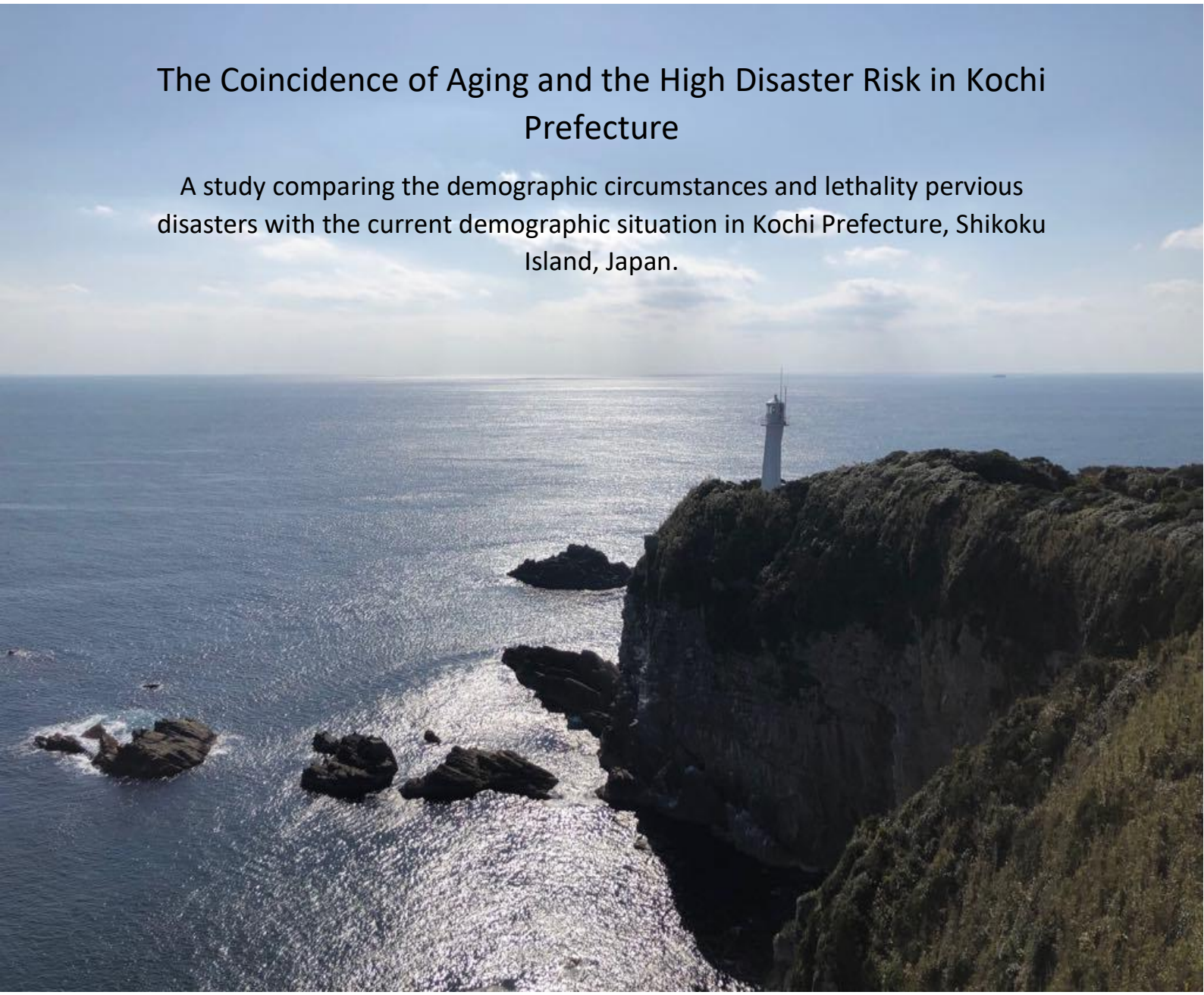
The Coincidence of Aging and the High Disaster Risk in Kochi Prefecture

A study comparing the demographic circumstances and lethality pervious disasters with the current demographic situation in Kochi Prefecture, Shikoku Island, Japan.



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Introduction

We all remember the horrible news, which spread around the World late in December 2004, the day after Christmas. A massive Tsunami hit the densely populated and by tourists appreciated beaches and coastlines of the Indian Ocean, especially Indonesia. It was the first time, many of the European heard about the natural disaster caused by massive submarine earthquakes. It was due the high number of fatalities, a total of 227,899 in several affected countries around the Indian Ocean, also a lot of tourists have been affected because they spent their holiday there, and the globalisation made the news spread faster. Also, many people there have not been aware and informed about the danger of a Tsunami. Seven years later, a massive submarine earthquake with a Magnitude of 9.1, the Tōhoku Earthquake, east of Honshū Island, Japan, triggered a massive tsunami with a maximum height of 38,90m (NOAA National Centers for Environmental Information, 2019), which hit the Japanese coastlines and killed 18,887 people (Okamoto, 2013). Japan was aware of the danger of tsunamis since they happen frequently. The Japanse government installed many tsunami warning systems, trained and informed the population and built many tsunami evacuation towers. But they underestimated the intensity of the earthquake and the height of Tsunami, which flooded many meant to be save evacuation points. Many of the fatalities have been old people, which weren't able to reach save areas in time or didn't know where to go or what to do. Thanks to the good preparation the number of fatalities had been far below these of the tsunami in the Indian Ocean. Since Japan is in a seismological very active region, they are expecting a huge earthquake at the Nankai Trough with a following tsunami in the near future, affecting hundreds of thousand people along the east coast in southern Japan.

Seismology in Japan

Earthquakes

Japan is known for its many earthquakes and tsunamis. This is due to Japans geographical position, which is located on the Ring of Fire, the most seismic region in the World. About 90% of the world's earthquakes occur there (USGS, 2019), many deep submarine trenches, even the deepest one, the Challenger Deep in the Mariana Trench and most of the active Volcanos are located along the Ring of Fire, which are the result of the movement and collusion of many lithospheric plates.

Figure 1 - The Ring of Fire (USGS, 2019)

In the Northern Part of Honshū Island, Japan, the Pacific plate is moving with about 9 cm per year towards the North American plate in western direction and dives under the North American plate, which is also known as a subduction zone. (Chang, 2011) The trench caused by this subducting process is called the Japan Trench. The North American plate is getting compressed by the Pacific plate and once it cannot withstand the tension, the energy is getting released, causing the plate to jump back forward its former position. The vibration, also known as earthquake, of the plate caused by this event can be felt, depending on the magnitude, the depth of the epicentre and the intensity, on the Island. Earthquakes in this Region occur regularly, but heavy tsunami generating earthquakes, like the Tōhoku earthquake on March 11th, 2011 with a magnitude of 9.1Mw recurrence every 800 to 1100 years. Other comparable events like the Jōgan-earthquake on July 13th, 869, and two older ones (BC 140 - AD 150 and ca. B.C. 670-910, which got calculated by the finding of thin sand layers on the Sendai plain) caused tsunamis flooding the coast of north eastern Japan. (K. MINOURA, 2001)

The Nankai Trough

Further south, approximately 900 km offshore of the pacific coast of central and southwestern Japan, is a submarine trough, the Nankai Trough. The Nankai Trough is one of the active convergent boundaries where historic great earthquakes were generated repeatedly. These large thrust earthquakes in the Nankai Trough are attributed to the subduction of the Philippine Sea plate beneath the overlying Eurasian plate (Ayako Nakanishi, 2002). The Trough can be separated into 2 segments, The Nankai Zone, off Shikoku Island and Kii Peninsula (*Figure 2 - Recent earthquakes* at the Nankai Trough segment A and B) and the Tonankai/Tokai Zone off Tokai and Suruga Bay (*Figure 2 - Recent earthquakes* at the Nankai Trough segment C, D and E). Strong earthquakes with a magnitude of ~ 8 or even higher happen in this region about every 100-150 years, see *Figure 2 - Recent earthquakes* at the Nankai Trough . As no such earthquake occurred in the Suruga Bay area, the eastern-most part of the earthquake zone, since the Ansei Tokai earthquake (M = 8.4) in 1854, it is expected that an earthquake having a magnitude of 8 or higher might hit there sooner or later and probably sooner. (Rikitake, 1999) The probability for such an earthquake raised from 30-40% for the following 10 years in the year 1980 to 35-45% for the following 10 years in 2000 and is still raising since no earthquake with an magnitude of 8 or higher occurred till now.

At the western-most part of the trough, the Nankai Trough, the last heavy earthquake occurred in 1946 with a Magnitude of 8.0, causing a tsunami. The reoccurrence rate in this zone is higher than of the eastern-most part because the tectonic plate movement in the Nankai Trough is slightly higher than in the Tokai Trough. The relative velocity in the parts off Shikoku Island is about 4.6 cm per year. (Rikitake, 1999)

	Tokai Trough	Nankai Trough
Relative velocity (cm/year)	4.0-4.1	4.3-4.6

Figure 2 shows the recent earthquakes at the Nankai Trough, the year they occurred, their magnitude and the affected segments. It illustrates the interval between the earthquakes which is between 90 and 137 years.

Figure 2 - Recent earthquakes at the Nankai Trough

Older People during a disaster

In the last 50 years, Japan got hit by many strong earthquakes, causing high damage to infrastructure and killing many people. But only two earthquakes, the Kobe Earthquake and the Tōhoku Earthquake killed more than thousand people (Catalog of Damaging Earthquakes in the World, 2019).

Kobe Earthquake (1995)

The Kobe Earthquake, also called "The Great Hanshin-Awaji Earthquake", which struck the Hyogo prefecture early in the morning of 17th January 1995, was a major disaster that left 6,433 people dead, 43,792 injured, and 510,000 homes damaged or destroyed. The total cost of damage in the whole prefecture, including buildings, railways and expressways, amounted to US$ 100 billion (Watanabe, 2013). As Figure 10 shows, about 15% of Japans total population were at given time above the age of 65. Statistics of the fatalities shows that 5,488 people died immediately and 945 more died due earthquake-related incidents later. While about 55% of the immediate deaths were people above the age of 60, almost 90% of the later earthquake related deaths were older people above the age of 60. Immediate deaths are deaths that happen during the impact phase of the earthquake, like crushing or burning, while earthquake related deaths are not directly caused by the seismic force, they are due to increased stress levels and lack of supplies, but also due to worse hygienic standards in the aftermath of the earthquake. Examples are increased acute myocardial infarcts, pneumonia or post-traumatic stress disorders (Tanida, 1996) (Keiko Ogawa, 2000).

As shown in *Figure 3* , a proportionally high number of female persons above the age of 60 were among the dead. Also, a relatively high number of dead people, about equally male and female, were in the age group 20-29 years. This is attributed to the high number of universities in the affected area. Most of the people (about 78%) were being crushed to death or died because the lack of oxygen and suffocated. Fires spreading in the demolished buildings killed about 12%, a slightly higher percentage among the older people (Watanabe, 2013).

Figure 3 - Proportion of local population that died in the Great Hanshin Earthquake stratified by age (data on age stratified population are based on 1990 census) (Tanida, 1996)

One of the main reasons why a high number of older people died immediately is due the standard of living. These people tend to live in wooden houses and a study of the affected area showed, that about

41% of wooden houses were demolished and a further 19% were damaged beyond repair, whereas only 7% of ferro concrete condominiums were demolished and a further 9% damaged beyond repair. Furthermore, elderly people tended to sleep in ground floor rooms, which were especially prone to collapse, when the earthquake occurred early in the morning. (Tanida, 1996).

After the shock many people fled from their home to the nearest shelters, which were usually set up in schools, sport sites and governmental buildings. It was like a "surviving of the fittest", the people who arrived there first, got the supplies which they needed first. Since the damage in the city was enormous, the shelters have reached their capacities soon, leaving the disabled and older people who arrived later, only the leftovers of supplies like blankets and as well space for staying. Okamoto describes the situation in his article as followed:

"*Senior citizens who were saved without major injuries soon weakened due to the harsh life of emergency shelters or life without normal conveniences at home. For elderly people with disabilities, life in the emergency shelter was extremely difficult in many respects, including toilets and meals. There was also a lack of caregivers, and there were cases in which people stayed in their own homes even when these were dangerous to live in. Elderly people were slow to evacuate and, by the time they arrived at the evacuation shelters, all the good spots had been taken, so they ended up on the concrete floors of the corridors or entrance halls, shivering as it was winter time*." (Okamoto, 2013)

The cold weather in the winter time and the lack of a healthy nutrition, often only cold and boxed meals got served, caused many old people to get ill, most of them suffering severe coughs and fever, even pneumonia was common. The living condition in the shelters were also harsh, often the heating was not powerful enough, the sanitary facilities where not made for disabled persons, it was dangerous for them to go there alone, especially during night time. Also, the people who needed rehabilitee programmes couldn't proceed them and many got bedridden.

Tōhoku Earthquake (2011)

The Tōhoku Earthquake, also called the Great East Japan Earthquake, with a Magnitude of 9.1, occurred on the 11th March 2011 at 14:46 local time, causing a Tsunami with a maximum height of 38,90 meters which hit the east coast of Honshu Island. (NOAA National Centers for Environmental Information, 2019) 18,877 people were killed by the earthquake and the tsunami and a further 470,000 survivors were evacuated to shelters because their houses and the infrastructure had been destroyed, about leaving a damage of about $360 Billion, making it the costliest disaster ever (Okamoto, 2013). In the worst hit Prefectures Iwate, Fukushima and Miyagi, a total of 126,600 houses had been destroyed or damaged beyond repair and around 8,000,000 houses were cut off electricity, leaving the region paralysed.

As shown in Figure 10, in the year 2011, about 23% percent of the Japanese population was 65+ years old, in two of the affected and researched cities, Miyako city in Iwate prefecture and in Ishinomaki city in Miyagi prefecture the proportion of older people was even higher, 30.2% and 27.2%. Figure 4 shows, that the most casualties who lost their life during the disaster, are above 65 years old, about 56%, which is about twice as high as the proportion of the total population. Among the post-disaster related deaths, about 89% are accounted to the elderly people. (Okamoto, 2013).

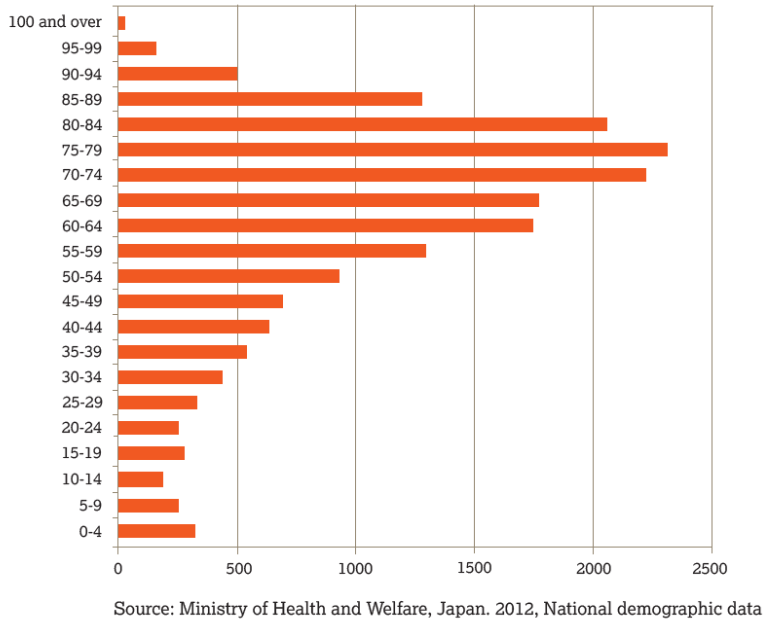


Figure 4 - Age distribution among the casualties (Okamoto, 2013)

Challenges for older People

A study done in 2013 by Okamoto Nahoko analysed the challenges and the needs of older people during the Great East Japan Earthquake and the aftermath, the life in the shelter, the recovery from the disaster and recommendations for future disasters. They interviewed 206 older people in Miyako city and Ishinomaki city and information was gathered by face to face interviews and group discussions. About 70% of the survey respondents were at home when the earthquake began. They described their alarm at being unable to stand up and fears of injury from falling belongings or the collapse of their houses as the tremors intensified. Reports on the severity of the tsunami were initially unclear and many older people remained in their homes tidying up and waiting for family members to return. While in many cases neighbours urged older people to leave their homes, some were unable to move immediately due to their physical or mental frailty. Consequently, older people who were not at home at this time were quicker to evacuate to higher ground, including those in functioning residential care homes who were immediately assisted. More than half the respondents moved to their assigned evacuation sites. Others went to higher ground such as mountainsides, temples and multi-storey buildings, judging these areas to be safer than the evacuation sites or to be the nearest place of safety.

The role of previous tsunami experience

The two prefectures involved in this study have historical experience of tsunamis, including the Meiji Sanriku earthquake and tsunami of 1896 in which 21,959 people lost their lives, and more than 10,000 homes were damaged. In living memory, the 1933 Showa Sanriku earthquake and tsunami killed 3,064 people and damaged 9,769 houses.[2] In both cases, Iwate prefecture was more heavily affected leading to a greater prominence of tsunami stories and local knowledge within families and communities that were carried through the generations. Consequently, those living in Iwate were better prepared for tsunami evacuation.[3]

Figure 5 - The role of previous tsunami experience (Okamoto, 2013)

The survey showed that in Miyako city, more old people (33%) escaped by themselves to the evacuation points and higher grounds by themselves than in Ishinomaki city (16%). Okamoto argued that the difference is due to a slightly higher percentage of older people living alone (22% in Miyako vs 9% in Ishinomaki), but mostly due to well established evacuation drills and a long history of previous tsunamis. *Over a third of respondents in Miyako city reported that stories of previous tsunamis were most useful in guiding their actions, while 28% reported that city-wide evacuation drills were critical. In comparison, respondents in Ishinomaki city reported warnings from neighbours most frequently (25%), followed by stories from the past (16%)* (Okamoto, 2013).

Problems during the evacuation

Due to the earthquake, many powerlines had been destroyed, resulting a loss of power for televisions, the main source of news and the non-battery powered radios. Some of the respondents said, that the strength of the impending tsunami was unclear due to different reports from different news sources (Mikio, 2014). Due to the damage of the earthquake, the activated tsunami warning sirens were not working properly in some areas, affecting the clarity of the messages and warnings spoken trough the speakers. People with hearing impairments had serious problems acquiring the needed information, some of them had been unable to hear the sirens and evacuation instructions (Okamoto, 2013). The main reasons listed at the World Bank report (Mikio, 2014) for the delay in the emergency evacuation were:

1. Inaccurate initial prediction of the severity of the tsunami slowed down evacuation behaviour
2. Electrical failure affected television and radio access to information
3. Malfunction of tsunami warning systems left many with no evacuation information.

The older the people are, the more problems and barriers appear on their evacuation routes. Steps, missing handrails, uneven grounds, missing pavements, walkways blocked by debris could become a real problem for the older people with poor mobility who are fleeing alone. Figure 6 shows the main problems for the elderly people during the Tōhoku earthquake, the information is gathered by the interviews done by Okamoto.

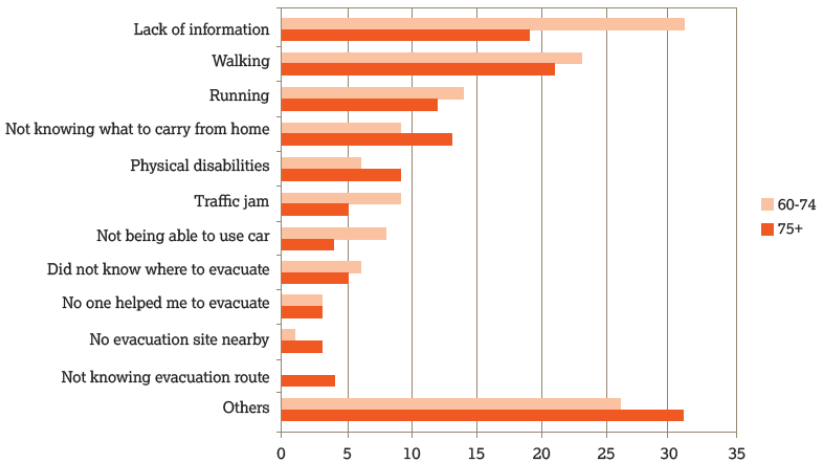


Figure 6 - Problems during evacuation (n=265, multiple answers possible) (Okamoto, 2013)

Problems at the shelter

The amount of shelters was underestimated for a disaster of the scale like the Tōhoku earthquake, 470.000 people had been displaced, the usual evacuation shelters in schools, libraries, community centres and city halls did not offer enough space in some regions, furthermore some private houses, hotels and nursing homes had to be converted. After the disaster, people found it difficult to get information about the disaster and their relatives, they could not find or contact them, many older people were forced to live without their usual support network, without caregivers and relatives, who know their daily routines, their medication and other needs.

The people reported that the slow distribution of items for basic needs like, food, drinks and clothes was one of the big problems. Not only the availability of the goods but also age-specific challenges for accessing these distributions made the life in the shelters harsh. For example, food was unfamiliar and hard to eat; water, provided in large bottles, was difficult to carry; and often clothes did not fit. Toilet and bathing facilities were not adapted or accessible for older people. Also, the people who preferred staying at home suffered by the shortage of goods, water, information and electricity.

Furthermore, it proved extremely difficult to accommodate and care for older people with physical and cognitive impairments within evacuation centres due to the limited access to proper care services. Many of the medical and care facilities had been damage or destroyed and only about 1/3 of the evacuation shelters had facilities for people who needed special service. Volunteer health teams helped address the initial service gaps in the aftermath of the disaster (Okamoto, 2013).

Older people are at a higher risk to get illnesses like a cold, the northern parts of Japan could have heavy winters, often the shelters are not well isolated and heated, which could lead to a pneumonia if not treated correctly with medicine. They are also at a high risk of cardiovascular disease, stroke, diabetes and dementia. This makes the age group especially sensitive to disruptions in heath access. Many of the old people were concerned about their health, especially those without access to transport, or with limited family support to visit a hospital or nearby doctor.

Okamoto summarised the consequences about the bad health conditions, sometimes leading to post-disaster related deaths, of the older people living in the aftermath of the earthquake:
“Post-disaster related deaths, not as a result of the tragedy itself, but of disaster-induced fatigue,

psychological trauma, or the aggravation of existing chronic diseases, caused numerous deaths. The severity of this situation is illustrated by the fact that following the initial emergency, 2,034 people suffered post-disaster related deaths and 47% of these were related to conditions developed while living in evacuation centres."

Since the destruction to houses and infrastructure in the area was serve and only a limited amount of suitable land for constructing temporary housing facilities was available, took it up to five months for evacuees to move from evacuation shelters to the new built temporary accommodations. New temporary housing facilities have been built in safe areas on higher ground where the tsunami did not reach, or in areas considered safe while tsunami protection walls were being rebuilt.

Kochi Prefecture

The risk of the expected earthquake and the aging population in Japan, especially in the rural prefectures and districts will cause a lot of challenges for the authorities. In Kochi prefecture, especially in Tosashimizu, the aging of the population, due to low fertility rates and emigration of the younger, working population class, to densely populated urban areas, is comparatively higher than in other parts of Japan.

Demography in Kochi Prefecture

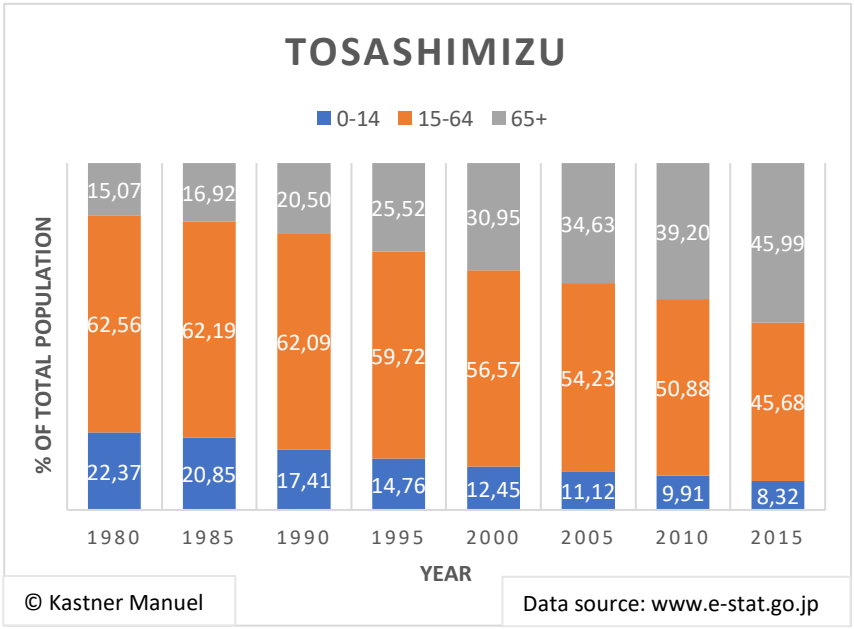


Figure 7 - Demography in Tosashimizu 1980-2015

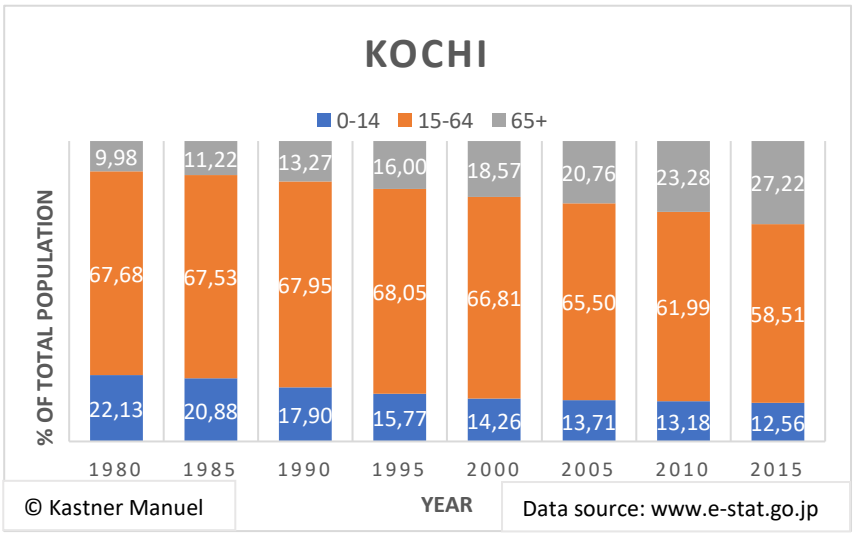


Figure 8 - Demography in Kochi city 1980-2015

While in 1980 only 9,1% of Japans total population were 65+ years old, till 2015 the number raised to 26,33%. The young population of people between 0 and 14 years decreased in given period from 23,5% to 12,5%. The share of the population between those two groups, the 15-64 years old, decreased in Japan from 67,35% to 60,30%.

The Figure shows, that the group of the older people is the only one rising in the last decades and in the future, it will further rise, since the fertility rates are still low, and the life expectancy is slightly increasing.

Compared with the demographic development of Japan, the one of Kochi city is quite the same, just a slightly higher proportion of older people living in the city.

In contrast to the urban centre of Kochi prefecture, the prefecture itself experiences a higher rate of aging. In the 35 years between 1980 and 2015, the share of the older people raised from an above-average 13,13% to 32,54%. Almost one third of the total population in Kochi prefecture is above 65 years old. The number of children between 0 and 14-year-old is only slightly below the Japanese average with 11,52% in 2015. The amount of population between 15 and 64 years old decreased to only 55,01% in 2015.

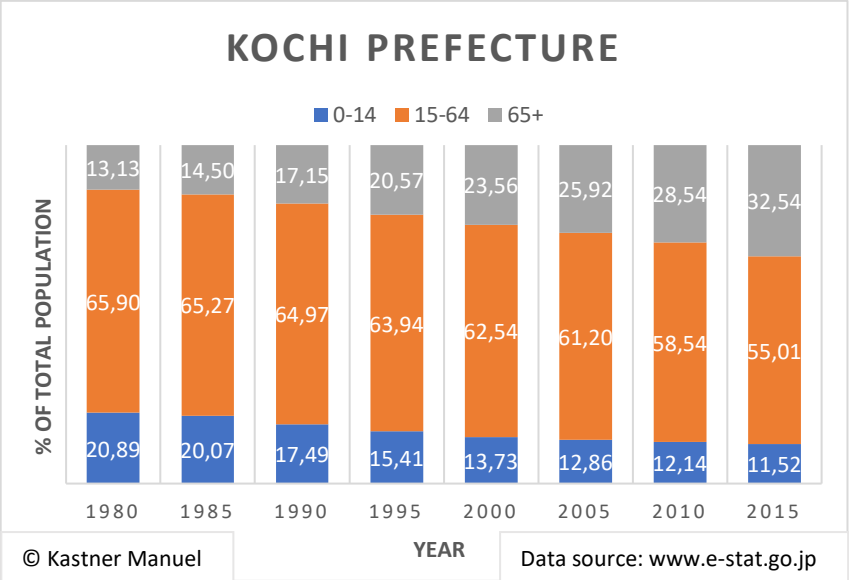


Figure 9 - Demography in Kochi Prefecture 1980-2015

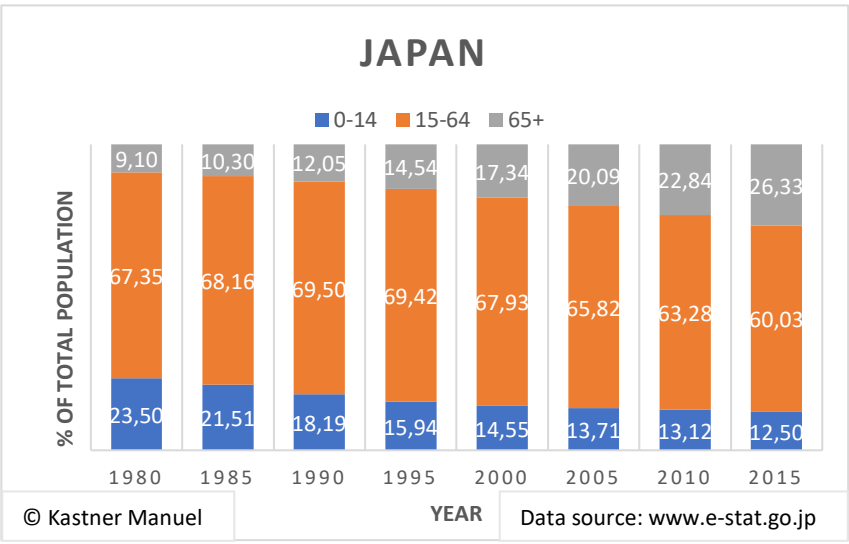


Figure 10 - Demography in Japan 1980-2015

Outstanding is the demographic change in Tosashimizu city. In 1980 already, in Tosashimizu 15,07% of the total population was above 65 years, that is about 6% more than in average Japan, while the share of the children was about the same. In the recent years, the aging in Tosashimizu developed rapidly, raising the share of elderly people to almost 46% while decreasing the one of middle age people to only 45,68% and the one of people below the age of 15 to 8,32%.

Since 2015, the biggest group in Tosashimizu are the people above 65 years old, soon reaching about half of the total population in the municipality. It is noteworthy, that the total population in Tosashimizu decreased between 1980 and 2015 by almost 50% whereas the total population of japan raised in given period by about 8%. In Kochi city the total population raised by about 6% while in Kochi prefecture the population decreased by a total of 12%. (Statistics of Japan, 2019)

These number show that the rural areas of Japan suffer emigration to urban areas and combined with the low fertility rates the aging is significant stronger in rural areas.

Tsunami preparedness in Kochi Prefecture

Tosashimizu

Tosashimizu is the southernmost city on Shikoku Island in Kochi prefecture (Figure 11) and has a lot of coastlines facing to the south and east which are especially prone for a future tsunami following a Nankai earthquake. This earthquake is expected to happen within the next 100 years, having a high chance happening in the till 2050. The landscape in the area is shaped by a lot of hills and mountain while the coastal line is a mixture between cliffs and sand beaches. Some of the cities in the district are built in tsunami safe areas, but others, like Tosashimizu city have a high risk of getting struck by one.

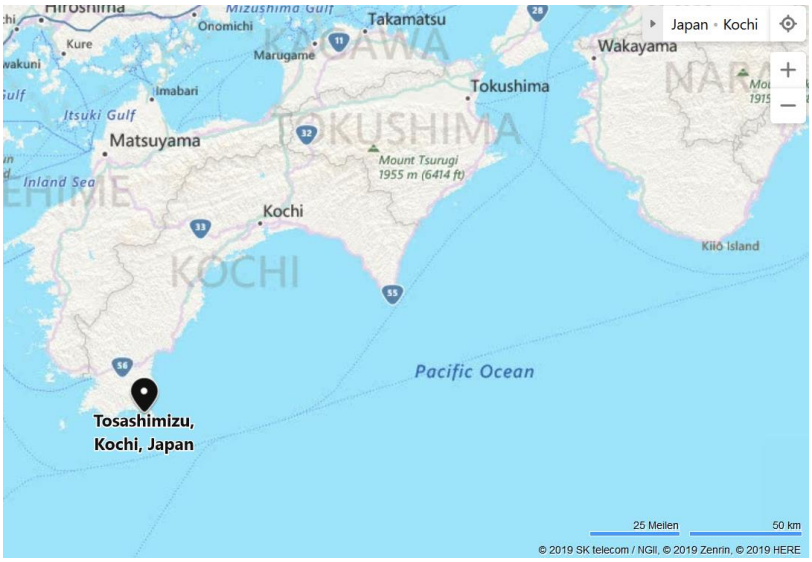


Figure 11 - Location of Tosashimizu

Picture 1 - Stairs, a part of the evacuation route (32°45'34.4"N 132°57'54.7"E)

Picture 2 - Handrails and stoneplates to ensure the evacuation route (32°45'33.8"N 132°57'55.3"E)

The local authorities and the population are aware of this problem and prepared with the help of experts many disaster risk plans for evacuation routes, shelters and tsunami hazard maps (Figure 13, Figure 14, Figure 15). In the area are many projects completed or still ongoing to decrease the vulnerability of the local population and to decrease the possible damage. On the one side, you can build protection, on the other side you can teach the locals how to protect themselves during a disaster.

Building tsunami protection could get expensive if you built a big tsunami wall or many evacuation towers but you can also use natural resources and the landscape as a protection, for example if you build evacuation routs on hillsides or plant a forest for tsunami protection. A local inspection in Tosashimizu showed that they are using both methods combined to reduce the potential tsunami damage. The geological situation in Tosashimizu city allows them to build many evacuation routes along the hillside to safer and high enough places. On the steep cliff like hillsides the locals build paved stairs while on the flatter hillsides the evacuation routes are sometimes not paved, only some stone plates lay on the ground to stabilize the ground. In some cases, the walkways are just natural trails in the grass or dirt. This could lead to big problems during an evacuation if the weather conditions are bad, if the ground is wet it could lead to slippery conditions causing people to fall. In this area, since there is a high proportion of elderly people, this could lead to people not reaching the evacuation points in time, especially during night time, when people need some time to realize what happens because they are still sleepy. On the positive side, many of the walkways had handrails to support the old and feeble citizens. (Picture 2 - Handrails and stoneplates to ensure the evacuation route

Picture 3 - A portable solar powerd light (32°45'31.8"N 132°57'56.2"E)

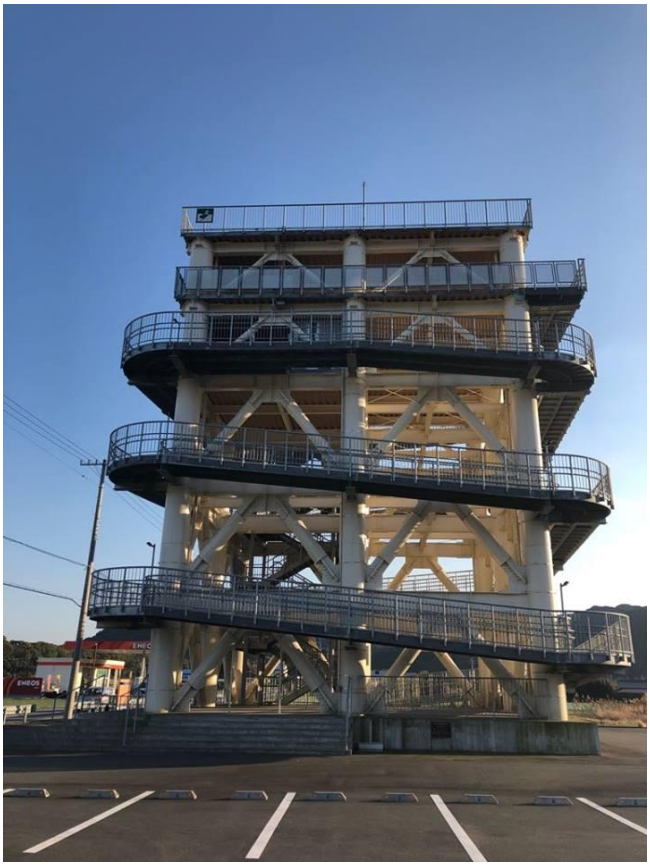
Picture 4 - Base of a portable light (32°45'31.8"N 132°57'56.2"E)

For the case that the earthquake happens during night-time, alongside the route are many portable, solar-powered lights. These lights can be taken out of their base and be carried by people who are fit enough. (Picture 3)

In another area of Tosashimizu, Oki, there is a big beach and some flat landsides with many buildings. Figure 15 shows the tsunami hazard map for the area. Some of the buildings are not near enough the hillsides so the locals had to build different tsunami protections. In the middle of the area, a big tsunami evacuation tower surpasses in height all the other buildings (Picture 5). This new tower was built as an evacuation spot for the locals, on top are many storage containers. These containers need to be filled with goods like medication, clothes, blankets, water and foods in the near future. To get on top, you can either use stairs or a ramp. For disabled people, both can cause problems, leading them to need help getting on top. Installing an elevator is because of expecting power cut offs following the earthquake not advisable. It would also increase the building and maintaining cost a lot.

Between the tower and the sea, a natural tsunami barrier is maintained. Local trees and bushes act as a kind of windbreaker, catch the sand blown from the seaside and create a natural barrier. This barrier will not be able to stop a massive tsunami, but it will take out some power of the wave. On the upside, this natural wall is very effective against storm floods and high waves during cyclones. Figure 12 shows a satellite photo of the natural barrier and the area. The Tsunami Evacuation tower is marked with a red dot on the picture.

In another area in Kochi prefecture, in Shimanto, a tsunami tower had been built as a multifunctional building with a library underneath it. This is an effective way to lower the costs of the tower itself and makes it more attractive for investors.



Picture 5 – Oki Tsunami evacuation tower (32°49'05.9"N 132°56'46.2"E)

One of the main problems that may occur during an earthquake in the area are many abandoned houses and other buildings. A local said, that these buildings are often unused after their owners die or left the city. Their children or other relatives, which moved to urban arears years ago, are often not willing to maintain these houses since the costs for repair and improvements are too high. Some of these buildings are in disastrous conditions which can make an earthquake disaster worse. Firstly, these buildings can collapse easily, which can lead in the densely build up city-centres to the collapse of other buildings, like a domino effect. These ruins can block the small paths between the houses, causing some of the evacuation routes getting unable to pass, especially for people with limited movements. Also, fire which could break out during an earthquake, could spread faster in those abandoned buildings.

Figure 12 - Location of the tsunami wall and tsunami tower

All these evacuation routes and sites are unnecessary when the people don't know that they exist or where they are located. To keep the people updated the local authorities publish evacuation folders which describe the latest doctrine on how to behave during earthquakes and what to do if the tsunami alarm goes off. There are also regularly tsunami drills to teach the people how to evacuate and which evacuation route is the best for them.

The local evacuation manager said, that the city has their own concept for the evacuation. Some people will get into their car and try to get the older, immobile people, how are too slow to evacuate by themselves, and drives them to safe points and higher areas. He mentioned, that the authorities are currently collecting information about the medicine the locals need and build up a supply of these and

store them at or near the evacuation sides. But it is important to keep the list updated and refresh the supplies since the population is changing and the medicine has expiration dates too.

Tsunami Hazard Maps

These are three of the tsunami hazard maps for Tosashimizu City, received from the official website of the town. It shows that the tsunami in inhabited areas will reach an approximately high of 10-15 metres, while in some exposed areas it can reach more than 20 meters. These maps have been chosen for the report since the pictures above have been taken in these areas. Figure 13 is an overview of the whole district of Tosashimizu and shows all the different tsunami hazard maps for exposed coastlines.

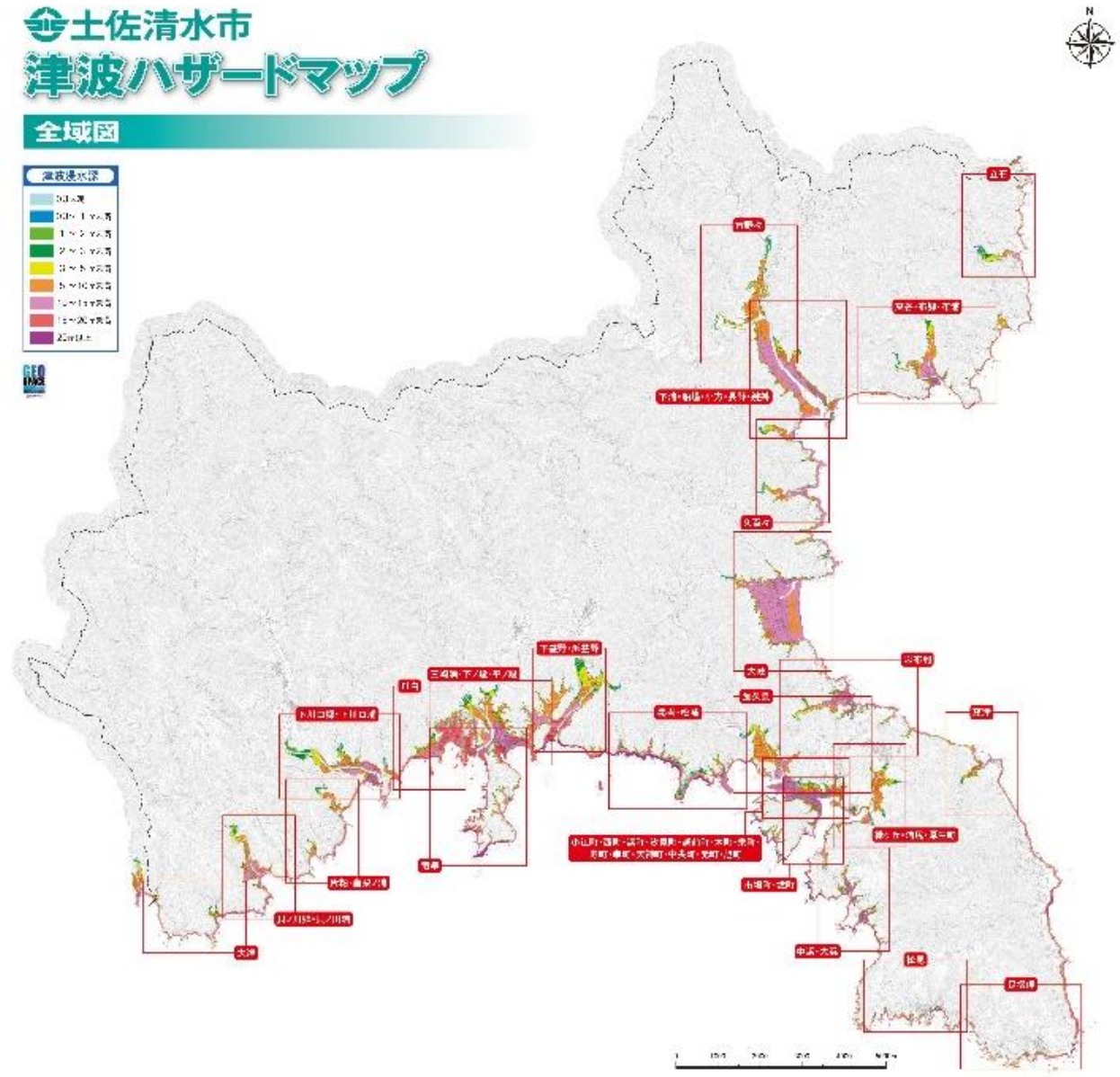


Figure 13 Tsunami hazard map of Tosashimizu district

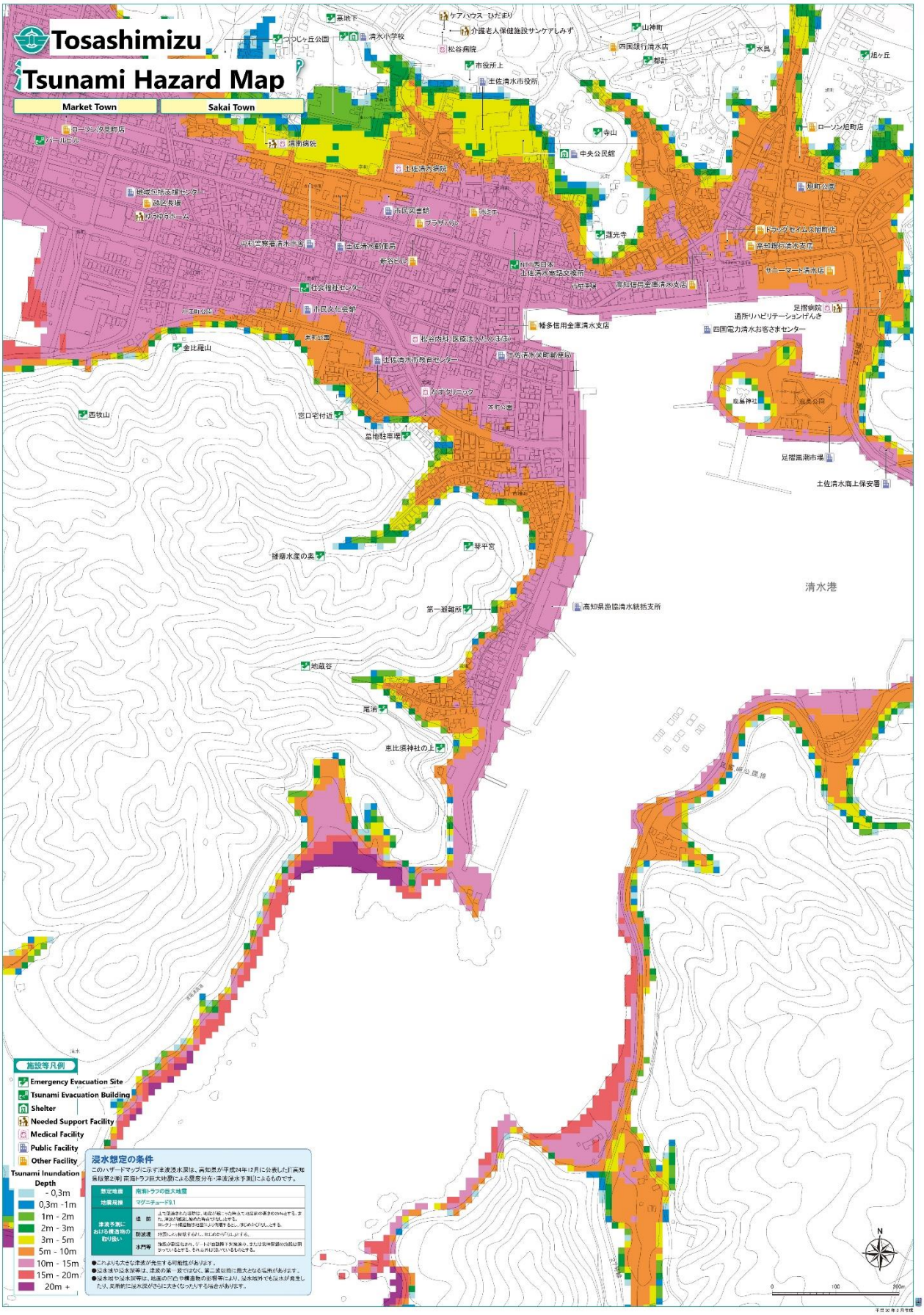


Figure 14 – Tsunami hazard map of Tosashimizu city

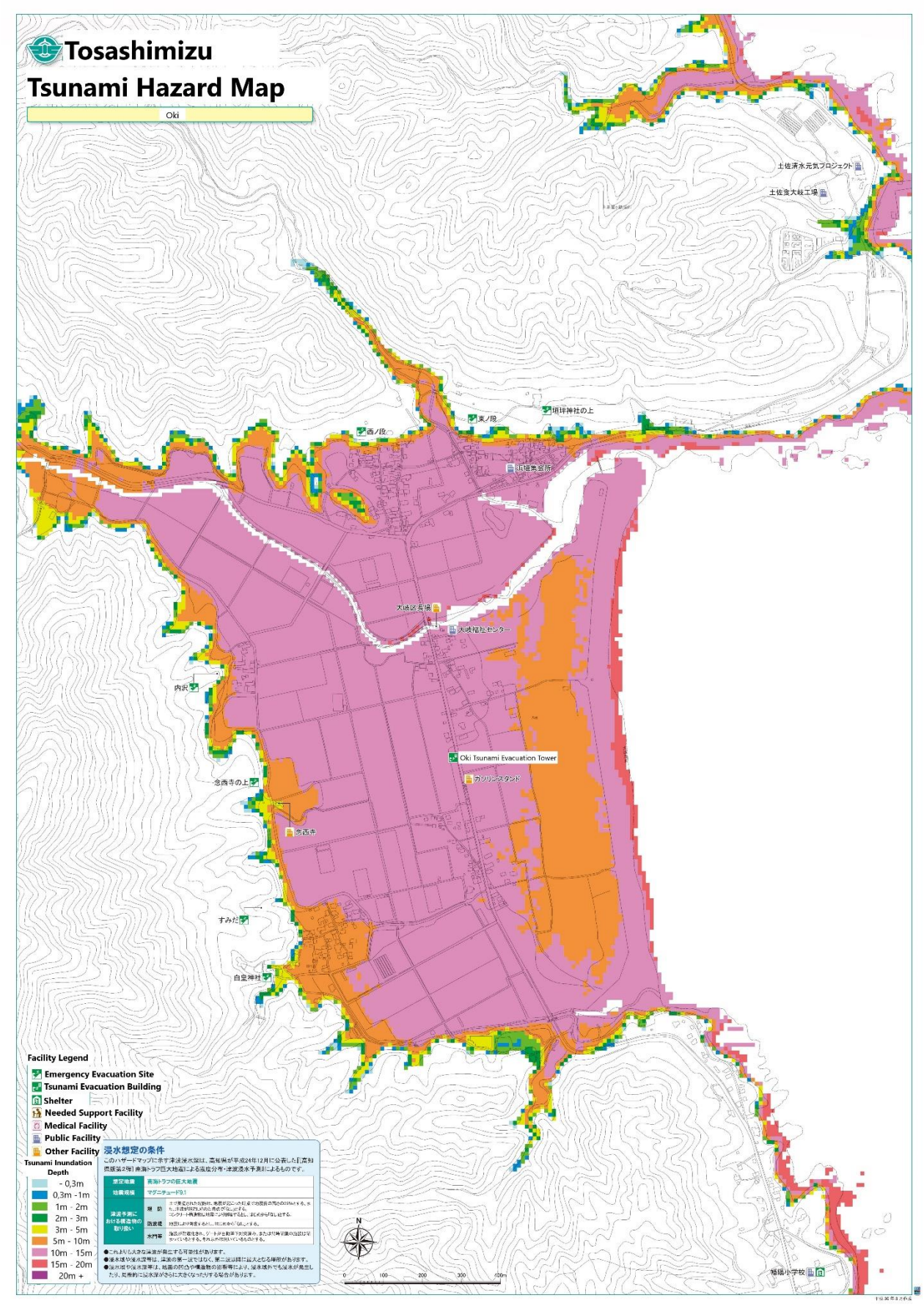


Figure 15 – Tsunami hazard map of Tosashimizu district / Oki beach

Two of these maps have been chosen for the report because their importance, Figure 14 shows the area of Oki Beach, the place of the Oki tsunami evacuation tower and the tsunami forest and Figure 15 shows the centre of Tosashimizu Town (Market Town and Sakai Town), the most inhabited area in Tosashimizu District.

The tsunami hazard maps have been released by Kochi Prefecture in December 2012 and show the distribution of tsunami inundation following a Nankai Trough earthquake. They estimated an earthquake of a magnitude of 9.1 while making the map. The author mentioned that maybe a bigger tsunami can occur and that the inundation level can increase locally. It is also expected that not the first wave, but the second wave will cause the highest inundation level in some areas.

Most of the area is expected to be flooded between 10 and 15 meters high (represented by the pink colour on the tsunami hazard map) while further landward the flood level drops continuous. Many areas are expected to be hit by a 5 -10-meter-high flood (orange colour on the map), for example the natural tsunami barrier, consisting of trees and sand dunes, in Oki Beach (Figure 15). On the coastline and in small bays the tsunami height is prognosticated to be 15 – 20 meters (red colour) or even above 20 meters (violet colour).

In Oki beach, the distance to the nearest evacuation site can exceed in some places 400m, for example, if you stay at the beach and need to run to the evacuation tower, it can take quite a while which could be a problem for elderly people could. On the other side, most of the houses are near the Oki tsunami evacuation tower, the only evacuation building in this area, or near evacuation site on the hillsides surrounding the bay. All these evacuation points are connected to the street system.

In Tosashimizu City, the density of evacuation buildings and evacuation sites is way higher, but this is due the fact, that the area is densely populated. The inhabits have in almost every area of the city an evacuation building or evacuation site within 200m. In the city centre is a various amount of evacuation buildings while in the outskirts many evacuation routs lead to higher places on the hillsides.

Conclusion

It is sure that in the near future a massive earthquake in the Nankai Trough will cause a big Tsunami. The size of the Tsunami will depend on the magnitude of the earthquake and other factors. Scientists are trying the best to calculate the maximum and expected size and impact of the tsunami, but history shows (2011 Tōhoku Earthquake) that they could possibly also underestimate the power of the wave. The most recent tsunami hazard maps for Kochi Prefecture are drawn based on a calculation of a magnitude 9.1 earthquake occurring in the Nankai Trough. An earthquake of this power is very unlikely to happen, the recent earthquakes in the last 700 years never exceeded the magnitude of 8.4 (Figure 2).

A big share of the casualties in recent earthquake and tsunami events had been old people, and the population in Japan, but especially in the rural areas, which will be hit by the Nankai tsunami, is aging. The higher proportion of older people will lead to new problems during the evacuation and in the aftermath, some of these problems can be solved due to the learning effect of previous disasters and due to technological development. It is important for the government and authorities to plan for the older people whenever they built evacuation routes and shelters. Sometimes, as a younger person who plans all these, you cannot imagine what small things might cause problems for elderly people. It is needed to adapt the plans to make sure they will work out with the high amount of elderly people too. In many areas there are yearly, sometimes even more often, evacuation drills. On the one side, they are important for the People to get to know the evacuation routine, but on the other side, people

may get used to it and do not take it serious during a real disaster. But the people know the routine and know where to go, and this is the important thing. The local government is putting a lot effort in building and maintaining the evacuation sites in Kochi Prefecture, collecting data about medical needs of the local population and trying to fill the evacuation shelters with supplies. But the filling of the evacuation sites with goods seems to be slowly. Sometimes it looks like they are not expecting the earthquake in the near future. History shows that it is very unlikely that it could happen like in the next year, but that is what a disaster makes so horrible, they often happen when you don't expect them. On the other side, it might be a problem if the earthquake doesn't happen during predicted time and the next generations don't take the risk as serious like nowadays, just a few years after the last heavy earthquake. Only the future will show what happens, it is very important that the locals always know where to go during a disaster and that the disaster evacuation sites are ready for the people in need.

Acknowledgment

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Some extra pictures

Picture 6 - A supplybox on top of a tsunami evacuation tower (33°01'20.4"N 133°00'46.9"E)

Picture 7 - A evacuation point in Tosashimizu (32°45'31.8"N 132°57'56.2"E)

Picture 8 - An abandoned house in Nakanohama, Tosashimizu (32°45'32.1"N 132°57'50.6"E)

Picture 9 - Tsunami evacuation tower and library in Shimanto (33°01'20.4"N 133°00'46.9"E)

Figures

All pictures taken by the author + coordinates of the picture.

References

(n.d.). Retrieved from https://commons.wikimedia.org/wiki/File:RuptureAreasNankaiMegathrust.png

Ayako Nakanishi, N. T.-O. (2002). Crustal structure across the coseismic rupture zoneof the 1944 Tonankai earthquake, the centralNankai Trough seismogenic zone. *JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 107,*.

Catalog of Damaging Earthquakes in the World. (2019, March 25). Retrieved from http://iisee.kenken.go.jp/cgi-bin/utsu/result_eng.cgi

Chang, K. (2011, March 13). *NYT*. Retrieved from https://www.nytimes.com/2011/03/14/world/asia/14seismic.html

K. MINOURA, F. I. (2001). The 869 Jōgan tsunami deposit and recurrence interval of large-scaletsunami on the Pacific coast of northeast Japan. *Journal of Natural Disaster Science, Volume 23, Number 2*, pp. 83-88.

Keiko Ogawa, I. T. (2000). Increased acute myocardial infarction mortality following the 1995 Great Hanshin-Awaji earthquake in Japan. *International Journal of Epidemology 2000, 29*, pp. 449 - 455.

Mikio, I. (n.d.). *Tsunami and Earthquake Warning Systems.* Japan: World Bank .

NOAA National Centers for Environmental Information. (2019, March 28). Retrieved from https://www.ngdc.noaa.gov/hazard/tsu.shtml

Official Kochi Website. (2019, March 13). Retrieved from http://www.city.kochi.kochi.jp/site/bousai/jisintsunami-hazardmap.html

Official Kuroshio Website. (2019, March 13). Retrieved from http://www.town.kuroshio.lg.jp

Official Tosashimizu Website. (2019, March 13). Retrieved from https://www.city.tosashimizu.kochi.jp/kurashi/section/kikikanri/007.html

Okamoto, N. (2013). *Displacement and older people - The case of the Great East Japan Earthquake.* Thailand: HelpAge International.

Rikitake, T. (1999). Probability of a great earthquake to recur in the Tokai district, Japan:reevaluation based on newly-developed paleoseismology, plate tectonics,tsunami study, micro-seismicity and geodetic measurements. *Earth Planets Space, 51*, pp. 147-157.

Statistics of Japan. (2019, March 20). Retrieved from https://www.e-stat.go.jp/en

Tanida, N. (1996, November 2). What happened to elderly people in the great Hanshin earthquake. *BMJ Volume 313*, pp. 1133-1135.

Toshitaka Baba, K. A. (2015). Large-scale, high-speed tsunamiprediction for the Great NankaiTrough Earthquake on the K computer. *The International Journal of HighPerformance Computing Applications*, pp. 1-14.

USGS. (2019, March 22). Retrieved from https://earthquake.usgs.gov/learn/glossary/?termID=150

Watanabe, T. (2013). *Older Persons in Emergency Situations: A case study of the Great Hanshin-Awaji Earthquake.* Japan: WHO Centre for Health Development.

Figure 2 - Recent earthquakes at the Nankai Trough: https://commons.wikimedia.org/wiki/File:RuptureAreasNankaiMegathrust.png