Research Paper

Disaster Waste Mitigation

Subtitle

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Abstract

Emergencies and disasters can strike anywhere on the planet, causing chaos on human health, lives, and the infrastructure that supports them. Disaster waste can hamper rescue operations and cause severe financial, ecological, and health consequences. Threat reduction, readiness, emergency response, relief, and recovery, as well as operations to restore infrastructure and repair shattered lives and livelihoods, are all part of disaster management.

Waste management during and after a disaster has also become a critical concern. Depending upon the type of calamity, its intensity, location, and nation, different approaches are taken to deal with the waste that is linked with it. Additionally, there are serious issues that need to be addressed regarding the ineffective enforcement of current laws and regulations, low standards of local competence and capacity, a lack of funding, and a lack of coordination and communication. Disaster debris exists in a range of shapes, sizes, and degrees of danger. As, 2016 Kumamoto earthquakes in Japan caused around 2.89 million tons of debris.

The current state of the art in disaster debris prediction consists mostly of models given by federal agencies in the United States, with many site-specific contributions from the corporate, Vital assets are disrupted in a variety of ways, including effects on public health, delays in the rebuilding process, contributions to local industries like tourism, a reduction in available landfill space.

Purpose of this paper is to study mitigation process of waste generated as the consequences of various disaster events along with current practices on quantification of generated waste through such disaster events.

Keywords

Disaster waste mitigation, disaster waste, post disaster approaches, disaster waste management.

1 Introduction

The two main factors that affects waste output during a disaster are the strength of the natural event and the urbanisation of the affected area. (Amato et al. 2019).

It is critical to evaluate the possible hazards in the region and determine the repercussions of disasters. Disasters can causeFailures in planning and design, but errors in development strategies can also contribute to catastrophe risk, as is the case in the majority of the disaster-prone cities of emerging nations(Kamat 2015)

Effective disaster waste management planning is a critical part of any disaster preparedness strategy. Estimating the expected amounts and composition of trash likely to be generated by future disasters, as well as identifying required resources and management options, is a critical component. Modeling disaster waste creation for earthquakes and flooding has been utilized in certain research to identify the components and volumes of disaster waste (Gupta, Bindal, et al. 2021).

2 Disaster waste and their characteristics

Because of devastating power, disasters such as earthquakes, tsunamis, and cyclones produce a tremendous amount of garbage. The amount of waste produced can be equivalent to ten times year's rate of typical municipal solid waste generation (Ministry of Environment Japan 2018) .

Unlike the usual generation of waste, the disaster waste is considerably unavoidable. The definitions say the waste is the material which has no use to the person and almost negligible value to the user, waste generated through disaster events needs special handling process (Gupta, Bindal, et al. 2021).

Factors that affect the waste generation after the event is based on the intensities and level of urbanization of the affected area. The waste produced as a result of such catastrophic occurrences is often 10 to 15 times more than the impacted area's normal yearly waste output. (Fadhlina et al. 2016) .

As per United Nations Environment Program (UNEP) guidelines, based on events, the types of waste can be characterizes as follows:

2.1 Earthquake

It includes collapsed building materials which usually requires heavy machinery and equipments to handle the clearance process of debris, earthquakes results in high quantity of waste compared to other disaster waste since all the building materials i.e., concrete, bars, wires etc. becomes waste.

2.2 Flooding events

In flood risk management, vulnerability is the most important concept. One of the most important goals of flood vulnerability assessment is to establish a clear link between theoretical flood vulnerability concepts and the regular administrative procedure (Kamat 2019).

Flooding results in mass displacement, thus leads to the large amount of household waste. The affected area may be contaminated with hazardous chemicals and other cleaning liquids usually used in households and other chemically vulnerable substances leading towards the considerable medical situations. Floods carries mud clay and stones that remains after draining of flood water that cause difficult access and recovery actions.

2.3 Tsunami

It strongly affects the large area including multiple infrastructure, debris from the affected areas could be mixed with the soil, trees, and vehicles that makes difficult handling and segregation.

2.4 Conflicts (short term or long term)

Usually results in the form of waste from missile, bomb and military operations which leads to massive disruptions. The waste can be segregated into flammable and inflammable materials. (Anttilator & Bjerregaard 2013)

3 Disaster waste management stages

Disaster waste management is critical since produced hazardous materials, causing impact on the built environment, and other aspects (Brown, Milke & Seville 2011a).

Disaster waste management includes the collection, processing, transportation, and treatment (recovery and disposal) of waste resulting from disasters. (Karunasena & Mallawarachchi 2014)

Management of disaster waste includes 6 stages as follows

3.1 & 3.2 Prevention, mitigation and preparedness

In these very initial stages, the focus can be on the reduction of disaster waste strategies before the event occurs where the preparedness could be based on the preparation of plan of safe removal and disposal of disaster waste.

3.3 Early warning stage

When a natural hazard (earthquake, storm, or flood) is proclaimed by the appropriate government agency (e.g., National Metrological Office, or Mineral Resource Department), the early warning stage begins. The Preparedness Plan is triggered as a result of this declaration, allowing relevant authorities to begin garbage removal from neighbourhoods, core business areas. In order to assure the secure storage of disaster wastes that might not be able to be transferred to authorised landfills due to disaster-related effects, temporary waste management facilities can be set up and constructed. To protect the safety of garbage collection and transport employees, it is not advised to begin operations after a tsunami warning has been issued.

3.4 Emergency response

A quick assessment of the kind, quantity, and location of the disaster's wastes is made since it is anticipated that some urgent "clean-up" would be needed to give emergency services access to the impacted communities. Efficient Catastrophe waste assessment helps determine the extent of work that needs to be done during the recovery phase as well as the necessary response operations to be activated after a disaster.

3.5 Recovery

The focus of recovery activities is on community evacuation (where needed) and relief from the disaster's effects. Prior to deploying recovery teams, the final preparation of the recovery activities (including accumulating any new data) is completed.

All damaged services and infrastructure to be restored, resumed, and rebuilt as part of the operations. Amenities, in partnership of development partners, to allow communities to return to their original state as quickly as possible, return to normal. The use of trained field operators is necessary for data collection and analysis.

3.6 Reconstruction

Management of waste produced not just by disasters but also from other causes, such as rebuilding operations, is a common part of reconstruction. Any damaged waste management facilities will most likely be repaired as part of the reconstruction process. The completion of the rebuilding work might take months or years. (Anttilator & Bjerregaard 2013).

Each phase's duration varies significantly amongst catastrophes. The emergency phase of waste management normally lasts a few days to two weeks and involves addressing any urgent threats to public health and safety (Secretariat of the Pacific Regional Environment Programme 2020).

4 Quantification of disaster waste

In the United States, debris quantities are assessed visually at the dump entrance based on the capacity of the vehicle bed, The current state of the art in disaster debris prediction consists mostly of models given by federal agencies in the United States, with many site-specific contributions from the corporate and academic sectors(Bekkaye, Graduate & Fellow no date).

4.1 A debris flow forecast model

A debris flow forecast model which is based on a water-soil coupling mechanism that uses the debrisflow watershed as the fundamental forecast unit, was developed here for disaster prediction.This forecasting model is a means of determining possible debris flow basins,locations at risk of debris flow within a forecastregion. It shows developed coupling relationship between the rainfall and the underlying surface, The new approach of debris flow forecasting may be used as long as the underlying surface and rainfall at the regional scale are known, Its precision and applicability were demonstrated in a case study in Sichuan Province(Zhang et al. 2014).

4.2 Regression analysis

A technique for estimating the amount of consumer durables owned by each family was developed using multiple linear regression analysis. The quantity of consumer durables owned by households was estimated using multiple linear regression analysis. The size of the household had a significant influence on the amount of all consumer durables held. For the years 2015 and 2035, the total median amounts of garbage created by TV sets, air conditioners, refrigerators, and washing machines in Ise-Shima were estimated. The sum of the top range values for both sectors equals 545,000 units, which is 61% of the yearly quantity handled at recycling plant (Tabata et al. 2016).

4.3 Mathematical models

The number of households in a developed urban/suburban region is considered in this model. $Q=H(C)(V)(B)(S)$ is the equation used where Q represents the amount of debris in yd3, H represents the number of households, C represents the storm category factor in yd3, V represents the vegetation characteristic multiplier, B represents the commercial/business/industrial use multiplier, and S represents the storm precipitation characteristic multiplier (Bekkaye et al. no date).

4.4 Decision Support Tool for Incident Waste

Online decision-making tool to aid in the effective and timely management of disaster-generated material in the aftermath of natural and man-made disasters I-WASTE offers a Waste Materials Estimator (WME), which is unique in that it predicts catastrophe waste tonnages as well as volumes and categorises the estimates by kind of debris, such as drywall, carpet, and furniture.(Bekkaye et al. no date)

5 DISASTER WASTE QUANTITIES

Disaster waste comes in a variety of shapes, sizes, and degrees of severity. 2016 Kumamoto earthquakes in Japan caused around 2.89 million tonnes of debris. However, this is a small fraction of the waste generated by Hurricanes Katrina and Rita along the Gulf Coast, which totalled more than 100 million cubic yards. For Sandy, the NYC Departments of Parks and Sanitation used Jacob Riis Park as a temporary "short dump," a temporary staging area for transporting debris to before choosing how to treat the waste in the long run.

The recent pandemic COVID 19 also had a detrimental effect on the environment since everyone stayed at home and produced a lot of plastic waste from restaurant delivery, single-use plastic containers, online package delivery, masks and gloves etc.

A variety of plastic-based personal protective equipment (PPE) was essential in ensuring the safety of medical professionals during the COVID-19 pandemic. However, there is rising worry about the unprecedented rise in single-use plastics (SUPs), which includes sharp and general wastes such as needles , gloves, surgical masks, surgical and medical supplies, and surgical and medical supplies(Gupta, Bindal, et al. 2021)

The reported waste volumes from significant disasters over the past few years are shown in Table 1. The amount of waste is recorded as either a mass or a volume. (Secretariat of the Pacific Regional Environment Programme 2020) .

Table 1. Waste Quantities from Previous Disasters

Year	Event	Waste quantities
2016	Tropical cyclone , fiji	23,525 tonnes
2015	Nepal earthquake	14 million tonnes
2013	Super typhon Haiyan philipins	190million tonnes
2011	The great east japan earthquke	31 million tonnes
2010	Haiti earthquake	23-60 million tonnes(Estimated)
2009	L'Aquila earthquake , Italy	1.5-3 million tonnes(Estimated)
2008	Sichuan earthquake, China	20 million tonnes
2005	Hurricane Katrina,US	76 million cubic meters
2004	Hurricanes Frances and Jeanne,Florida,US	3 million cubic meters
2004	Indian ocean tsunami	10 million cubic meters
2004	Hurricane charley,US	2 million cubic meters
1999	Marmara earthquake, Turkey	13 million tonnes
1995	Great Hanhin-Awaji earthquake, kobe,japan	15 million tonne

Source: (Secretariat of the Pacific Regional Environment Programme 2020)
(Ministry of Environment Japan 2018)

As indicated disasters such as earthquakes, tsunamis, and cyclones occur often throughout Asia and the Pacific. Due to their powerful destructive force, these produce a lot of waste. Due to its properties, it can equal tens of years' worth of typical municipal waste, yet waste is difficult to treat (Table2.). (Ministry of Environment Japan 2018)

6 WASTE TREATMENT OPTIONS

Numerous disaster-related waste products can be recycled. Materials such as soil for landfill covers, aggregate for concrete, and plant waste for compost can all be used after a disaster (fertilisation and slope stabilisation). Following are few benefits as per Secretariat of the Pacific Regional Environment Programme 2020:

1. Decrease in the amount of landfill area required.
2. Reduction in the number of raw material needed during the re-building.
3. Transportation of raw materials and debris is reduced.
4. The creation of jobs (for developing countries in particular).

Recycling should be processed according to each material's specifications, which necessitates the use of specific plant equipment. Although burning is not a recommended solution from environment point of view but following the Great Hanshin-Awaji earthquake and the Indian Ocean Tsunami, open burning has become a popular disaster waste management technique to avoid waste related complications later.

In some circumstances, open burning is recommended as a required management strategy to eliminate urgent threats, although there is limited information on exactly when it is to be applied. There hasn't been such studies on open burning specifically in terms of recycling and waste-to-energy treatment techniques after disaster (United Nations Environment Programme 2012).

7 CHALLENGES IN DISASTER WASTE MANAGEMENT

Managing disasters debris is time-consuming and expensive, poor management or inadequate preparation can lead to increased expenditures, cleanup delays, and negative environmental and societal consequences(Bekkaye et al. no date).

As of Karunasena & Mallawarachchi (2014) Minimum requirements for effective waste management include -

1. Ensuring that all individuals in charge of and overseeing initiatives have the necessary experience and that appropriate safety systems are in place.
2. Ensuring that as much personal protective equipment (PPE) as feasible is used, including for casual worker personnel (i.e., those engaging in cash-for-work)

7.1 Risk to public health and vulnerabilities

Disaster debris endangers public health and safety, imposes a significant psychological load on victims, and impedes the delivery of emergency aid and supplies to impacted communities throughout the recovery process(Bekkaye et al. no date). Health hazards can take many forms, including biological, electrical, ergonomic, and fall dangers. These health risks are frequently caused by the lack of readiness, as well as the use of risky method, Inadequate use of personal protection equipment (PPE), for example, may result in injuries from sharp items such as knives. Nails, metal fragments, and shattered glass, as well as dangerously positioned objects dropping from above storage, such as drums, boards, or boxes(Pradhananga, ElZomor & Kasabdji 2021).

7.2 Environment

The environmental effect and operational cost are influenced by a number of factors such as the distances between the fields of concern and the management site, as well as the scope of a preliminary manual sorting conducted by citizens, the financial burden of each stage involved (Amato et al. 2020).

Environmental problems and natural calamities are strongly connected. Poor environmental management and land use can increase the environment's susceptibility to disaster while also causing direct physical harm to the ecosystem during natural disasters. The decision and implementation of emergency waste management methods will affect the disaster's environmental effect. (Secretariat of the Pacific Regional Environment Programme 2020).

7.3 Mixed waste

"Mixed waste" made up around 60% of DW and the majority of the total waste treated. DW was disposed of in the same manner as other waste. Although the legislation stipulates that DW should be processed by municipalities (cities) in the event of a disaster, the fundamental policy in this situation was to use private-sector processing facilities. This represents the issues that arise when temporary sorting stations are set up to handle waste that will be processed in existing facilities. Resources were recycled as much as possible (wood chips, concrete rubble, scrap metal, and so on) for this process, and RPF (Refuse Paper and Plastic Fuel) efforts were launched (Brown, Milke & Seville 2011b).

7.4 Disposal of Disaster Waste

When a disaster strikes, debris and waste accumulate to the point where existing waste disposal facilities and employees are overloaded. Hurricane Katrina, for example, produced fifty times the amount of waste that cities regularly produce . The storm wreaked havoc on the Gulf Coast, causing $100 billion in damage and destroying up to 275,000 dwellings . Even with federal assistance, localities may lack the necessary equipment, expertise, or funding to properly dispose of this waste .

7.5 Disaster waste management costs

The expenses of waste management vary depending on the event and the circumstances, much like waste quantification.No attempt has been made to determine the indirect and direct costs of disaster waste management, except from FEMA's estimate of a 27 percent overall disaster waste management cost.

On the other hand, indirect expenses are significantly more challenging to estimate following a disaster. Vital assets are disrupted in a variety of ways, including effects on public health, delays in the rebuilding process, contributions to local industries like tourism, a reduction in available landfill space, the impact of waste trucks on the roads, environmental impact remediation that frequently results from improper and/or illegal dumping, and increased resource depletion.

The recently available minimal cost information for cleaning programmes is summarised in Table 2. The recovery processes as a result(Brown et al. 2011b).

Table 2: Disaster waste management costs following past disasters(Brown et al. 2011b)

Disaster	location	Debries quantities	Cost
2004 Indian ocean tsunmi	srilanka	0.5 million tonnes	US$5-6 million
2004 Indian ocean tsunmi	Thailand	0.8 million tonnes	US$2.8 million
2004 typhoon tokage	Tokage ,japan	44780 tonnes	US$15-20 million
1999 kosovo conflict	Kosovo	100,000 tonnes	US$2.35 million
Hurricane charley	Florida, US	19 million cubic yards	US$286 million
Hurricane jeannesand	Palm beach, US		US$ 20/ cubic yard pickup

france			
1998 central florida tornedoes	Osceola country, US	250,000 cubic yards	US$8 million

Numerous case studies highlight financial and economic concerns. These include lowering the cost of trash management (disposal, transportation, and labour), making money from recycling, and bringing in new workers. Particularly recycling has the potential to considerably lower trash management costs. (Secretariat of the Pacific Regional Environment Programme 2020).

8 CASE STUDY

8.1 The 2014 Srinagar Floods

8.1.1 City profile

Srinagar (figure 1.) is located in the Kashmir basin of the state of Jammu and Kashmir (India). The city is divided into two main physical sections (Right River Division and Left River Division), having 68 municipal wards.

The right river division is divided into two administrative zones - east zone containing eight administrative wards and the north zone, which has nine administrative wards

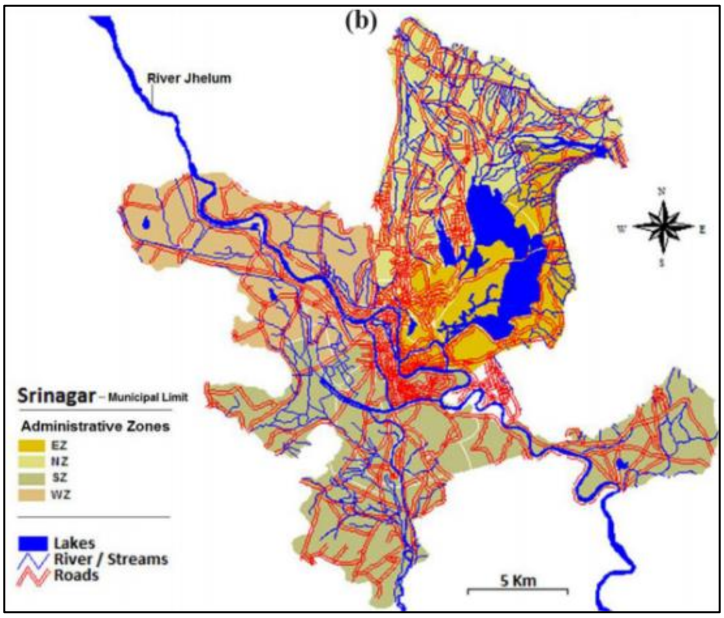

Figure 1 location map.sourcs: (Alam et al. 2018)

The left river division is also divided into two administrative zones: the west zone, which has eight administrative wards and the south zone, which has nine administrative wards(Alam et al. 2018).

On the basis of average annual growth rate from 2006 to 2020, the city has also been named one of the world's hundred (92nd) fastest rising cities. The city's size grew from 12 km2 in 1901 to 300 km2 in 2011.

8.1.2 Flooding in Srinagar

Flooding in Kashmir Valley has a long history (Figure 2.), dating back to 1841. When the valley was turned into a lake in 1902, it was considered an exceptional event. Four flood episodes occurred in successive years from 1981 to 1991, resulting in significant economic damage. The September 2014 floods killed around 275 people in J&K, including 45 in Srinagar. The increased frequency of floods might be ascribed to the city's fast and unplanned development to accommodate the surging population, including massive migration from rural regions during the previous three to four decades. The south of Srinagar has traditionally served as a "flood sponge," acting as a barrier to flood flows (Gupta, Barwal, et al. 2021).

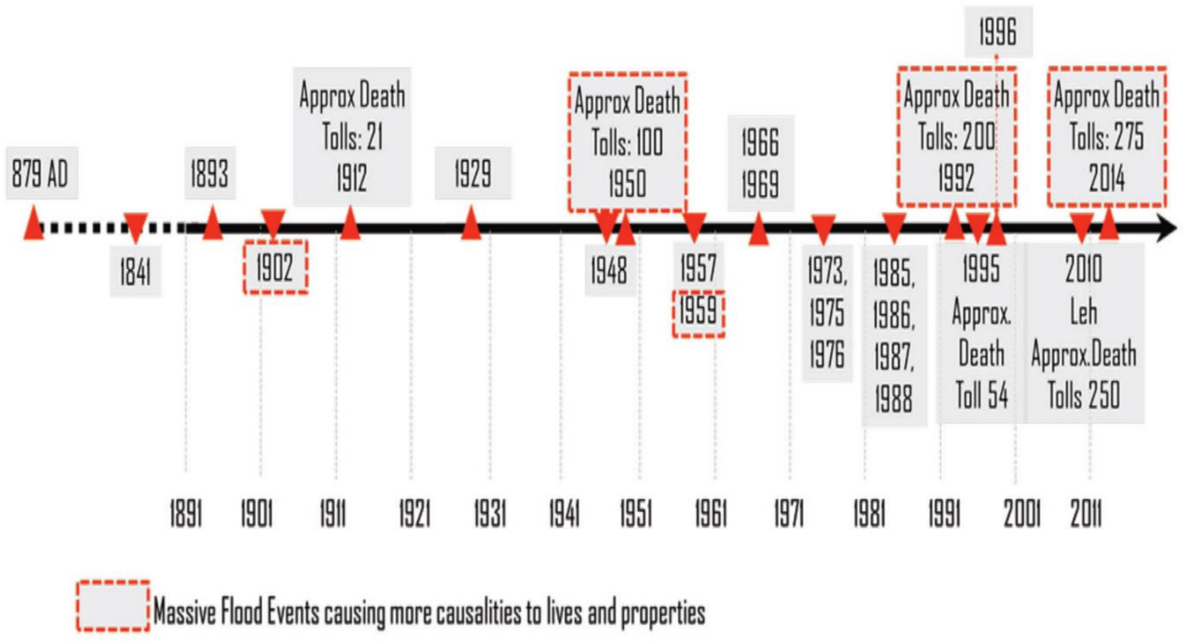

Figure 2 flood events.source: (Gupta, Barwal, et al. 2021).

The 2014 Kashmir foods caused severe damage in the valley, highlighting the susceptibility of the city of Srinagar in particular(Gulzar et al. 2021).

On September 2, 2014, Srinagar was flooded by a five-day period of torrential rain, with major areas of the city submerged as the river Jhelum overflowed its normal water level, flowing at 23 feet above normal (5 feet above the danger mark). The river's discharge rate was 70,000 cusecs, which was three times higher than typical (Gupta, Barwal, et al. 2021).

8.1.3 Flood risk profile of Srinagar

The city, containing 33 municipal wards, is at high risk, while the rest of the area, comprising 23 and 12 municipal wards, respectively, is at moderate and low risk. There is a need for planned actions (structural and non-structural) to reduce the emergent risk(Alam et al. 2018).

8.1.4 Effect on Critical Infrastructure

There are no technical criteria for food-resistant structural design, as there are for earthquake-resistant construction. A critical research requirement is flood-hazard quantification investigations, followed by the development of analysis and design procedures that take into consideration local building materials and processes(Gulzar et al. 2021).

Seventy percent of Srinagar's central region was flooded, with the lowest recorded maximum flood level (HFL) ranging from 10 to 20 feet. Administrative centres such as the Civil Secretariat, Divisional Civil/Police Headquarters head office, police control room, District Administrative head offices, major hospitals, and gasoline stations were all flooded (Gupta, Barwal, et al. 2021).

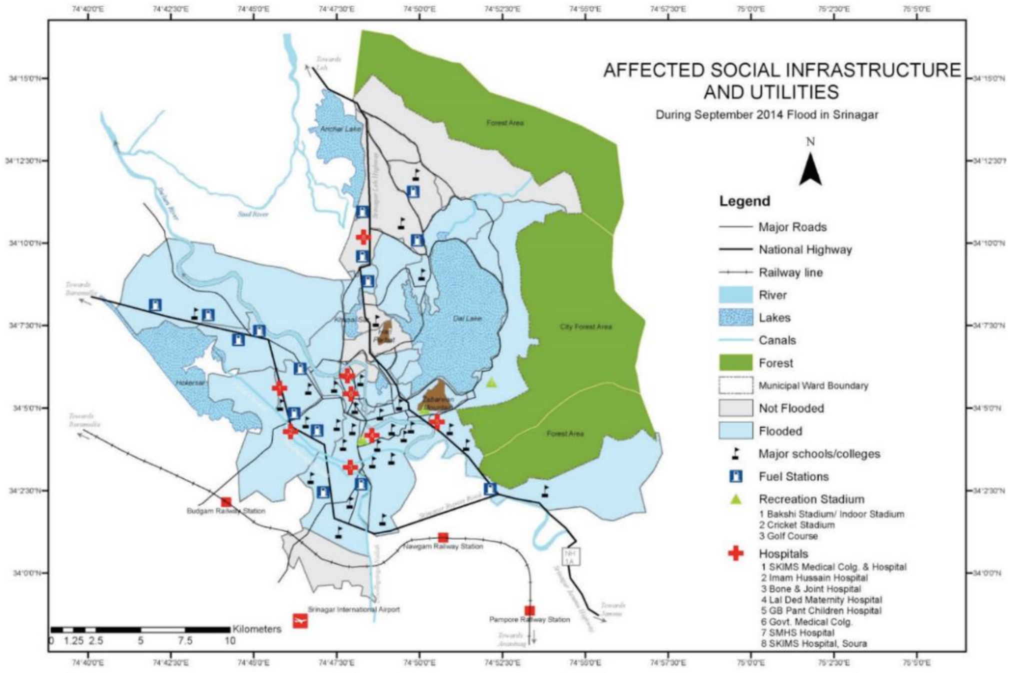

Figure 3 affected infrastructure. Source: **(Gupta, Barwal, et al. 2021)**.

8.1.5 Waste quantities

In total, 85,157 metric tonnes of waste materials were gathered during the operation, which involved Around 17,836 truck trips to Srinagar's city waste site in Achan. The amount of garbage and waste collected during post flood operations climbed from 48 metric tonnes on September 11, 2014, to 2422 metric tonnes on October 3, 2014. Every day, an average of 1051 MT of rubbish was lifted, which was over 5 times the regular amount (Gupta, Barwal, et al. 2021).

8.1.6 Waste collection and disposal strategy

A well-constructed Scientific Landfill Site, strategically positioned in Achan, Saidpora, Srinagar, was away from any risk of water inundation. It has a computerized weighing bridge that keeps a complete record of waste and garbage vehicle movements. In less than two months, it easily absorbed almost 85,000 kg of post-flood garbage. SMC (Srinagar municipal corporation) used over 5000 people, 200 machineries (JCBs, bulldozers, trucks, loaders, waste compacters, etc.) including a considerable number of trucks from non-flooded areas, and sanitation instruments like as disinfectants and anti-odour treatment for the "Mission Clean Srinagar" operation. Safety clothes, gloves, and gumboots were provided to the field crew (Gupta, Barwal, et al. 2021).

CONCLUSION

Disasters are rapid, unplanned changes that occur in a single location, resulting in significant harm, the loss of life and property, and the need for more effort before normal operations can resume.

Furthermore, calamities may produce a considerable volume of waste and debris. Additionally, disaster waste management may have a long-term effect on the response to the disaster as well as the area's long-term rehabilitation and reconstruction.

Governments may successfully safeguard persons, countries, communities, and ecosystems, as well as their means of subsistence, cultural legacy, economical resources, by using efficient waste management planning to decrease catastrophe risk. This will increase their resilience. Disasters are rapid, unforeseen changes that occur in a single location, resulting in significant harm, the loss of life and property, and the need for further labour to restore normalcy.

Furthermore, disasters may produce a substantial quantity of waste and debris. and disaster waste management may have a long-lasting effect on the recovery process on the region that was damaged by the tragedy being rebuilt.

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