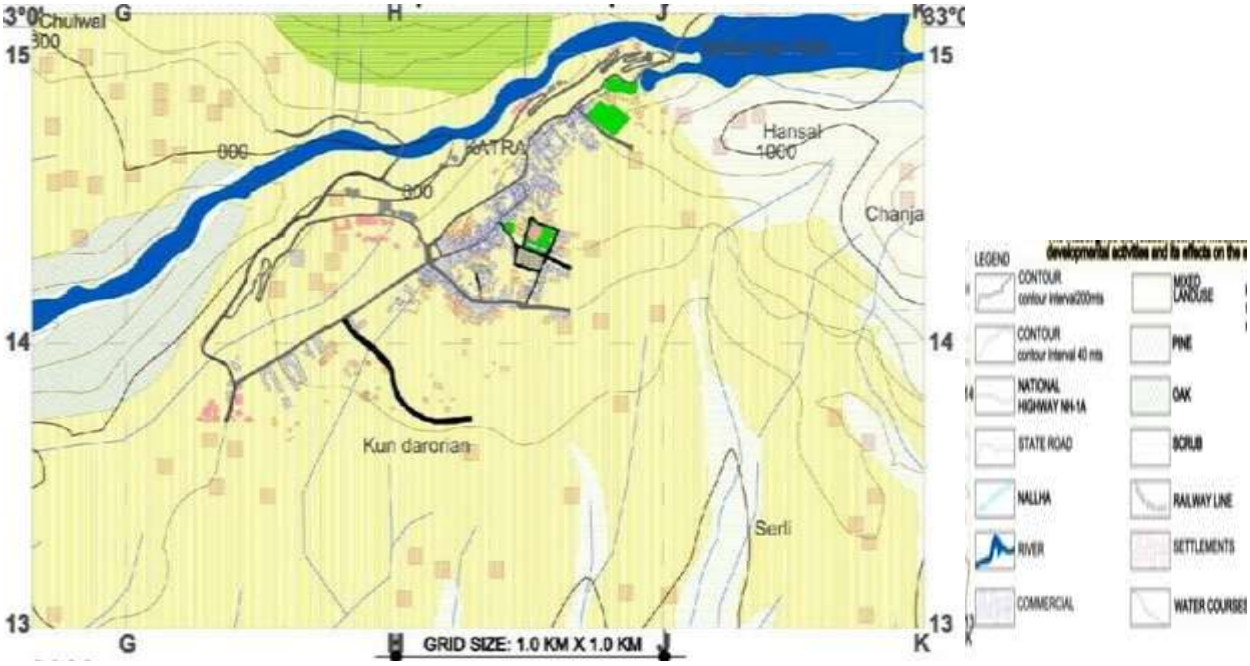


Fig. no 1.3 Map showing the landuse of 1995 of the region. After the formation of Shri Mata Vaishno Devi Shrine Board.
Map depicting sudden change as commercial development coming out with reducing the agriculture land.
Source: On the personal analysis and based on certain readings by the Author.

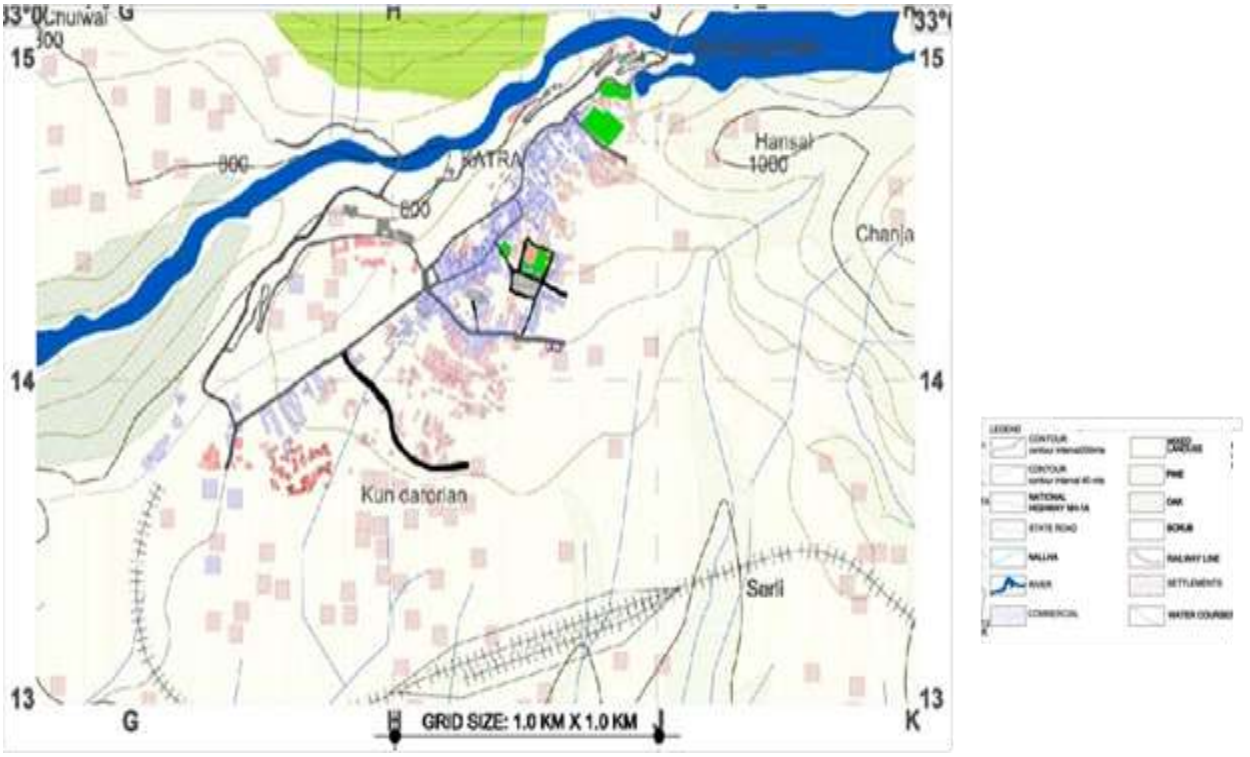
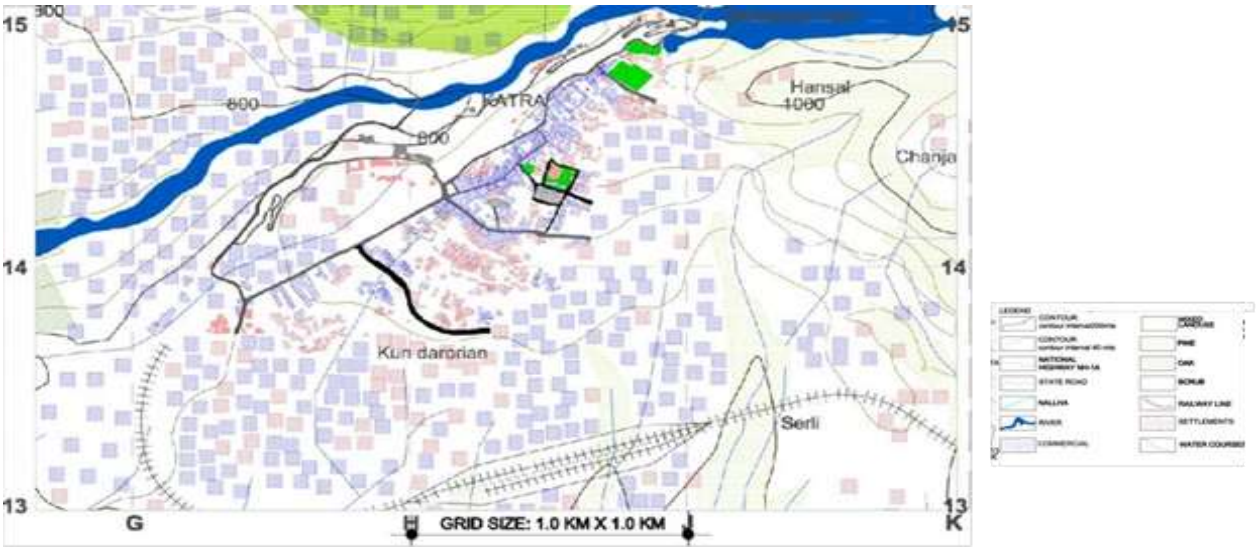


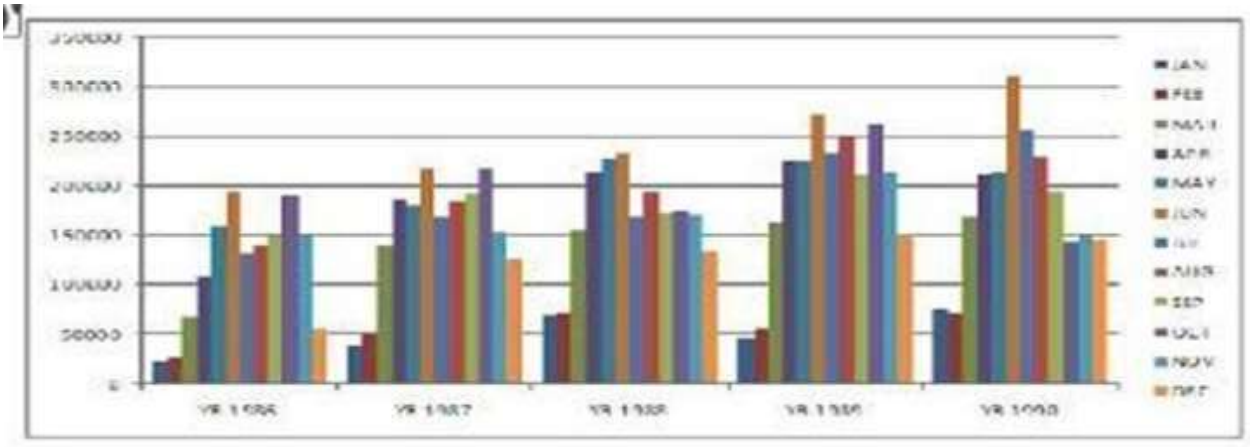
Fig. no 1.4 Map showing the landuse of 2009 of the region.
Map showing full dominance of unplanned commercial development with negligible open spaces



Source: On the personal analysis and based on certain readings by the Author.

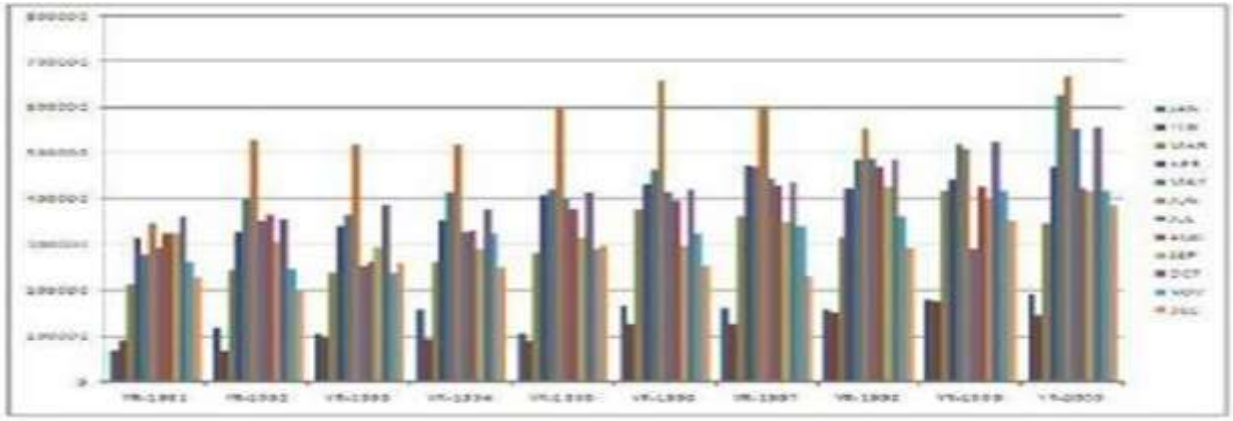
Fig. no 1.5 Map showing the landuse of 2020 of the region if the unplanned development is continued in the same manner. Only commercial spaces with no space left.

Source: Anticipated on the personal analysis and based on certain readings by the Author



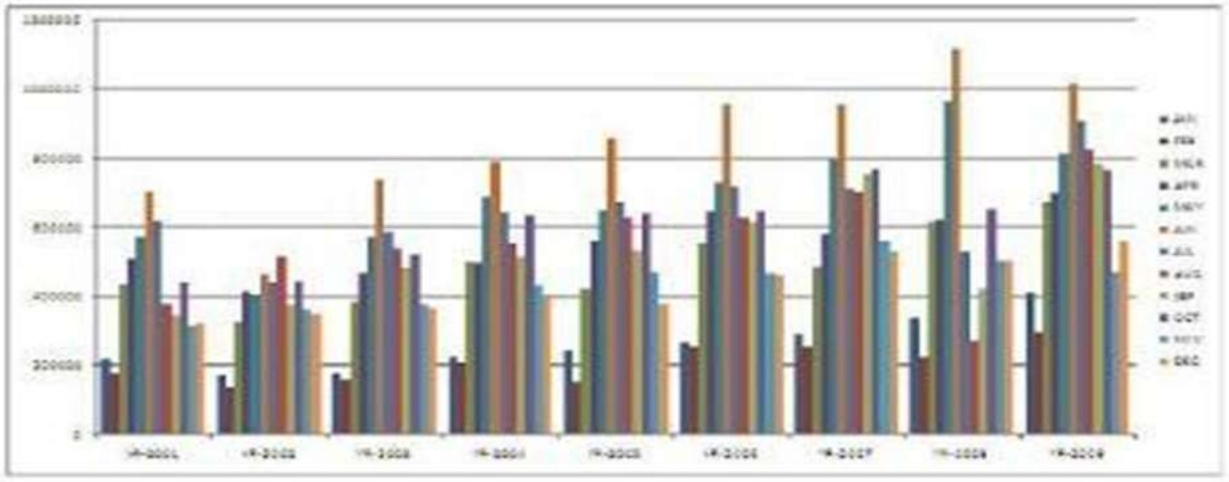
Tab. no 1.3 Table showing the trend of floating population from 1986-1990

Source: Shri Mata Vaishno Devi Shrine Board.

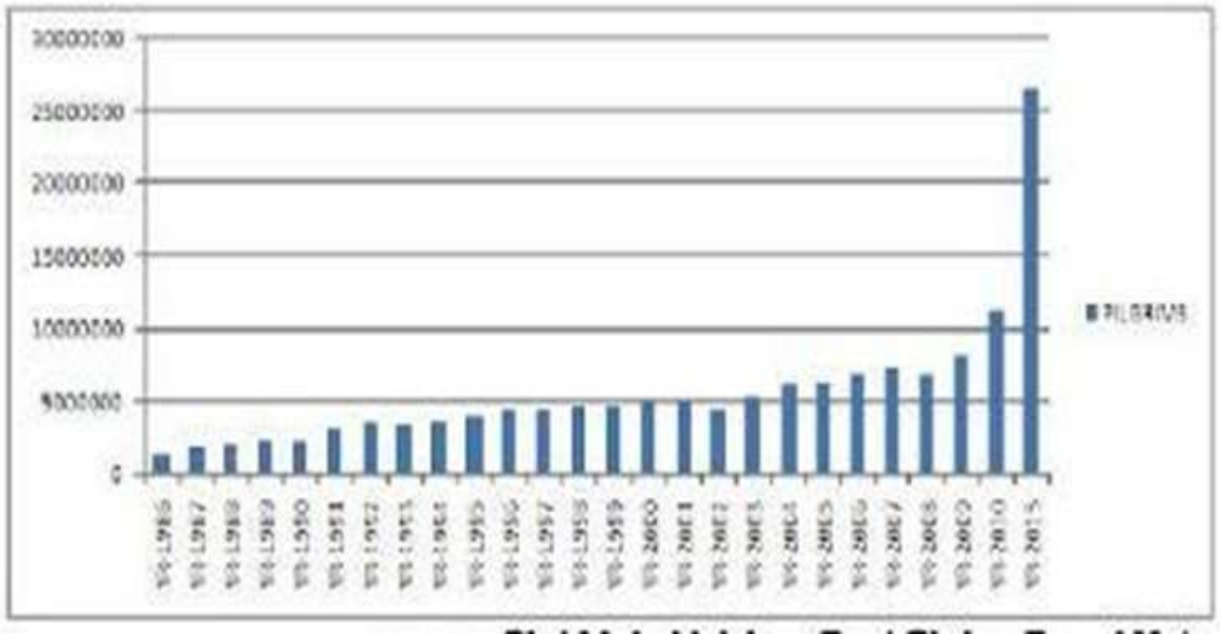


Tab. no 1.4 Table showing the trend of floating population from 1991-2000

Source: Shri Mata Vaishno Devi Shrine Board



Tab. no 1.5 Table showing the trend of floating population from 2001-2009
Source: Shri Mata Vaishno Devi Shrine Board

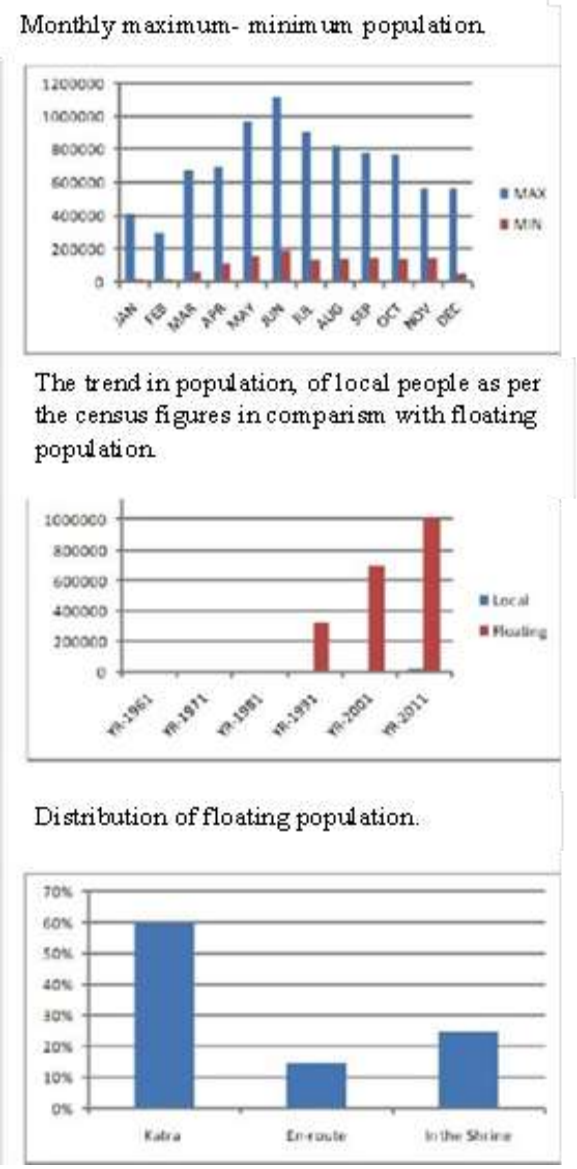


Tab. no 1.6 Table showing the trend of floating population from 2001-2015
Population after 2009 worked out on keeping view of the same growth rate.
Source: Final report Ministry of Tourism Government of India By--ACNielsen ORG-MARG Pvt. Ltd, New Delhi

Analysis from the tables shows the dominance of floating population over local population which can be a great threat to the region in terms of ecology as to accommodate a huge number of pilgrims hotel industry started emerging out and suddenly the cost of living started changing whether in terms of Land, Food and Water; the three basic amenities. Government of India's Ministry of Tourism, has shown the requirement of hotel and rooms as per the growth and demand rate of the region which says that what is required is double the amount what is right now available.

The concern is if this requirement is filled up there will be a complete disaster in the region regarding the ecology of the region as it will change the whole of the hydrology of the region which plays an important role in developing the healthy and hygienic atmosphere.

Monthly maximum- minimum population.



Tab. no 1.7 Table showing the trend of floating population from 2001-2015

Population after 2009 worked out on keeping view of the same growth rate.

Source: Final report Ministry of Tourism Government of India

By--ACNielsen ORG-MARG Pvt. Ltd, New Delhi

SEWAGE

Katra does not have any organized sanitation or sewage system facilities at present. In most parts of old city, night soil is drained to the roadside drainage system which are known as bucket kind latrines. This is carried by the sweepers who dump it in designated areas. Natural nallahs too transport the night soil and sludge from some areas causing an increase in the breeding of flies and odour problems which are highly unsanitary conditions. Middle and higher-income groups use septic tanks in hopes of a safer disposal system which, however, is lacking. To combat, Sulabh Shochalaya Internation has constricted a toilet block with a septic tank and soakage pit in Katra. However, most of the hotels in Katra let the waste into the drains/ hill slopes which causes unsanitary conditions. Even worse, the open drains meant for excess rain are now being used as open sewers by locals, especially in congested areas.

MUNICIPAL SOLID WASTE

Due to the high inflow of pilgrims, on any peak day, there are about 40,000 people in Katra. This results in high production of MSW; sometimes as high as 16 tons.

WASTE STATUS

High inflow of pilgrims causes the population of Katra to peak at 40,000 some days which results in higher production of Municipal Solid Waste (MSW)

a. MUNICIPAL LIQUID WASTE AND DRAINAGE

Lack of a drainage system in Katra has led to unhygienic conditions. Sweepers manually manage the sewage situations in a very conventional way which sometimes means being dumped in the open Rainwater carries this to main nallahs, thus increasing the pollution.

b COLLECTION AND DISPOSAL

There is no proper drainage and sewerage system in Katra for collection and disposal of Municipal Liquid Waste. Most parts of the city depend on flushing the night soi or using bucket latrines. The sweepers carry the night soil from the latrines in a bucket on their head or hand carts which is unhygienic. On top of that, the night soil leaves residue where it's dumped and it attracts flies resulting in nuisance accompanied by odour. The night soil remains at its point of generation for a long time exposing it to flies causing odour and nuisance. Carrying the night soil in buckets is prone to leakage and spillage which is a health hazard on its own. Even the septic tanks used

by middle and upper-income groups don't guarantee harmless clearance of the wastes. Natural nails also carry night soil and sludge which is dumped into them, causing pollution, offensive smell, fly nuisance, etc.

c MUNICIPAL SOLID AND LIQUID WASTE MANAGEMENT

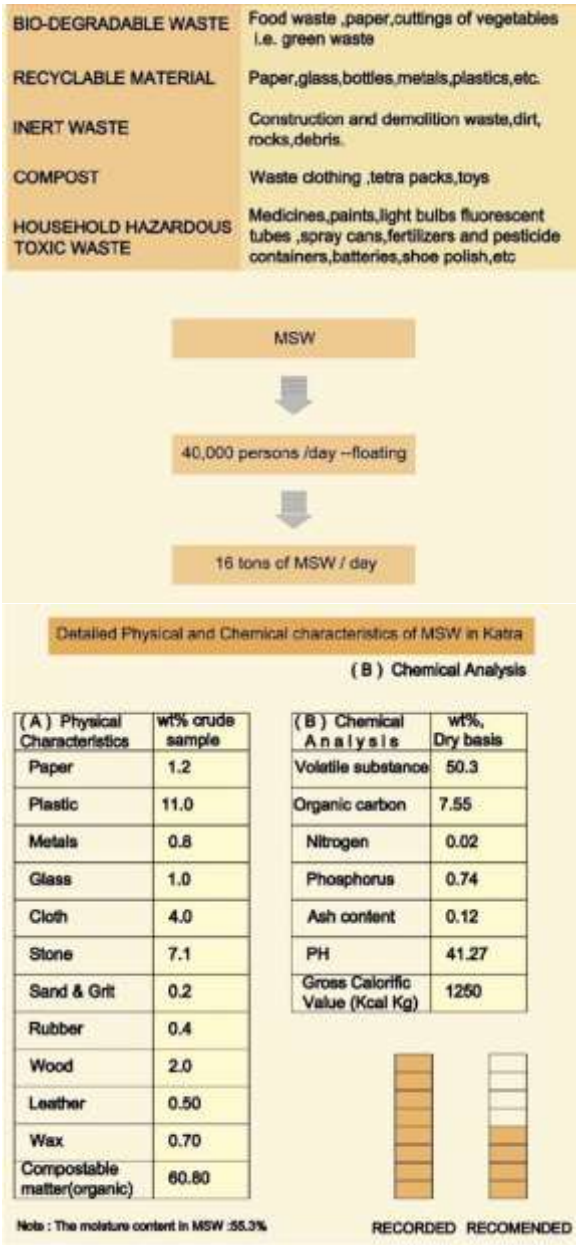


Fig no 1.6 Figure showing physical and chemical characteristics of MSW in Katra.

Source: Report on Ecological study of Katra, by J&K State Pollution Control Board.

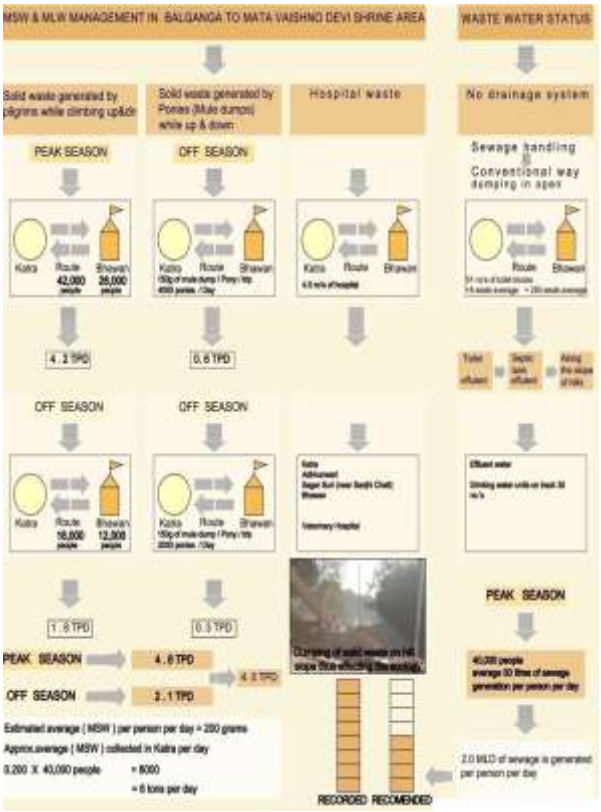


Fig. no 1.7 Figure showing generation of Municipal solid and liquid waste

Source: Report on Ecological study of Katra, by J&K State Pollution Control Board.

Estimated average (MSW) per person per day = 200 grams

Approx.average (MSW) collected in Katra per day

0.200 X 40,000 people = 8000

= 8 tons per day

S.no.	Activity	Environmental benefit	Economical benefit
1.	Use of natural treatment method	Source of energy is natural hence no use of non renewable source of energy. Recovery of nutrients	Saving in costs of electricity for pumping or running and operating machinery
2.	Reuse for domestic purpose	Less demand for fresh water hence saving in the fresh water resource.	Reduction in fresh water procurement & treatment costs. Reduction in water bills.
3.	Reuse for irrigation	Conserving fresh resource. Nutrients are recovered are applied back to ground.	Saving in costs for fertilizers. Application of nutrient rich water gives better crop yield.
4.	Reuse for hotel industry	Conserving fresh water resource	Reduction in costs of fresh water supply
5.	Ecological use such as wetlands	Promoting biodiversity, wildlife habitat,developing aquatic ecosystem.	Harvested reeds could be used to produced bio-fuels like ethanol.
5.	Stream augumentation	Increase in the stream flow flow,enhance aquatic and wildlife habitat.	.....
6.	Ground water recharge	Increase in level of ground water ,storage for future use.	.....

Fig. no 1.8 Figure depicting the benefits of treatment and reuse of wastewater for different purposes.
Source: Report on Ecological study of Katra, by J&K State Pollution Control Board.

Environmental	Economic	Social
Conservation of fresh water resource Resource recovery Minimizing the potentially negative impacts due to release of partially treated water from STP's Prevention of pollution of water bodies due to release of untreated wastewater. Conservation of aquatic bio-diversity provide wildlife habitat.	Saving in cost of augmentation & developing fresh water resources Constant water availability could lead to changing cropping patterns,encourage market gardening & give better yield. The high nutrient content of the waste water helps farmers to save on the fertilizers costs & its reliable supply helps increase the cropping intensity.	Reliable source of water could allow farmers to take up double cropping & or market gardening getting better and improved yield which in turn would uplift the living of the poor farmers. Since waste water is available throught the year, the urban poor farmers & migrant labourers are assured of employment throughout year. Health hazards due to spread of contagious diseases are avoided.

Source:CEPT library-unpublished thesis .

SOLID WASTE

CONSERVES ENERGY :

Using recycled materials as raw materials to make new products saves a significant amount of energy.
Comparision with their virgin counterparts :
Recycled newspaper uses 40% less energy.
Recycled plastic uses 70% less energy.

SAVES NATURAL RESOURCES :

Using recycled materials we can log fewer forests ,mine fewer metals& drill for less oil.
Every ton of newspaper or mixed paper recycled saves the equivalent of 12 trees.
Every ton of office paper recycled saves the equivalent of 24 trees.
Every ton of steel recycled conserves 2500 pounds of iron ore ,1400 pounds of coal & 120 pounds of limestone.

Fig. no 1.9 Figure depicting the implications of reuse of treated wastewater.
Source: Report on Ecological study of Katra, by J&K State Pollution Control Board.

CONCLUSIONS

Since solid waste generation in Katra town and on route collectively is approximately double the quantity with respect to the population expected. So it is very vital to take care of this issue immediately. Appropriate techniques with technical layouts of effluents clearance needs to adopted and monitored regularly to confirm that it is not disturbing the nearby surroundings and creating unhealthy unhygienic threats to the society or residents around.
At the domestic level, accurate separation of left-over must be practiced, for example the practice of black, green and blue containers; all organic matter should be reserved separately for composting, which is unquestionably the finest technique for the accurate removal of this waste. A major cause of flies is organic waste and composting can help get rid of it easily. Organic waste can be composted and then used as nourishment.
Horse dung which is collected in huge amounts due to a number of horses being used for Yatra should be segregated from other waste and further can be turned into a valuable asset, thus converting a problem into an opportunity.
Proper scientific landfill sites should be allocated in nearby areas to take care of non-biodegradable waste.
In future after saturation of this landfill site, proper capping should be done and later used as public open green common spaces.

d INFERENCES

Proper training of workers for collection and transportation of MSW & MLW.
At present also Katra is short of water and by looking at the trend of increase of pilgrims there will be tremendous pressure on the natural water resource and it is very likely that the city will face the water crisis in near future.
It has to be seen that sanitation facilities are provided to the entire population. Less water-intensive flushing systems need to be developed & incorporated to save unnecessary wastage of water.
There is a task ahead before Environmental Engineers, City planners and Landscape Architects as to how to reclaim & reuse municipal wastewater with the growing demand for water and bridge the gap between supply & demand.
It is time to manage the sewage by natural treatment system followed by post-treatment to make them energy-efficient and economical. Choice of the reuse technology may vary according to geographical conditions.
It should be made mandatory for all upcoming buildings to treat and reuse their wastewater for non-potable purposes.

- A large quantity of sewage is left untreated in the river Banganga which is affecting the natural resource of water.
- It is hampering the aquatic ecosystem (flora and fauna) and in turn the avifauna and causing health hazards to people also.
- Even if Katra municipality constructs the STPs, these would not be adequate to treat the entire sewage and may become redundant due to the huge amount of operating costs.
- There is a need for an energy-efficient, cost-effective and eco-friendly treatment method.

- Reuse of the treated water would help in conserving the freshwater resource which may deplete in the near future due to increasing demand. Thus, further reuse of treated wastewater needs to be studied.

Following this is the study of different treatment methods to find a suitable method of treatment of wastewater which is eco-friendly, cost-effective and efficient.

d (i) TREATMENT METHODS:

Several different procedures can be adopted to clear-out wastewaters depending on the origin and kind of composition. The following treatment systems are discussed in brief:

a. CONVENTIONAL WASTEWATER TREATMENT PROCESSES

Characteristically sewage management comprises of four steps. The first step is to separate the solids from the wastewater. Then the mixed organic matter is changed into a compact form by means of a water-borne microorganisms. Finally, the biological objects are neutralized then disposed of or re-used, and the treated water is disinfected chemically or physically.

1. Primary treatment –Usually mechanical procedure
2. Secondary treatment –Biological method
3. Tertiary treatment – Advanced biological, chemical and physical methods
4. Disinfection –Killing of pathogens and harmful microorganisms by Ozonation, chlorination, reverse osmosis process.

Most widely used conventional treatment method is activated sludge treatment. Other variants include aeration method as well.

b NATURAL TREATMENT PROCESS

Natural biological systems can be used as potential purification systems in a controlled manner. This includes using different forms of ponds, land treatments and wetlands. These processes use naturally occurring elements to treat water either individually or in combination with some mechanical process. These methods can be further classified as follows:

1. Bioremediation – Waste Stabilization ponds
2. Mechanical treatment processes – Aerated ponds
3. Phytoremediation – constructed wetlands, root zone treatment
4. Terrestrial processes –Soil aquifer treatment, subsurface flow wetland
5. Miscellaneous – Use of plants or a combination of all treatment systems

Except for waste stabilization ponds, these processes are usually part of a larger treatment system and come into operation after the primary removal of solids, sand and grit is done.

Types of treatment methods:

d (ii) ACTIVATED SLUDGE PROCESS:

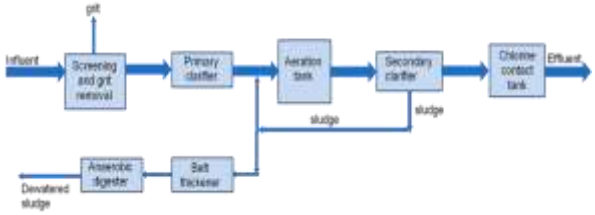


Fig. no 1.10 Figure depicting the implications of reuse of treated wastewater.

Source: Paper on Compendium of Sanitation systems and technologies.

Activated sludge involves aerobic bacteria to break down organic matter in the wastewater and generate seage which is of better quality. A rich supply of oxygen is needed to keep the conditions aerobic and mass suspended.

- The incoming wastewater is mixed in an aeration tank under aerobic conditions. The presence of microorganisms oxidises the carbon to produce new cells, carbon dioxide and water.
- During this process, bacteria clumps together into what is known as flocs which are then transferred to a secondary tank and allowed to settle down.
- The sludge is then recycled and again sent for the same process starting from aeration.
- The steps are modified for desired BOD, nitrogen and phosphorus levels.

Suitability:

- It only works for a centralised treatment facility and needs a well-trained-staff, constant electricity and an intricate management system.

- The process is usually carried out after all solids are removed from the water and before the final refining step.
- This process only eliminates soluble, colloidal and particulate organic matter for biological nitrification and phosphorus removal with large volumes of flows.
- Given its intricacy, staff needs to be highly trained for operation.

Health Aspects/Acceptance:

- The amount of space required is huge and hence the location is usually away from the targeted densely populated areas.
- The effluent although of high quality is still a health hazard.

Maintenance:

- All the mechanical devices require constant maintenance.
- The incoming and outgoing wastewater must nbe monitored closely to make sure everything is normal.

Pros & Cons:

- Works well against shock-loading
- Possible to work at different hydraulic as well as organic loading rates.
- Upto 99% reduction in BOD and pathogens
- Process can be tweaked for specific results
- Can easily incur chemical or microbiological problems
- More treatment is necessary before final discharge
- Local sourcing may not be possible
- Expert required for design and supervision expert design and supervision
- Hugecapital and a high operation cost
- Need for constant electricity

d. (iii) TRICKLING FILTER:

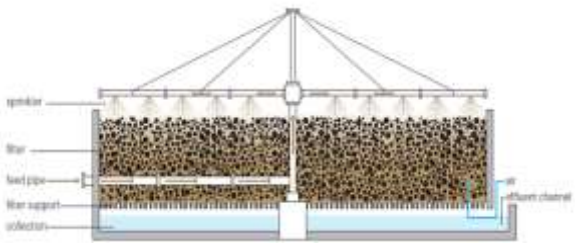


Fig.1.11 Flow diagram of Activated sludge process
Source: Paper on Compendium of Sanitation systems and technologies

A Trickling Filter is a fixed bed which under anaerobic conditions can work as a filter. In essence, water is sprayed over this fixed bed. As the water is allowed to trickle down, The organics in the water are broken down by the biomass in the filter material.

The trickling filter has a high specific surface area and as a result is filled with rocks, gravel, shredded PVC bottles or any specially designed materials.The specific surface area is usually 30 and 900 m^2/m^3.

1. Pre-treatment is required to make sure there is no clogging and the treatment is efficient. The wastewater is sprayed over the filter by a sprinkler. The organics in the wastewater are oxidized to carbon dioxide and water and a new biomass is generated.
2. In the new biomas, the levels of oxygen are low; hence the inner layers are deprived of oxygen.
3. The filter that is used is 1 to 3m deep. The ideal materials used inside the filter have a high surface to volume ratio. The materials are also needed to be light and durable with plenty of space for air circulation. Gravel or crushed rock sit on top of the list because of their low cost as well. Their particles are also uniform.
4. The filter for constant air flow needs to have vents on both sides to allow air to essentially pass through its entire length. The slab is perforated allowing for sludge and excess wastewater to settle at the bottom. As the biomass thickens, the low oxygen levels enter it into an endogenous stage allowing it to slough off. However, sloughing can also be a byproduct of high rate loading.
5. The final product of wastewater is allowed to clarify in a separate tank where the biomass settles down and then removed.

Suitability:

1. The wastewater needs to be clarified beforehand to rid of any solid impurities so the filter doesn't clog.
2. In any case of issue, a skilled person needs to be on hand to troubleshoot and fix problems.
3. The sprinklers need access to wastewater and electricity at all times.

4. Because of their compact size, peri-urban or large, rural settlements are most benefited.
5. Suitable for almost all environments with special adaptations possible for non suitable ones too.

Health Aspects/Acceptance:
Should be away from settlements due to fly and odour nuisance. Appropriate measures need to be taken for pre-treatment and even post treatment to ensure no one comes in touch with the still hazardous discharge.

Maintenance:
The sludge accumulated on the filter should be periodically cleaned to ensure it doesn't clog. High hydraulic loading rates are used to clean the filter and flush away all impurities.. The packing has to always be kept moist. This sometimes becomes tricky especially during power failures or even in places where keeping a constant water flow is tricky.

Pros & Cons:
- There is a possibility of various organic and hydraulic rates.
- The amount of land required is small.
- Capital costs and operation costs are high.
- Expert design and construction is required.
- Constant electricity and wastewater flow is needed for efficiency.
- The odour and flies are a byproduct which can be harmful..
- Local sourcing difficult
- The incoming wastewater has to be treated before.
- Complex engineering is required for the dosing systems..

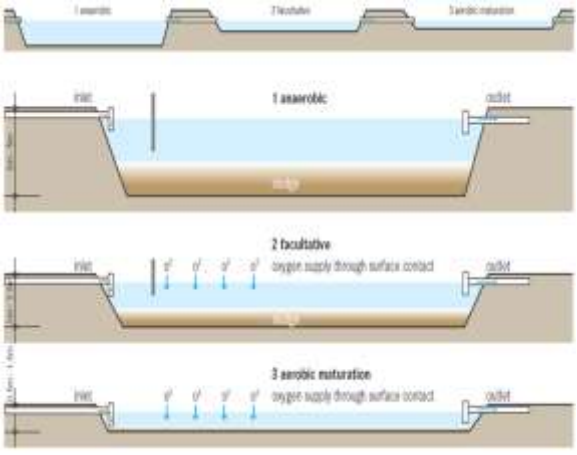


Fig no 1.12 Schematic sections of Waste Stabilization Pond
Source: Paper on Compendium of Sanitation systems and technologies
For high efficiency, WSPs are linked in a set of three or more. The effluent is transferred from anaerobic pond to the aerobic pond via facultative pond.

Anaerobic pond:
1. To reduce solid and BOD as a part of pre-treatment.
2. to 5m deep with a short detention time of 1 to 7 days.
3. Wastewater characteristics and loading decide the design.
4. Anaerobic bacteria is used to convert organic carbon into methane.During this process, 60% of the BOD is removed. It helps treat even strong wastewaters.

Facultative pond:
1. Receives effluent from anaerobic pond.
2. Shallower than anaerobic pond, the top layer gets oxygen from natural diffusion and algae whereas the bottom layer remains anaerobic.
3. Settleable solids are allowed to settle on the bottom of the pond.
4. Total BOD reductions are almost 75%.
5. 1 to 2.5m deep with a detention time between 5 to 30 days.

Aerobic or maturation pond:
1. Maturation, polishing, or finishing pondis the last step and provides the final level of treatment.
2. It is 0.5 to 1.5 m deep to allow maximum sunlight for photosynthesis.
3. Photosynthesis allows for high oxygen levels during the day which drop at night.
4. Pathogen removal occurs here.
5. Along with photosynthesis, wind mixing also helps supply oxygen.
6. Clay, asphalt, compacted earth, or other impervious materials are used to line to avoid leaching and a protective barrier is constructed to avoid runoff and erosion.

Suitability
- Common and efficient way to treat wastewater.
- Works best in warm, sunny climates.

- In cold climates as well, retention times and loading rates can be tweaked for optimal treatment rate.

Health Aspects/Acceptance

- Although pathogen level is low, the water should still not be used for any task - recreation or direct use.
- For maximum removal, a number of ponds can be used and the final one can be used as an aquaculture pond to bring income and source local food plants.

Maintenance

- Grease trap treatment to remove garbage is important for maintenance
- Desluding must be done every 10-20 years
- Fencing is needed to prevent people or animals from entering the area.
- Any vegetation or macrophytes should be removed to allow for maximum light .

Pros & Cons:

- Pathogen levels go down a lot
- Local sourcing possible
- Short term employment opportunity as construction workers
- Operation cost is low
- Electricity is not required
- Correct design eliminates flies and odour
- Expert design and supervision needed
- Capital cost is varied because of land
- Large land area needed
- Secondary treatment is definitely required or a special discharge system needs to be devised. appropriate discharge

d (iv) AERATED POND:

An Aerated Pond is a large, outdoor, aerobic reactor. Oxygen is supplied by mechanical aerators and the organisms are kept suspended for increased organic degradation and nutrient removal.

1. The ponds can be deeper and can tolerate much higher organic loads than a maturation pond.
2. Increased aeration allows for increased degradation and increased pathogen removal.
3. Can function in more northern climates.
4. Incoming wastewater has to be screened and treated beforehand to remove garbage or any coarse material. The solids are separated in a settling tank.
5. Small area is required hence making it suitable for rural and peri-urban areas..
6. 2-5 m deep with a detention time of 3 to 20 days. The tank is lined to prevent leaching with the help of impervious materials including clay, asphalt, etc.

Protective berm built around the pond is needed to protect it from runoff and erosion.

Suitability:

1. High concentration wastewater can also be treated to decrease pathogen content by a good margin. Uninterrupted electricity and availability of replacement parts are of utmost importance to prevent extended downtimes.
2. Range of functioning climates is higher than WSPs but it is best for large areas with cheap lands away from settlements.

Entry should be prevented by fence because of aeration units and hazardous water.

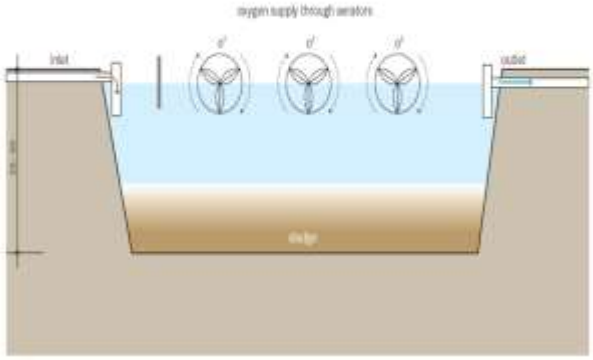


Fig no 1.13 Schematic section of Aerated Pond
Source: Paper on Compendium of Sanitation systems and technologies

Maintenance:

A permanent skilled staff is required to maintain the aeration machinery and for any repairing needs. Desludging is required every 2 to 5 years. Prevention of any foreign material entering the pond such as garbage.

Pros & Cons:

- Provides resistance against shock loading
- Pathogens are reduced by a high margin

- Short term employment opportunity as construction workers
- Insects and odour can be avoided by proper designing.
- Requires large land area.
- Secondary treatment is definitely required or a special discharge system needs to be devised. appropriate discharge
- Expert design and supervision needed-
- Skilled operation and maintenance personnel is needed on the clock..
- Local sourcing may not be possible.
- Constant electricity required.
- Capital costs are on the higher side and the operating costs are variable as well.

d (v) HORIZONTAL SUBSURFACE FLOW WETLAND:

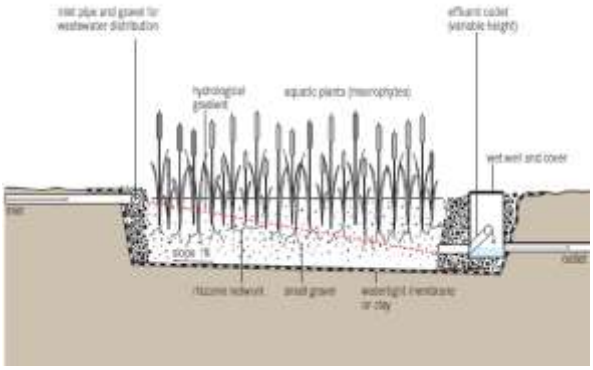


Fig no 1.14 Schematic section of Horizontal Sub surface flow wetland

Source: Paper on Compendium of Sanitation systems and technologies

A Horizontal Subsurface Flow Constructed Wetland is a channel filled with gravel, sand and aquatic vegetation. As the water is allowed to flow horizontally filter material filters out the particles and the organic material is degraded by the microorganisms.

The water level in this setup is maintained at 5 to 15cm below the surface to ensure subsurface flow. For maximum flow path of water, the bed is built wide and shallow. A wide inlet zone is built for an even flow. For this treatment to be efficient, pre-treatment is required as well. The bed used is prone to leaching and this is avoided by lining the walls with impermeable materials. The bed filling on the other hand, 0.5 to 1m in depth, is of small, round, even gravel (rough 3-32 mm diameter). For minimum clogging, the gravel should be clean and free of fines. Sand is also an acceptable filler but can clog more easily. Alternative filter materials include PET which have been successful so far. Removal efficiency depends on the base area and the maximum possible flow is a function of cross-sectional area. A good inlet valve is essential in ensuring short circuiting doesn't happen. The outlet can be varied for optimum treatment. The filter media removes solids, and attaches the bacteria to it. It also acts like a vegetation base. Facultative and anaerobic bacteria degrades the most organics and the vegetation allows for the organics to be degraded even more by supplying extra oxygen. Plant roots are also a factor that determines the permeability. Deep, wide roots from nutrient rich environments are very prevalent. A common choice of root is Phragmites australis (reed) because of its horizontal rhizomes that can penetrate the entire depth. Natural decay, predation by higher organisms and sedimentation facilitates pathogen removal.

Adequacy

Clogging is a very common problem and hence why primary treatment is important before allowing water to flow into the wetland. This results in the fact that untreated domestic water (black water) cannot be treated by this. This method is best suited for places who are looking to improve effluent quality after primary treatment (septic tanks).

This option is best where cheap land is available but the constant maintenance required lifelong should be kept in mind. This wetland can be used for small sections of urban-areas, peri-urban and rural communities depending on the water volume. Single households can even design their own wetlands. This type of treatment is best suited for warm climates but it can be designed for freezing climates too with reduced biological activity.

Health Aspects/Acceptance

Because of no standing water, mosquito breeding is reduced compared to Free Water Surface Constructed Wetlands (T5). The wetland can also be integrated into wild areas and parklands and is also aesthetically nice.

Maintenance

As time passes, repeated use accumulates solids and bacteria on film. Therefore, the film needs to be replaced after 8 to 15 years. Effective primary treatment can reduce solid concentration before wastewater enters the wetland and this should be overseen by the maintenance activities. Lastly, growth of trees should be avoided as it can interfere with the liner and harm it.

Pros & Cons:

- Less space is required in comparison to free water surface constructed wetlands.
- Delivers extraordinary decline in BOD, suspended solid and pathogens.
- Contrary to mosquito breeding in free water surface constructed wetlands here it is opposite.
- Locally obtainable resources can be used for construction and for regular repair works.
- Native workers can be promoted by small time occupations.
- Electrical energy is not required.
- Professional details and drawings with supervision is necessary.
- For avoiding obstruction pre cure is necessary.

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