Ⅲ．研究成果の刊行に関する一覧表

研究成果の刊行に関する一覧表

雑誌

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
M. Miyajima	Resilient Water Supply System for Earthquake and Tsunami	Journal of Water Supply: Research and Technology – AQUA	63(2)	86-94	2014
井本祐司、鎌田素之、山口太秀、相澤貴子	高濁度原水における二段凝集処理最適化の検討	第50回環境工学研究フォーラム講演集		137	2013
相澤貴子、安藤茂、冨井正雄、伊藤雅喜、堤行彦、鎌田素之	高濁度原水に対する実用的な中小水道事業体向け支援対応方策	第16回日本水環境学会シンポジウム講演集		177-178	2013
安積良晃、中山宏二、中川勝裕、冨井正雄、安藤茂、藤原正弘、相澤貴子	中小水道事業体支援を目的とした原水水質悪化に対する方策の検討（Ｉ）―浄水場の運転管理に関するアンケート調査結果等に基づく考察―	第64回全国水道研究発表会講演集		208-209	2013
堤行彦、伊藤雅喜、鎌田素之、佐藤仁是、安積良晃、冨井正雄、相澤貴子	中小水道事業体支援を目的とした原水水質悪化に対する方策の検討（Ⅱ）―高濁時凝集剤注入管理指標とアルカリ度代替指標に関する実施設データの解析と評価―	第64回全国水道研究発表会講演集		210-211	2013
向後隆蔵、早川英司、三好礼子、伊藤雅喜	中小水道事業体支援を目的とした原水水質悪化に対する方策の検討（Ⅲ）―小型浄水処理装置による高濁度時の濁度漏出条件の検討―	第64回全国水道研究発表会講演集		212-213	2013
早川英司、向後隆蔵、三好礼子、伊藤雅喜	中小水道事業体支援を目的とした原水水質悪化に対する方策の検討（Ⅳ）―小型浄水処理装置による高濁度時の濁度漏出抑制方策の検討―	第64回全国水道研究発表会講演集		214-215	2013
鎌田素之、井本祐司、山口太秀、海老江邦雄、相澤貴子	中小水道事業体支援を目的とした原水水質悪化に対する方策の検討（Ｖ）―集塊化開始時間測定法による新たな凝集処理制御に関する検討―	第64回全国水道研究発表会講演集		216-217	2013
桐村昭充、渡部和弘、長田克也、鈴木泰博、武内辰夫、宮島昌克、相澤貴子	近年の地震被害実態に基づく新簡易耐震診断手法の提案	第64回全国水道研究発表会講演集		660-661	2013
M. Miyajima	Performance of Drinking Water Pipelines in Liquefaction Areas in the 2011 Great East Japan Earthquake	International Journal of Landslide and Environment	1(1)	61-62	2013

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
Y. Tsutsumi, M.Itoh, M. Kamata, M. Fujiwara, S. Ando, M. Tomii, Y. Asaka, K. Nakayama and T. Aizawa	Evaluation of Water Quality Indicators Related to Water Treatment Processes and Practical Treatment Method against High Turbidity Raw Water	Proceedings of the 5th IWA Aspire conference & exhibition		8	2013
N. Mizuno, M. Suzuki, T. Onuma, K.Taira, T. Aizawa	Water Quality Surveys of Shallow Wells Damaged by Tsunami in the Great East Japan Earthquake -Case of Minamisanriku -cho in Miyagi Prefecture-	Proceedings of the 8th US-Taiwan-Japan Workshop on Water System Seismic Practices		373-383	2013
M. Miyajima	Verification of a Prediction Method of Earthquake Damage to Water Supply Pipeline by Using Damage Data of the 2011 Great East Japan Earthquake	Proceedings of the 8th US-Taiwan-Japan Workshop on Water System Seismic Practices		43-49	2013
Y. Imoto, M. Kamata, D. Yamaguchi and T. Aizawa	Application of Two-stage Coagulation for High Turbidity Raw water	Proceedings of JWET2013		16	2013
A. Kirimura, Y .Suzuki, T. Aizawa, M. Fujiwara and M. Miyajima	Simplified Evaluation Method of Seismic Resistance for Water Treatment Facilities	Proceedings of 6th China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering			2013
M. Miyajima	Damage to Water Supply Pipelines in the 2011 Great East Japan Earthquake	Proceedings of 6th China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering			2013

Ⅳ．研究成果の刊行物・別刷

（主要な発表論文別刷）

Resilient Water Supply System for Earthquake and Tsunami

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Abstract

This paper focuses on resilient water supply system for earthquake and tsunami. The 2011 off the Pacific coast of Tohoku Earthquake generated not only strong ground vibration but also tremendous tsunami. Although some of water supply system suffered damage and water suspension occurred extensively, earthquake resistant pipe survived and quick recovery of water delivery was done. We must learn many lessons from the earthquake and tsunami disasters and exchange the lessons internationally. In this paper, earthquake performance of water supply pipeline during the earthquake and tsunami is summarized first. Next, the paper introduces an application of Japan's earthquake resistant technology in the City of Los Angeles.

Key words | earthquake, earthquake resistant pipe, seismic guideline, tsunami, water supply system

INTRODUCTION

In Japan, earthquake resistant technology and seismic design guidelines for drinking water facilities have been advanced and revised based on observed damage in the past major earthquakes. Because earthquake resistant pipes did not suffer damage in recent huge earthquakes such as the 1995 Hyougo-ken Nambu Earthquake (Kobe Earthquake) and the 2011 off the Pacific coast of Tohoku Earthquake (Tohoku Earthquake), earthquake resistance of water supply pipelines against earthquake was verified. On the other hand, the 2011 Tohoku Earthquake generated a tremendous tsunami and the tsunami hit extensive areas. We must learn new lessons from the tsunami disaster. The present paper summarizes lessons from the recent earthquakes and tsunami. It also discusses a test installation of Japan's earthquake resistant pipe in the U.S. to establish resilient water supply system for earthquake and tsunami.

DAMAGE TO WATER SUPPLY FACILITIES BY TSUNAMI

Damage Characteristics by Tsunami

The 2011 Tohoku Earthquake generated a tsunami of unprecedented height and special extent along the northeast coast of Japan. In the majority of flooded areas, residents have not been able to return home after the event because most buildings and houses have been washed away. As a result, there has been no need to distribute water in these areas, and most of the damaged pipelines have been left unrepaired. Thus we have not been able to collect the entire data of damage to water supply pipelines. So far, the following damages have been revealed.

Causes of damage by the tsunami are roughly classified into three categories: inundation, washing away and scouring of surface ground. Some intake facilities were inundated and had not functioned for a long time because of high concentration of sodium chloride in groundwater (Photo 1). Photo 2 shows damage to a water pipe bridge, which was completely washed away. It is unknown yet which caused this kind of damage, water pressure, floating wreckages or both. We should study the force acted on the water pipe bridge during the tsunami through damage analysis. Photo 3 shows damage to buried pipeline. The pipe was exposed as the covered soil had been scoured by the tsunami. The mechanism of damage to the pipe, that is, how much force was acted on the pipe in what way, is still unknown, waiting to be clarified in future.

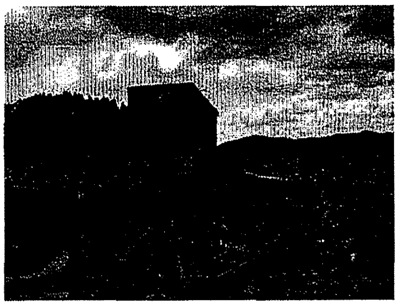

Photo 1 | Inundated intake facilities (Sukedukuri No.2).

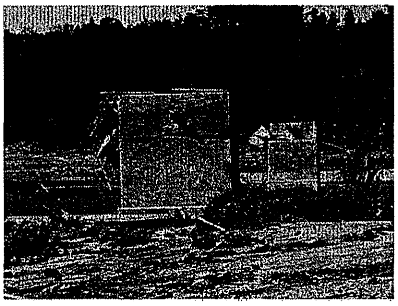

Photo 2 | Washed-away water pipe bridge.

Photo 3 | Damage to pipe by tsunami-induced scouring

Field survey of surviving earthquake resistant pipes from tsunami

The earthquake resistant joint ductile iron pipes (ERDIP) did not suffer damage at all in the 2011 Tohoku Earthquake. A field survey was conducted on surviving ERDIP buried in the tsunami-hit area at Ishinomaki City in Tohoku region. Photo 4 shows an ERDIP exposed above ground surface by scouring caused by the tsunami. The exposed pipelines were covered by debris of crushed wooden houses and a steel container as shown in Photo 5. This pipeline is ERDIP with 300 mm of nominal diameter, installed in 2010. Deformation of pipeline, displacement and bending angle at each joint were measured for fourteen pipes as shown in Figure 1.

Figure 2 illustrates a horizontal distance to a pipeline from the edge of a road before and after the earthquake. Because the road was not dislocated horizontally or deformed by the earthquake and tsunami, this figure indicates that the pipeline moved about 40 cm. Figure 3 shows the bending angles at joints measured at the field. The maximum bending angle is 7.5 degrees at the joint No. 11. It seems that the pipeline was exposed above ground by the scouring, hit by a steel container and debris in undertow of the tsunami, and moved to the coastline. There was, however, no damage to ERDIP and water suspension did not occur.

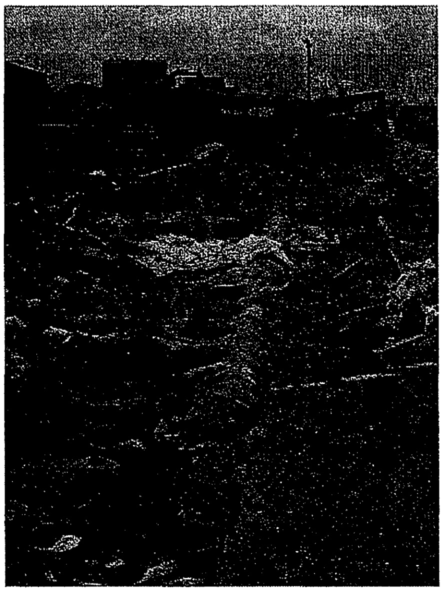

Photo 4 | ERDIP exposed above ground.

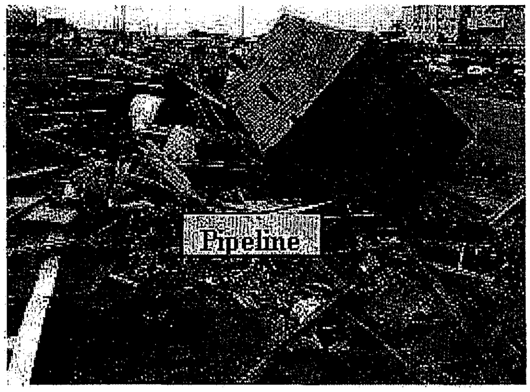

Photo 5 | ERDIP covered by debris.

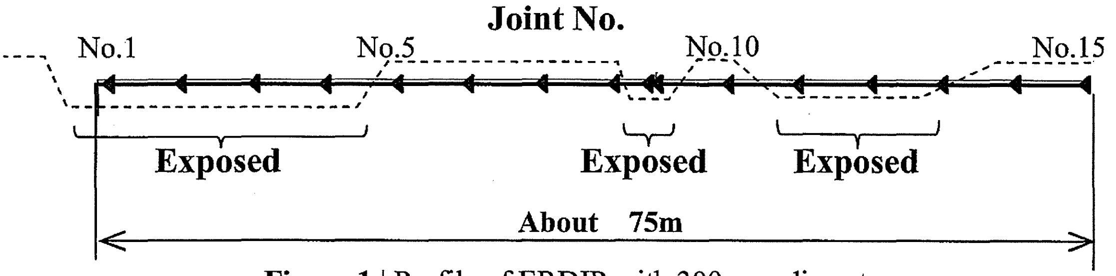

Figure 1 | Profile of ERDIP with 300 mm diameter.
(Dashed line indicates the level of the ground surface after the earthquake.)

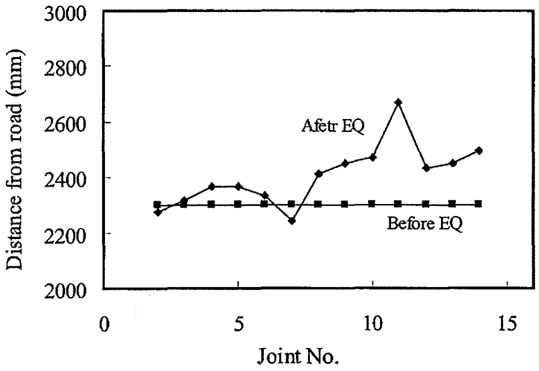

Figure 2 | Distance to the pipeline from a road edge before and after the earthquake.

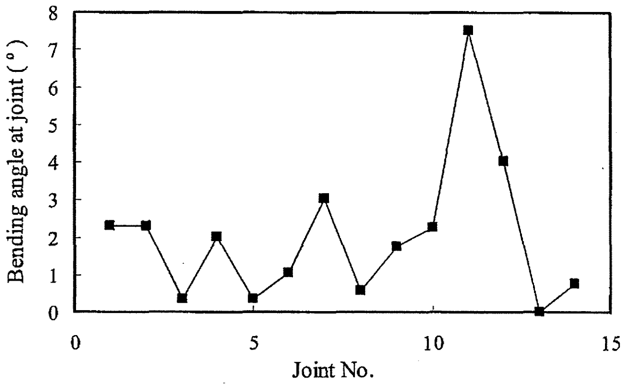

Figure 3 | Bending angle at joint measured at the field.

DAMAGE TO WATER SUPPLY PIPELINE IN STRONG GROUND MOTION AREA

The maximum JMA (Japan Meteorological Agency) seismic intensity of this earthquake was 7, which was recorded in Kurihara City, Miyagi prefecture. 7 is also the maximum grade of JMA scale. The JMA seismic intensity in the surrounding Osaki City, Tome City and Wakuya Town was 6+. The damage to buried pipeline in those municipalities, including Kurihara City, is discussed here. Figure 4 illustrates distribution of JMA seismic intensity estimated by QuakeMap (National Institute of Advanced Industrial Science and Technology) and sites of damaged water supply pipeline in the four municipalities. JMA seismic intensity estimated by QuakeMap is given in each 250 m cell. Table 1 lists the number of cells by each level of JMA seismic intensity. According to QuakeMap, 7.6%, 33.6%, and 23.8% of the total area marks the JMA seismic intensity of 7, 6+, and 6-, respectively.

The main types of buried water pipes in Japan are ductile cast iron pipes (DIP), grey cast iron pipes (CIP), steel pipes (SP), polyethylene pipes (PE), polyvinyl chloride pipes (PVC), and asbestos cement pipes (ACP). Figure 5 illustrates an accumulated damage rate of each pipe type. This figure indicates that the damage to pipeline starts to occur at 5+ of JMA seismic intensity and the damage rapidly increases at 6+.

Micro topography classification map of surface ground by J-SHIS (National Research Institute for Earth Science and Disaster Prevention) is used here. This data is also organized in 250 m cell. Micro topography classification can be divided into two categories, which are Bad (soft ground in which pipe is susceptible to earthquake damage) and Good (ground type other than Bad), as shown in Table 2. Figure 6 illustrates a distribution of ground categories, JMA seismic intensity and the sites of damage. Many damages occurred at the boundary between Bad of more than 5+ and Others.

Figure 7 illustrates a comparison of damage rate by pipe type in the two micro topography classification categories. This figure suggests that the damage rates in Bad are much greater than those in Good.

Table 3 lists a piping length in each level of JMA seismic intensity, categories of micro topography classification and pipe type. There was no damage to ERDIP and fusion-bonded polyethylene pipe in this earthquake. According to Table 3, about 45 km of ERDIP and about 15 km of fusion-bonded PE survived in the strong ground motion area where JMA seismic intensity was more than 6- and the micro topography classification category was Bad.

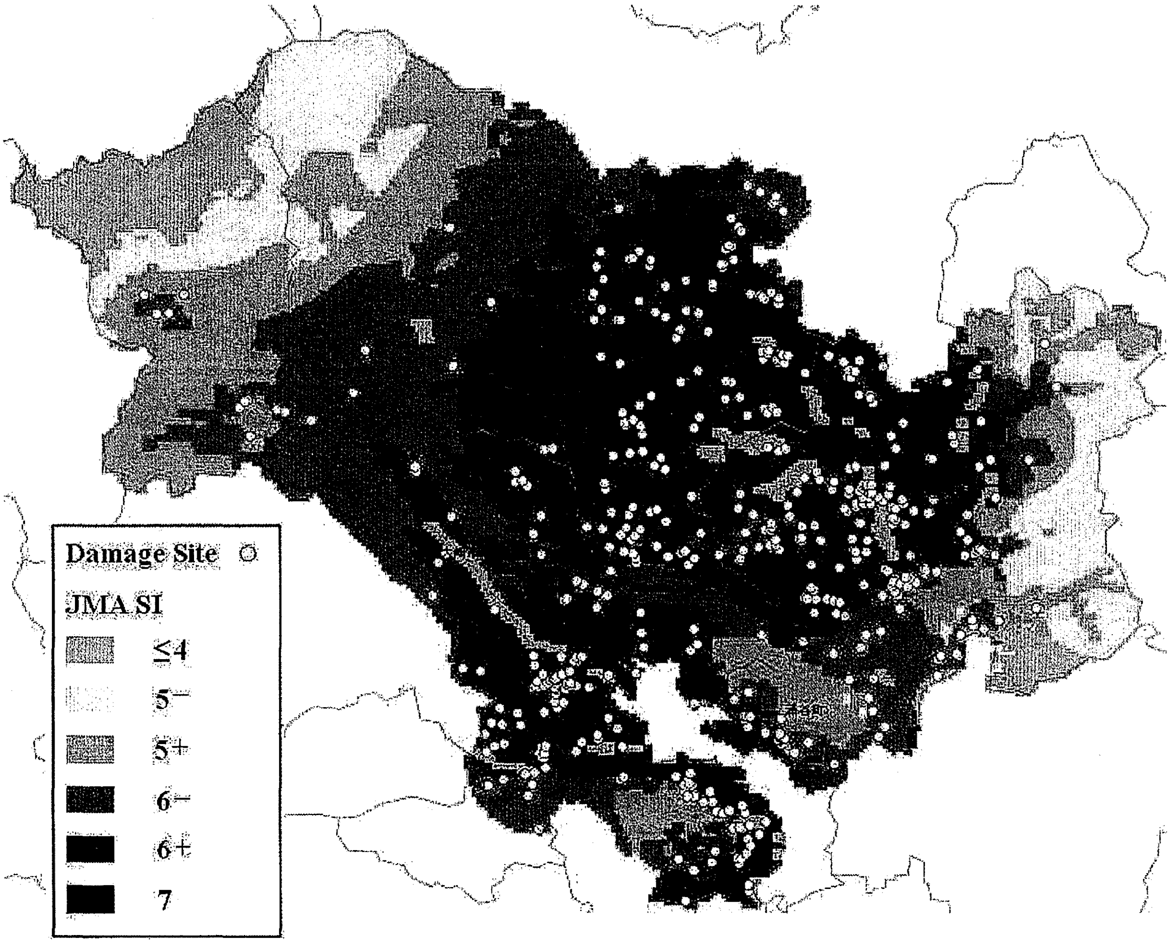

Figure 4 | Distribution of JMA seismic intensity and sites of damage.

Table 1 | Number of cells in each level of JMA seismic intensity

JMA SI	Kurihara City	Osaki City	Tome City	Wakuya Town	Sum	Percentage
Others	156	297	543	35	1,031	2.8%
≤4	80	1,403	294		1,777	4.8%
5-	1,448	855	1,902	12	4,217	11.4%
5+	1,647	2,486	1,292	465	5,890	16.0%
6-	3,452	3,456	1,209	672	8,789	23.8%
6+	4,315	4,814	3,026	243	12,398	33.6%
7	2,137	29	622		2,788	7.6%
Sum	13,235	13,340	8,888	1,427	36,890	100.0%

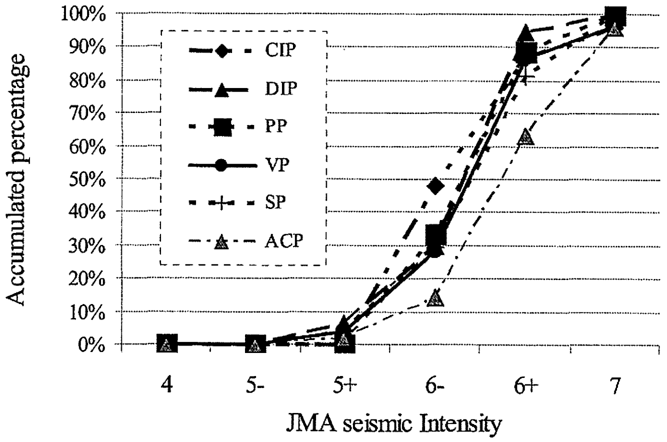

Figure 5 | Accumulated damage rate of each pipe type.

Table 2 | Micro topography classification and its categories

No	Microtopography	Category
1	Mountains	Good
2	Piedmont areas	
3	Hill	
4	Volcanic areas	
5	Volcanic piedmont areas	
6	Volcanic hills	
7	Mesa	
8	Quality gravel plateau	
9	Loam plateau	
10	Lowland valley	Bad
11	Alluvial fan	
12	Natural levee	
13	Backswamp	
14	Old River Road	
15	Delta & Coastal lowland	
16	Reef & In gravel	
17	Dune	
18	Reef & Between the lowland	
19	Reclaimed land	
20	Filled land	
21	Rocky & reef	
22	Riverside	
23	River channel	
24	Lake	

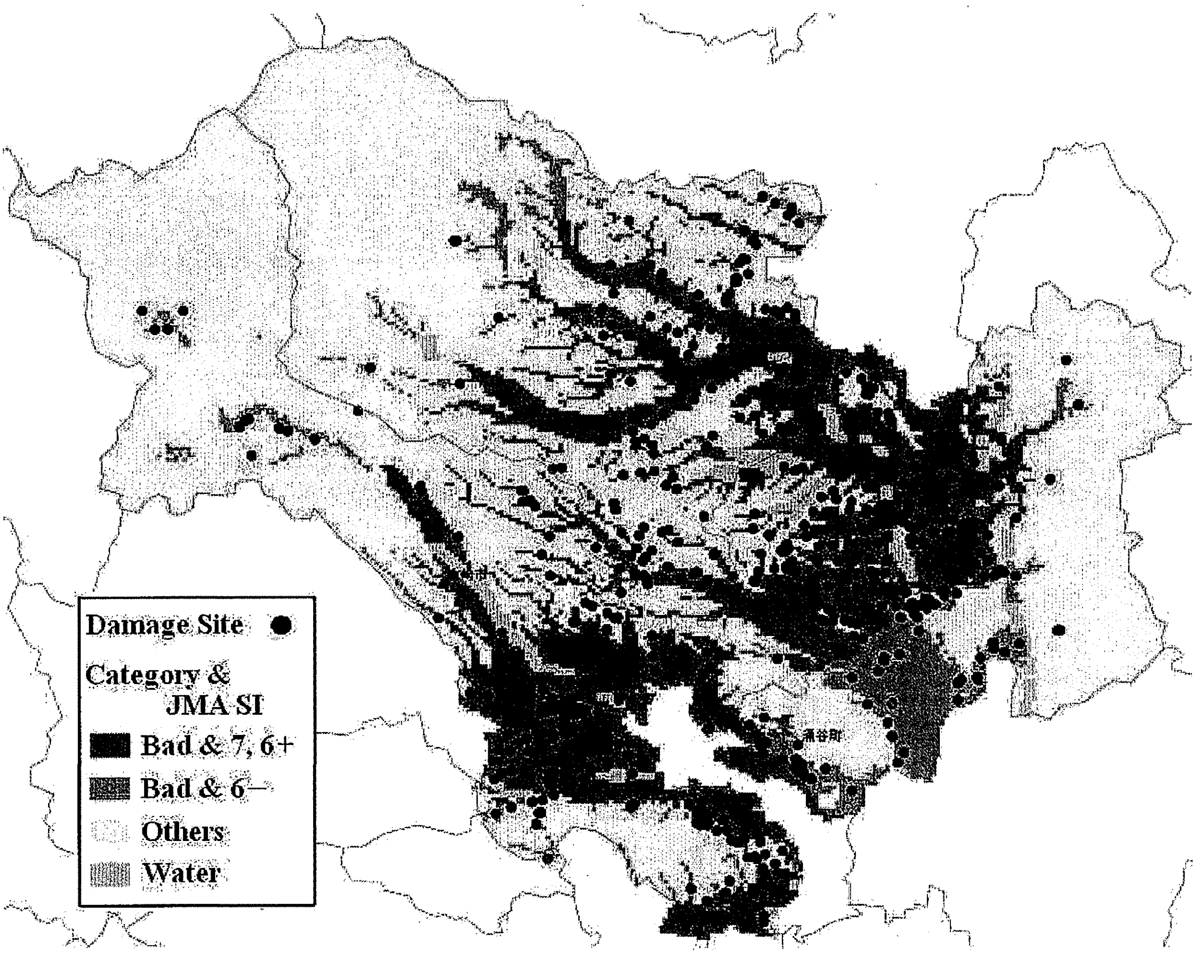

Figure 6 | Distribution of ground categories, JMA seismic intensity and the sites of damage.

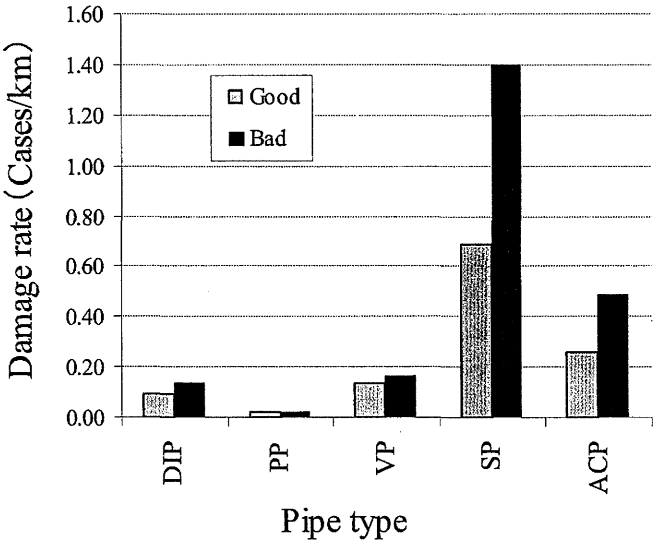

Figure 7 | Comparison of damage rate of each pipe type in micro topography classification category.

Table 3 | Piping length in each level of JMA seismic intensity, categories of micro topography classification and pipe type

Unit: m

Category	JMA SI	CIP	DIP (ERJ)	DIP	PE (Fusion)	PP	VP	SP	SUS	ACP	Others	Sum
Good	<4		1,499	1,232	12	4,860	10,915	180	75	52	0	18,825
	4					435	445	0			0	881
	5-		1,076	10,020	409	4,949	17,681	892	34	35	0	35,095
	5+	627	4,767	45,326	9,500	23,730	115,270	3,116	132	4,726	41	207,235
	6-	404	14,017	90,504	9,083	63,873	265,575	5,561	306	10,929	1,118	461,380
	6+	930	11,337	82,438	5,687	57,004	357,647	2,667	92	14,935	275	533,009
	7		900	21,545	613	10,029	79,164	682		15,743	53	128,730
Sum of Good		1,961	33,596	251,064	25,304	164,880	846,696	13,098	639	46,420	1,487	1,385,154
Bad	≤4	536	842	17,739	1,572	13,663	54,481	2,831	560	3,985	14	96,223
	5-			113		200	587	30	10		0	940
	5+		1,905	14,022	2,576	16,908	42,309	1,255	331	562	101	79,967
	6-	4,344	20,551	87,439	16,536	68,613	288,032	7,157	778	10,648	176	504,358
	6+	15,863	44,501	329,648	13,155	142,744	839,706	15,029	1,545	34,686	592	1,437,468
	7	4,499	1,974	38,234	1,614	28,999	154,013	1,582	140	23,753	333	255,139
Sum of Bad		25,241	69,773	487,195	35,453	271,127	1,379,127	27,884	3,364	73,632	1,215	2,374,096
Sum		27,202	103,369	738,259	60,757	436,007	2,225,824	40,982	4,004	120,052	2,702	3,759,250

Note: ERJ: Earthquake Resistant Joint

EARTHQUAKE RESISTANT DESIGN AND TECHNOLOGY

Seismic design guidelines for drinking water facilities have been revised several times based on lessons learned from the past major earthquakes. The 1995 Kobe Earthquake had a significant impact on the earthquake-related policies in Japan because it was the first earthquake in its history to directly hit a modern large city, Kobe. Promptly after the event, in 1997, major revisions were made to the seismic design guidelines with the concepts of Level 1 and Level 2 earthquake ground motion and Rank A and Rank B facility importance rating newly introduced. As a result, the earthquake resistant performance was regulated as listed in Table 4.

Table 4 | Level of required earthquake resistant performance

Degree of importance	Earthquake level Level 1	Level 2
Rank A	Operational capacity is not affected.	Seismic damage is minor and does not severely affect operational capacity. Restoration requires minimum effort.
Rank B	Seismic damage is minor and does not severely affect operational capacity. Restoration requires minimum effort.	Seismic damage is minor and does not severely affect operational capacity, but restoration is necessary.

Notes:

Level 1:	The maximum level of earthquake which may occur during the service period of the facility
Level 2:	The maximum level of earthquake which may occur at the site of the facility in the future. Generally, level 2 ≥ level 1.
Rank A:	High-priority facilities (such as intake stations, purification plants and trunk pipelines)
Rank B:	Other facilities.

Experiences of hazardous earthquakes have also advanced earthquake resistant technology for water pipelines. DIP accounts for 60% of all the buried pipes. Since earthquake damage to these pipes primarily consists of pull-out at joint, joint structures have been improved following major earthquakes. DIP joints are mainly divided into Types A, T, K, S, S-II, NS, and GX (Table 5). Older joints of Types A, T, and K do not have a joint disengagement prevention mechanism. On the other hand, Types S and S-II, developed more recently in 1982 (Table 6), are seismic joints with high earthquake resistance, bending and expanding substantially to accommodate differential settlement of soft ground and large ground deformation induced by liquefaction, keeping pipe from being pulled out of joint. In the wake of the 1995 Kobe Earthquake, an easy-to-install Type NS joint was developed to promote widespread use of seismic pipes. In the Kobe Earthquake and the 2011 Tohoku Earthquake, no damage was caused to these three seismic pipes, demonstrating their high earthquake resistance. The most recent development of seismic DIP joint is Type GX.

Table 5 | Characteristics of different joint types

Joint type	Characteristics
A	A rectangular rubber gasket is placed around the socket and the joint bolts are tightened with a gland.
T	A rubber gasket is placed around the socket and the spigot is inserted into the socket.
K	A modified version of Type A. This has only a rubber gasket which a rectangular one and a round one are combined.
S, S-II	A rubber gasket and a lock ring are placed around the socket and the spigot is inserted into the socket. The joint has good earthquake resistance with high elasticity and flexibility and a disengagement prevention mechanism.
NS	The same level of earthquake resistance as Type S but is easier to install.
GX	Even easier to install than Type NS and have longer service life.

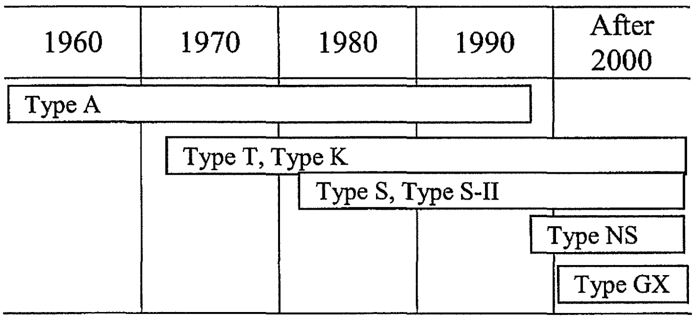

Figure 8 | History of DIP joints.

APPLICATION OF EARTHQUAKE RESISTANT TECHNOLOGY IN LOS ANGELES

ERDIP is available and used only in Japan. A Japanese pipe manufacturing company and the Los Angeles Department of Water and Power (LADPW) have, however, collaborated on a proposal to implement a pilot project to install ERDIP in Los Angeles. LADWP would be 1st to use ERDIP in the United States of America. Purpose of the pilot project is to allow the LADWP to become acquainted with the ERDIP, to obtain direct observations and experience of the design and installation procedures, to compare the design and installation of ERDIP with pipes normally installed by LADWP, and to make own assessment on suitability for using the ERDIP to improve network reliability

The pilot project firstly started to identify areas damaged by ground failure during the 1994 Northridge Earthquake such as Balboa Blvd region, Roscoe Blvd Region and Studio City/Sherman Oaks Region (Figure 9). Then, two pilot areas were determined: relatively level ground in San Fernando Valley (Roscoe or Balboa Blvd.) and sloped and curvy roads in Studio City/Sherman Oaks area.

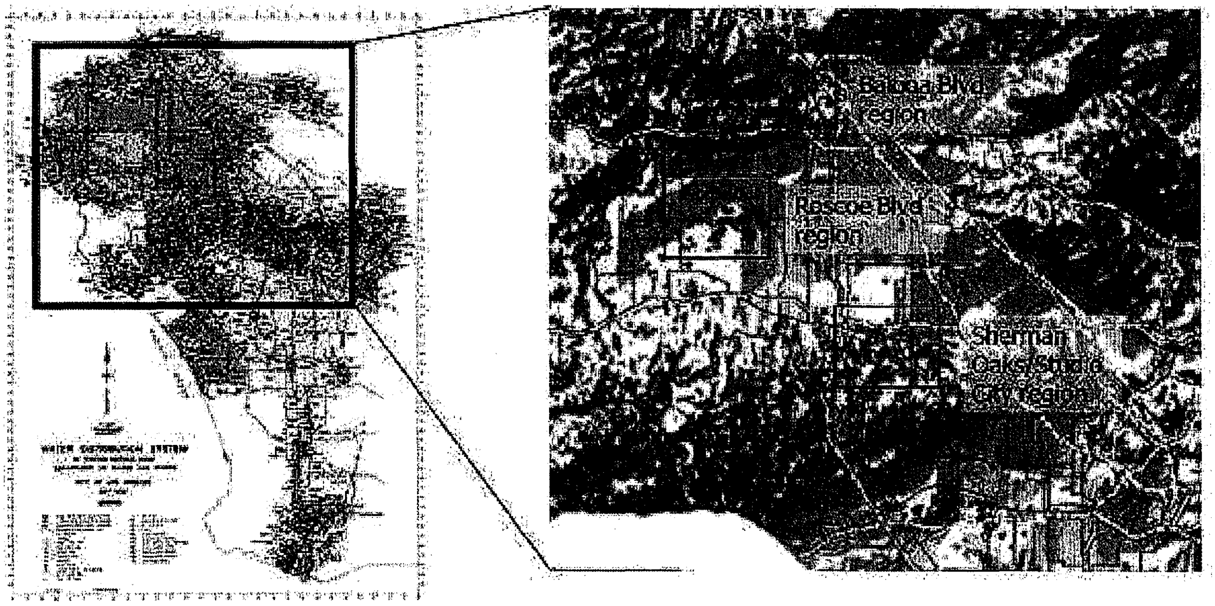

Figure 9 | Locations of pilot projects in Los Angeles.

The pilot project in Roscoe Blvd. & Reseda Blvd. aims at direct comparison of installing standard US manufactured push-on DIP with Japanese ERDIP in the same street with the same diameter pipe with the same crews and improving the seismic performance of an area previously damaged from permanent ground deformations. Proposed main replacement in Contour Drive is not completely consistent with proposed long-term seismic improvement program, but is consistent with pilot project for benchmarking pipe installation in hillside area while meeting current pipe replacement needs.

CONCLUSIONS

In the past 20 years, the water supply system in Japan has experienced huge earthquakes such as the 1995 Kobe Earthquake and the 2011 Tohoku Earthquake, which was followed by tsunami. We have learned many lessons from the disasters while their damage analysis is still being conducted. Challenges posed by earthquake and tsunami are not specific to Japan but are faced by many other countries around the Pacific Ocean such as New Zealand, California of the USA, China, Taiwan etc. Therefore, we must continuously exchange lessons learned from these damaging events and collaborate to establish resilient water supply system for earthquake and tsunami.

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高濁度原水における二段凝集処理最適化の検討

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1. はじめに

(1) 研究背景

気候変動に伴うゲリラ豪雨や長時間にわたり局地的な豪雨が降ることで原水の急激な濁度上昇が発生するケースが多く報告され，取水や給水を停止する事例の報告が相次いでいる．水道事業体はこのような急激な濁度変動や高濁度原水への対応が急務であるが，特に中小規模の水道事業体では施設更新等の大規模な改修は困難であり，また，技術者が不足している水道事業体も多いことから簡便かつ低コストで対応できる浄水処理技術が求められている．

(2) 研究目的

これまでの研究より，急激な濁度変動に対応する簡便かつ低コストな対策として，凝集剤種類を変更すること，具体的にはより塩基度の高い凝集剤を使用することや二段凝集処理を行うことが有用であること示されてきた．本研究では浄水場内の設置した模擬実験プラントを使用し，高濁度原水を対する二段凝集および凝集剤の種類が与える処理水に与える影響について検討し，高濁度原水に対応可能な浄水処理技術について検討を行う．

2. 実験方法

(1) 実験方法

今回の実験は，実際の浄水場と同様の処理を行うことができる凝集沈殿砂ろ過プラン（METAWATER社製）（図1）を浄水場内に設置し，浄水場に流入する原水を用い，急速攪拌及び緩速攪拌の攪拌強度，前段凝集剤注入率を実験プラントを設置した浄水場と同等程度に設定し，より浄水場に近い条件で実験を行った．実験は二系統ある実験装置を1回の実験を180分の連続運転とし，砂ろ過塔損失水頭以外の数値においては，数値が安定した実験開始より150～180分における測定値の平均を用い，異なる二条件で処理した際の処理性比較を行った．具体的には，粒径別に二段凝集の効果を確認するため，砂ろ過水濁度測定の際に粒子径別に粒子数をカウントすることのできる卓上形ハイブリッド微粒子計（METAWATER社製）を用い，ろ過水濁度・各粒径の粒子数の測定を行った．

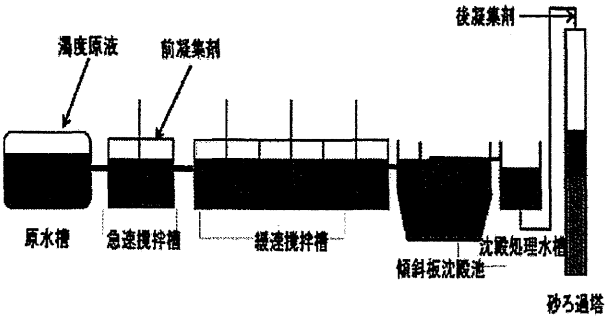


図1　模擬実験プラントの処理フロー

(2) 実験条件

今回の実験では凝集剤として，塩基度のことなるポリ塩化アルミニウム（PACl）を使用した．使用したPAClの塩基度は，塩基度52～56（通常塩基度PACl），塩基度68～72（超高塩基度PACl）の二種類である．

濁度溶液として，取水口にて原水を採取し減圧濃縮により高濁度の原液を作成し，濁度溶液を添加することで擬似的に高濁度原水を発生させ実験を行った．

今回の実験における設定濁度は50度，100度とし，前段凝集剤の注入率は，浄水場の過去の注入率をもとに決定し，後凝集剤の注入率は，0，2，5mg/Lの三条件ににおける沈殿水濁度，砂ろ過損失水頭，砂ろ過水濁度，砂ろ過水における粒子径0．5〜1μm，1〜2μm，2〜3μmの粒子数の測定を行い比較検討を行った．

3．実験結果

(1) 実験結果

原水濁度50度における両凝集剤を使用した際の砂ろ過水の粒径別粒子数を図2および図3に示す．尚，粒子数の単位は粒子径0．5〜1μmがCount/mL，粒子径1〜2μm，2〜3μmがCount/100mLである．この際の沈殿水濁度は通常PAClでは3．2〜3．7度，超高塩基度PAClでは2．8〜3．4度であり，大きな差は認められなかった．また，原水濁度100度における両凝集剤を使用した際の砂ろ過水の粒径別粒子数を図5および図6に示す．この際の沈殿水濁度は通常PAClで5．0〜6．7度，超高塩基度PAClで4．2〜4．8度であり，原水濁度50度の場合と比較すると凝集剤による違いが認められた．図2，3より原水濁度が50度場合，沈殿水濁度がほぼ同じにも関わらず，後段凝集に用いる凝集剤の違いにより，特に粒子径0．5〜1μmの粒子数に大きな違いが認められた．また，凝集剤の注入率によっても粒子径0．5〜1μmの粒子数に違いが認められ，凝集剤の種類，注入率を最適化することでより清澄な砂ろ過水を得られることが示された．

図4，5より原水濁度が100度の場合，どちらの凝集剤を使用した場合でも注入率が高い実験条件で粒子径0．5〜1μmの粒子数の増加が見られた．図4に示した後段凝集剤注入率が5mg/Lの際の砂ろ過損失水頭は実験期間で約6．7kPa増加していたことから破過の前兆であると考えられる．比較的高い濁度でも二段凝集は砂ろ過水の濁質低減に有用な方法ではあるが，注入率が高い場合には破過を起し，砂ろ過水の水質が低下する可能性があることが示された．

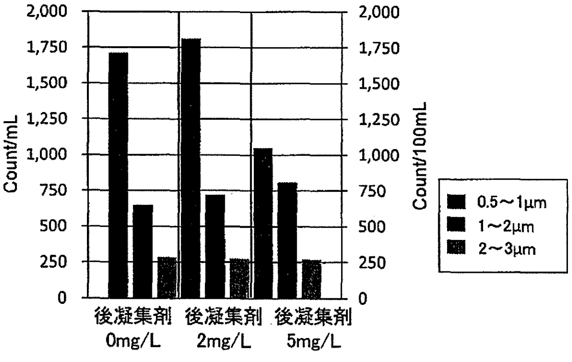


図2　原水濁度50度における通常塩基度PACl使用時の砂ろ過水の微粒子数

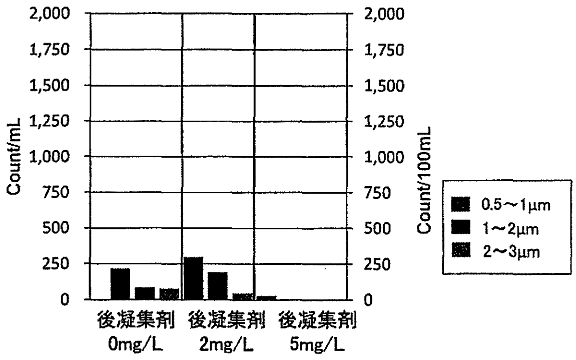


図3　原水濁度50度における超高塩基度PACl使用時の砂ろ過水の微粒子数

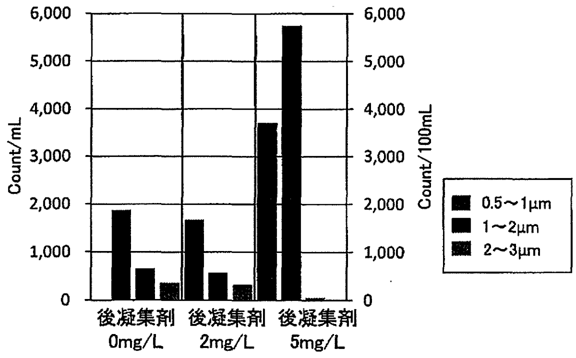
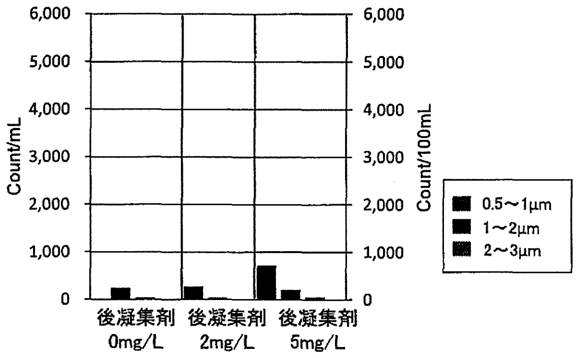


図4　原水濁度100度における通常塩基度PACl使用時の



砂ろ過水の微粒子数

図5　原水濁度50度における超高塩基度PACl使用時の砂ろ過水の微粒子数

4．まとめ

安価で簡易な設備で実施が可能である二段凝集に関して，凝集剤の種類，注入率等を変化させて模擬実験プラントで実験を行ったところ，塩基度の高い凝集剤を使用することで，特に粒子径0．5〜1μmの粒子数を再凝集により砂ろ過で捕捉し，低減できることが示された．しかし，原水濁度が高く，後段凝集剤注入率が過剰になると砂ろ過への負荷が過大となり破過を起す可能性があり，適正なタイミングで砂ろ過の逆洗を行わないと逆効果となることも示された．

Performance of Drinking Water Pipelines in Liquefaction Areas in the 2011 Great East Japan Earthquake

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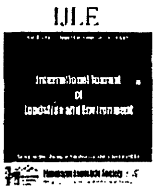

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Keywords: Liquefaction; drinking water pipeline; the 2011 Great East Japan Earthquake

1 Introduction

An earthquake occurred on March 11, 2011 at 14:46 JST in the north-western Pacific Ocean at a relatively shallow depth of 32 km, with its epicenter approximately 72 km east of the Oshika Peninsula of Tohoku region, Japan. The earthquake generated a tsunami of unprecedented height and special extent along the coast of the main island of Japan. The earthquake and tsunami caused about 20,000 deaths and about 6,000 people missing and injured.

Many other kinds of geo-disaster such as liquefaction, landslide, etc. were triggered by this earthquake. Liquefaction occurred extensively at Tohoku region which is close to the epicenter of the earthquake and also at Kanto region which is 300 km away from the epicenter. Many houses and underground infrastructures were damaged severely by liquefaction. The damage to the drinking water pipelines by liquefaction is focused in this study.

Water supply facilities were damaged severely and water supply to about 2.57million houses in the wide area from Tohoku to Kanto regions were disrupted just after the earthquake. This paper deals with a performance of drinking water pipeline in liquefied areas.

2 Damage rate of drinking water pipelines in liquefaction area

Extensive liquefaction occurred in Chiba and Ibaragi Prefectures in Kanto region. Especially liquefaction in filled land in Urayasu City of Chiba Prefecture caused large ground settlements and severe damage to buried pipelines. The damage to drinking water pipelines installed in the filled land in Urayasu City is introduced here.

Fig. 1 illustrates a drinking water pipeline network and sites of damage to buried pipeline in a part of Urayasu City. The area in a yellow line in this figure shows a filled land and severe liquefaction occurred in this area. The total piping length in this area was 200.93 km and the number of damage was 321, so the damage rate is 1.60 cases/km. The damage rate of pipeline buried in the reclaimed land of Kobe, Ashiya and Nishinomiya Cities in the 1995 Kobe Earthquake was 1.77 cases/km. So, the degree of damage seemed to be similar in both cases. Peak ground velocity was about 30 cm/s in Urayasu and in Kobe area in the 1995 Kobe Earthquake was around 100 cm/s. The peak ground velocity of Urayasu was much smaller than that at Kobe area in the 1995 Kobe Earthquake, but the degree of the damage was similar. This means that the effect of liquefaction on pipeline damage may be nearly constant and it is independent of peak ground velocity when liquefaction occurred.

Fig 1. Drinking water pipeline network

3 Performance of earthquake resistant pipelines in liquefied area

Performance of actual installed pipelines was surveyed at the eastside of Sendai City where liquefaction occurred. This area was flooded about 2m by the tsunami after the earthquake. Road was undulated, utility pole and traffic sign subsided about 1m by liquefaction as shown in Photo 1. The measured pipeline is earthquake resistant ductile iron pipes with S2 type joint in the nominal diameter 300 mm as shown in Fig. 2. The behavior of the pipes of about 80m intervals was measured by TV camera inserted in the pipelines.

Settlement of the ground surface of the study site occurred about 0.3m in a section of about 50m from the threshold by the earthquake as shown in Fig.3. The pipelines followed the ground displacement. Two consecutive joints near 70m point were fully expanded. The sum of the amount of expansion and contraction of each joint is 240 mm; amount of expansion was equivalent to 0.3% of the pipeline length. This amount was within the capacity of 1 percent expansion amount of the pipeline.

The measured pipelines could absorb ground displacement by expansion/contraction performance to allowance limit of some joints. Moreover, the behavior of the joints was found to be locally concentrated. It is considered that this was due to the ground strain was concentrated locally because of ground uniformity. In such places, the pipelines had absorbed the large ground strain by expanding the adjacent joints, even if a joint expanded up to allowance limit. In other words, the effectiveness of the chain structure pipeline absorbed ground deformation has been demonstrated.

4 Concluding remarks Pipeline

The performance of the drinking water pipelines in liquefaction areas caused by the 2011 great east Japan Earthquake was focused in this study. The following conclusions may be drawn based on the present study.

(1) The damage rate of drinking water pipeline in filled land in Urayasu City was 1.60 cases/km. This value is similar to the damage rate of pipeline buried in the reclaimed land of Kobe, Ashiya and Nishinomiya Cities in the 1995 Kobe Earthquake.

(2) The effect of liquefaction on pipeline damage may be nearly constant and it is independent of peak ground velocity when liquefaction occurred.

(3) Photo. 1 Subsidence of utility pole induced by liquefaction in Sendai City

The earthquake resistant ductile iron pipe had absorbed the large ground strain by expanding the adjacent joints in liquefaction area in Sendai City.

Acknowledgements

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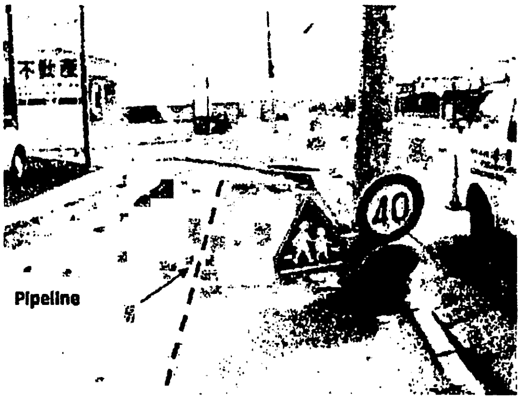

Photo. 1 Subsidence of utility pole induced by liquefaction in Sendai City

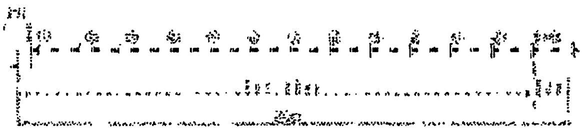

Fig 2. Measured pipeline (DN300×80m) in Sendai City

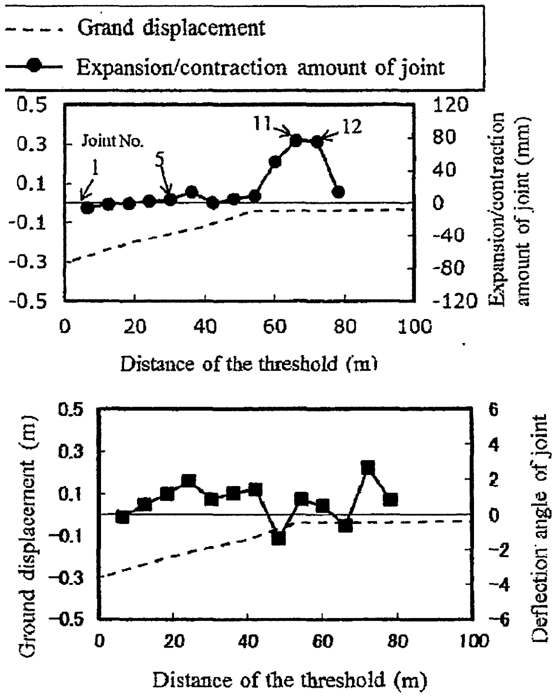

Fig 3. Expansion/contraction amount of joints and vertical displacement of ground surface

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Evaluation of Water Quality Indicators Related to Water Treatment Processes and Practical Treatment Method against High Turbidity Raw Water

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Abstract

This paper reviews a study where we examined issues and challenges facing small water utilities in managing high turbidity raw water in the conventional treatment processes, with a special focus on its impacts upon coagulation and sedimentation, based on the findings of which we proposed treatment measures and evaluated their effectiveness. This study concludes that turbidity, alkalinity, pH, and organic matters are important indicators; EC is available as an alternative indicator of alkalinity; exponentiation equation ($Al=a \cdot T^{b+1}$) is useful to determine the coagulant dose best fit to address high turbidity caused by heavy precipitation events; and that the re-coagulation (two-step coagulation) is an easy method to guarantee stable treatment of raw water with high turbidity, based on the data from actual and pilot plants.

Keywords
Coagulation; high turbidity; sedimentation; small water utility; water treatment

INTRODUCTION

The increased occurrence of heavy precipitation events associated with global warming presents a challenge to water treatment systems, raising turbidity levels much higher in surface waters. The high turbidity is particularly a problem in coagulation and sedimentation processes, often surpassing sand filtration capacity for proper turbidity reduction. Such problems related to very high turbidity are presented and their measures are reported in Taiwan and Pakistan (Lin W.W. et al., 2004; Zahiruddin K., 2011).

In Japan, the questionnaire and interview research by Aizawa et al. (2012) reports that many Japanese small water utilities are in trouble of managing coagulation and sedimentation treatment processes for high turbidity raw water and need an easy method to guarantee its stable treatment to keep the filtrate turbidity equal to or below 0.1 degrees (0.14NTU).

First, this paper reviews important water quality indicators concerning coagulation and sedimentation control in the conventional treatment processes during high turbidity periods, in which the turbidity of raw water could reach several hundred degrees. Second, the paper proposes simple and easy measures for small water utilities to better manage high turbidity raw water, by analyzing actual water treatment plants (WTPs) data and evaluating their treatment measures with a pilot plant. In the context of this paper, a small water utility means a utility serving under tens of thousands of people.

RESEARCH AND EXPERIMENTAL METHOD

Table 1. Outline of actual water treatment plants (WTPs)

WTP	Plant capacity (m^3/d)	Characteristics of raw water			Raw water source	Remarks
		color	alkalinity	pH		
A	64,400	high	low	medium	river water, peaty	
B.	7,200	high	low	medium	river water, peaty	
C	937,700	low	high	high	lake	acid adding
D	126,700	low	high	high	lake	
E	22,800	low	low	medium	river	
F	200,000	low	low	medium	river	

Analysis of WTPs data on high turbidity raw water. Table 1 shows the six WTPs in Japan we analyzed in this study. These WTPs draw from different water sources and the data of their water samples were abstracted under high turbidity conditions. The data was analyzed to evaluate water quality indicators affecting coagulation and sedimentation processes for high turbidity raw water.

Identification of challenges and treatment measures with the pilot plant. Based on the data analysis, experiments were conducted at the pilot plant ($3.6m^3/d$) to identify the most effective treatment method for high turbidity raw water when using the PACl (Poly Aluminum Chloride) as coagulant. The schematic diagram of the pilot plant is shown in Figure 1. To use as raw water, artificial turbid water was made from mixing kaolin and bentonite (1:1) and diluting the mixture with tap water whose chlorine had been removed by GAC.

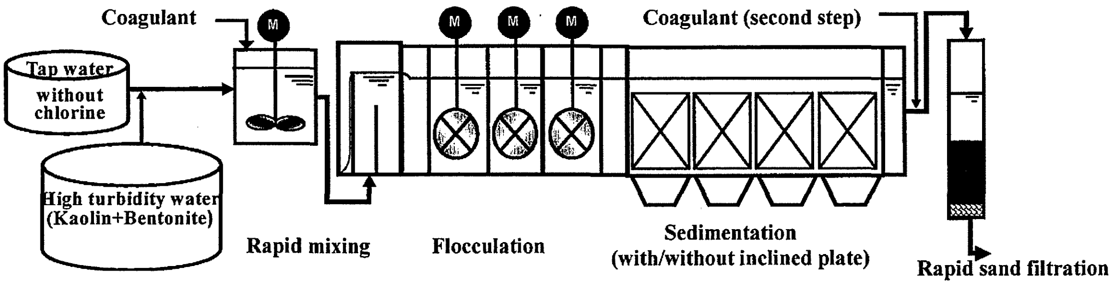

Figure 1. Schematic diagram of pilot plant

RESULTS AND DISCUSSION

Analysis of water treatment plants (WTPs) data to investigate important water quality indicators for coagulant dose control during high turbidity

Behavior of color during high turbidity and the coagulant dose for color. Figure 2 shows a correlation between color and turbidity during high turbidity periods at A and B WTPs, which use raw water sources of high color originated from peat. As is shown in the figure, the color increases with the increase in turbidity, meaning it would be more difficult to control coagulation and sedimentation processes for high turbidity raw water due to higher coagulant consumption caused by color.

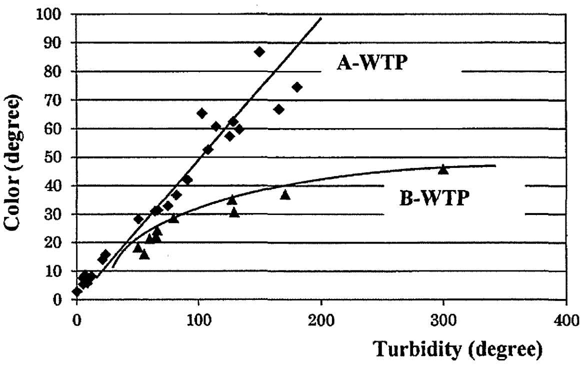

Figure 2. Correlation between color and turbidity of raw water