

Cases, Causes, and Impacts of Safety Incidents at AD Systems

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– Anaerobic Digestion Topics Part 3

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Introduction

- Anaerobic digestion (AD) offers many benefits:
 - Generate energy
 - Reduce environmental pollution
 - Produce organic fertilizer
 - Increase revenue
 - ...
 - **BUT** AD can also pose serious risks to health, life, and property.
- Objectives of this study:
 - **NOT** to paint a negative image of AD
 - **BUT** to
 - Raise awareness
 - Understand causes and impacts
 - Promote a safe and sustainable use of AD

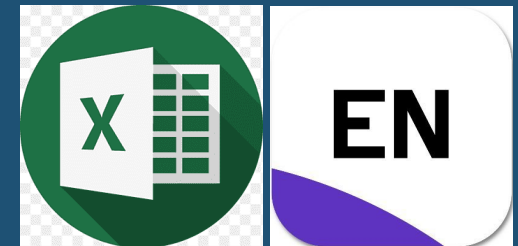


www.chemtrack.org/News-Detail.asp?TID=2&ID=37

Methods

- Data collection:
 - Literature review
 - Internet search: Google TM, Google Scholar TM, Web of Science TM
 - Conversations with AD extension workers
- Database building:
 - Software: MS Excel, EndNote TM
 - Data coding: Dates, locations, circumstances, fatalities, injuries, damages, victims' genders and ages, etc.
- Data analysis:
 - Sources of event reporting
 - Geographical distribution
 - Chronological distribution
 - Causes and impacts
 - Measures to mitigate the risks

???



Case Sources in 3 Continents

Europe

- Scholarly publications
- News media

North America

- News media

Asia

- News media
- Scholarly publications
- Final project report & personal communication



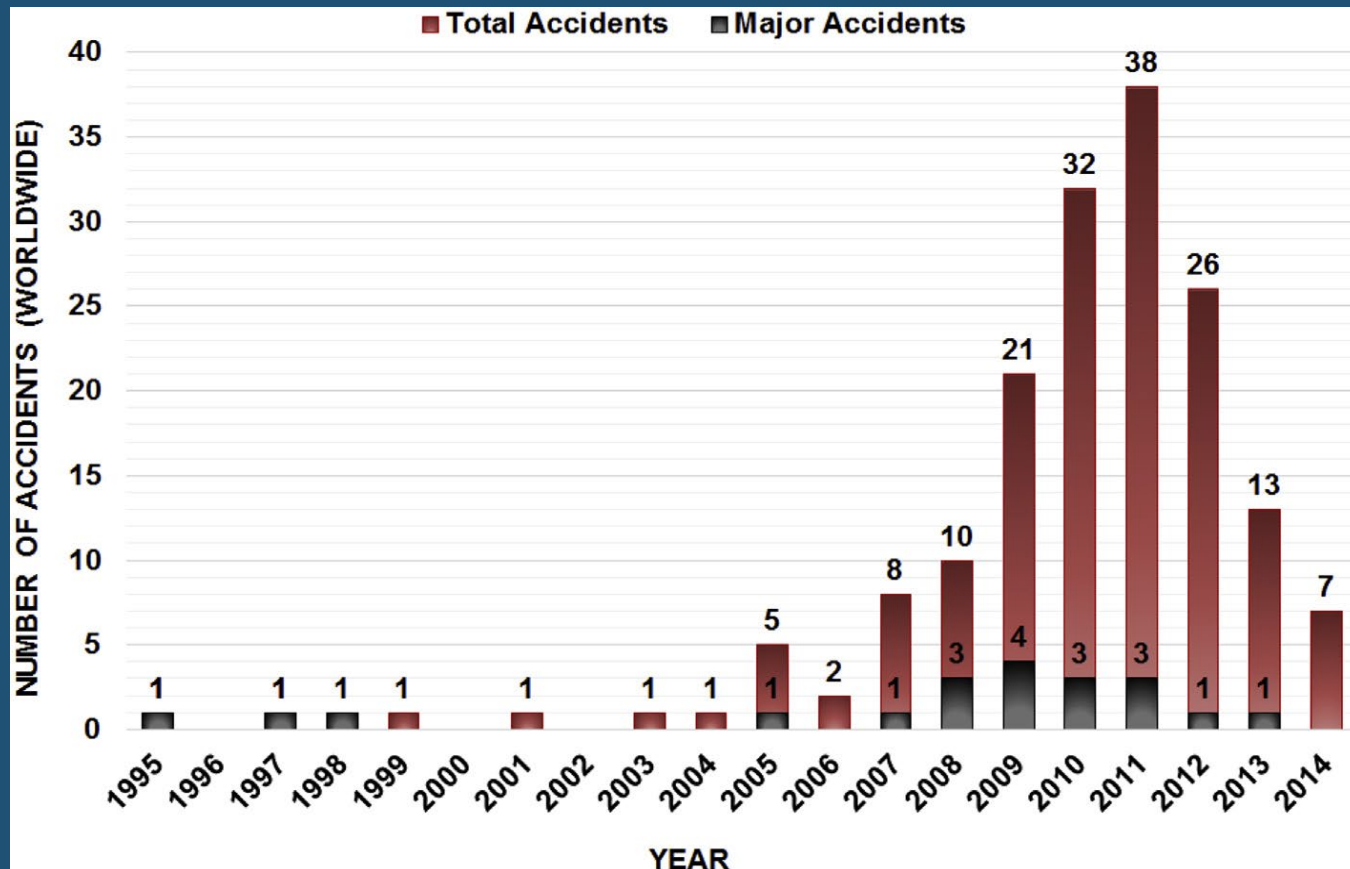
Cases in Europe



Map from Wikipedia.com

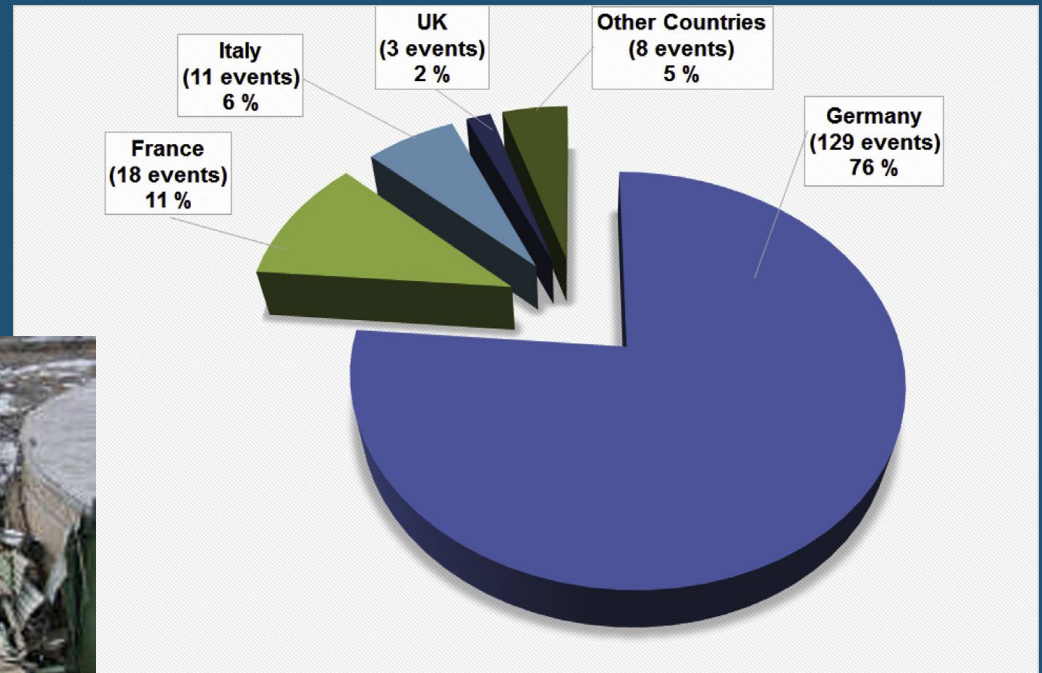
169 Cases in Europe (1995–2014)

12% (20 cases) of the 169 were major accidents (*major emission, fire, or explosion leading to serious danger to human health or the environment*).



Casson Moreno et al. 2016. *Renewable Energy*. 96, 1127-1134.

169 Cases in Different Countries



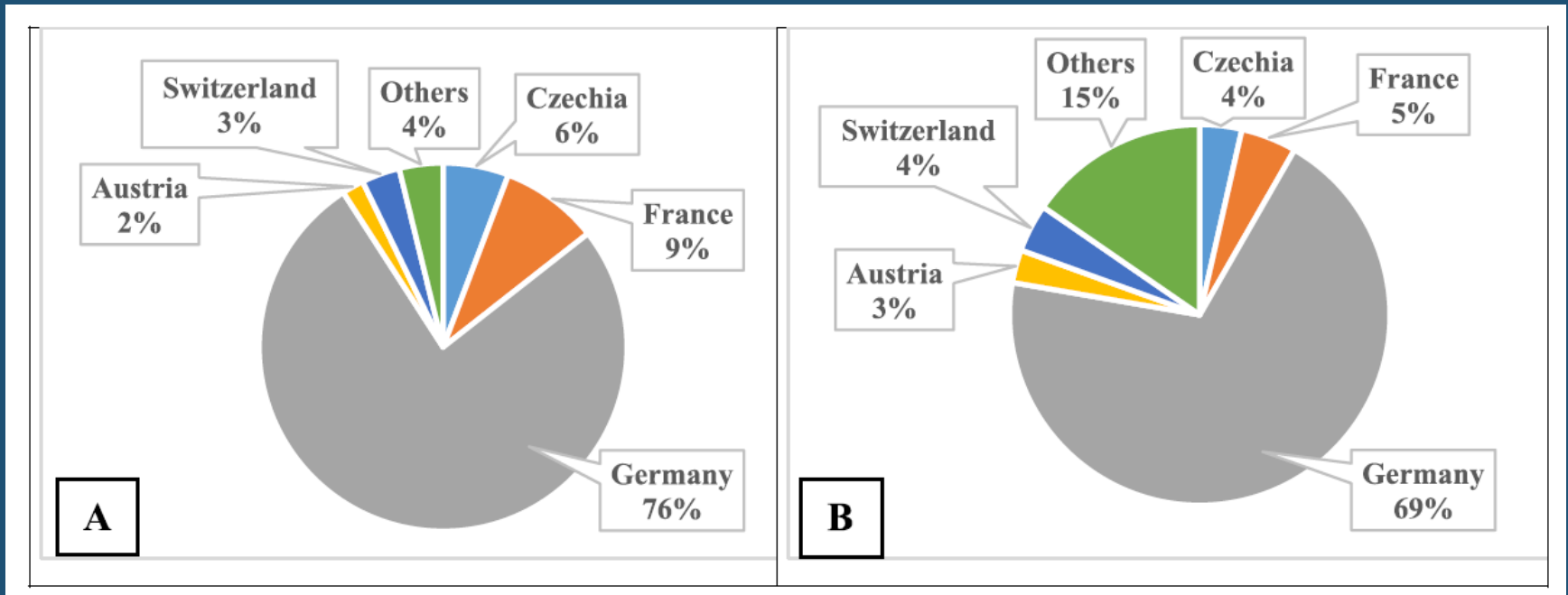
Damage in an AD incident

Jenkins et al., 2013. *Loss Prevention Bulletin* (229), 19-24.

Countries of the 169 cases

Casson Moreno et al. 2016.
Renewable Energy. 96, 1127-1134.

208 Cases in Europe (2006–2016)



Share of accidents in individual countries of 208 events (A). Share of individual countries in the total number of biogas stations in 2015 (B).

2 Additional Cases Before 1995

1. In 1976 a concrete biogas digester exploded in Åkeshov (Sweden).
2. Aug. 22, 1990, a biogas digester exploded at Vejle WWTP (Denmark).



Aftermath of the accident on August 22, 1990, in Denmark.

Hedlund, 2017. 25th Eur. Biomass Conf. pp. 1804-1814.

2 More 2015 Cases in Denmark

1. Aug. 6, 2015, several people were overcome by hydrogen sulfide at Hashøj Biogas while **unloading food waste**.
2. Nov. 29, 2015, a **storm** severely damaged the exterior insulation on digesters at Holsted biogas.



In the facility of Hashøj Biogas where several people were injured on Aug. 6, 2015.

Hedlund, 2017. 25th Eur. Biomass Conf. pp. 1804-1814.

Hedlund and Madsen, 2018. J. Chem. Health & Safety. 25 (6), 13-21.

7 Other Cases in Denmark

1. Dec. 2, 1999, at Ribe, a **severe storm** caused a digester to collapse. The digester damaged a neighboring tank, probably another digester, and partly crushed to buildings.
2. Late Jul. 2002, a **lightning strike** had damaged the flare at Blåbjerg biogas causing **leaked foul biogas** for at least 1½ weeks.
3. Sep. 2, 2005, a covered tank with degassed manure from a biogas digester "**exploded**" at Hemmet.
4. Mar. 20, 2007, the outer protective membrane of a double membrane **gas storage holder collapsed in a storm** at Hashøj biogas .
5. May 20, 2009, a **biogas powered public transportation bus caught fire** at Jernbane Allé, Vanløse.
6. Early Sep. 2013 a **silo with dried sludge exploded** at Bjerghmarken WWTP.
7. May 25, 2014, a **biogas storage “burned down”** in Thorsø.

2 Cases in England and Hungary

Dec. 3, 2020, Avonmouth, Bristol, England. Wesset Water's anaerobic digester explosion killed four people.

<https://www.industrytap.com/what-may-have-caused-the-avonmouth-anaerobic-digester-explosion/55634>



2021, Hungary: Explosion in the Nyírbátor Biogas Plant - three people died.

Daily News Hungary · Bátor Média · Oct 14, 2021

Cases in USA (North America)



Map from Wikipedia.com

4 Cases in USA (2011–2016)

- 1 April 17, 2011, Linwood, **New York**. Noblehurst Farms lost its digester, in an early morning **fire**.
<https://www.manuremanager.com/noblehurst-farms-loses-digester-in-fire-3731/>
- 2 July 2012, Oakley Farm in Aumsville, **Oregon**. An **explosion** at the anaerobic **manure digester**.
https://www.oregonlive.com/pacific-northwest-news/2012/07/methane_fueled_explosion_at_au.html
- 3 Aug. 6, 2014, Town of Vienna, **Wisconsin**. An **explosion** destroyed the roof of a 1.25-million-gallon **manure digester**.
<https://www.manuremanager.com/manure-digester-explosion-in-wisconsin-sparks-fire-15850/>
- 4 Nov. 2016, Lowell, **Michigan**. Lowell Energy AD digester exploded due to a buildup of methane gas, resulted in a ruptured tank cover, a lingering odor and spilled waste.
<https://www.waste360.com/safety/michigan-biodigester-explodes-methane-gas-buildup>

3 Cases in USA in 2017 & 2018

- 5 Jan. 22, 2017, **International Paper** in Cantonment, **Florida**. An **explosion** caused significant structural damage to the largest pulp digester as well as the power house at the mill.
<http://www.northescambia.com/2017/01/my-heart-sank-mill-manager-speaks-out-about-explosion-future-of-ip>

- 6 Jan. 2018, **Missouri**. Gas build-up leads to **explosion** at **Blue River Wastewater Treatment Plant**, Part of the building collapsed.
<https://www.kshb.com/news/local-news/gas-build-up-leads-to-explosion-at-blue-river-wastewater-treatment-plant>

- 7 Aug. 30, 2018, **Chicago**. An **explosion** at a **water reclamation plant** in appears to have been caused by methane gas ignited by a worker's welding torch.
<https://www.wateronline.com/doc/explosion-at-chicago-water-reclamation-plant-injures-0001>

2 Cases in USA in 2020 & 2021

- 8 April 2020. Jay, **Maine**. A paper mill disabled by a dramatic **explosion**. No one was injured but 230 workers were left without jobs. The mill will close in the first quarter of 2023.

<https://apnews.com/article/explosions-maine-susan-collins-angus-king-4dfd183575a0f364a4545bec0e1132e6>



Photo from AP News.

<https://apnews.com/article/391dfff9b3768186d3ad318fa30f11fb/gallery/8139f20f69904163b8ebe9756ecea959>

- 9 June 8, 2021, Stockton, **Iowa**. Bob Baenziger Jr., 54, died while performing a **dive to repair a broken cable at the bottom of a million-gallon anaerobic digester tank at Sievers Family**. (From multiple

source, including <https://www.desmoinesregister.com/story/news/2021/07/30/diver-robert-baenziger-jr-drowns-iowa-farm-accident/5427513001/>)

Cases in Asia



Map from Wikipedia.com

143 Cases in Asia (1958–2022)

Cases and losses

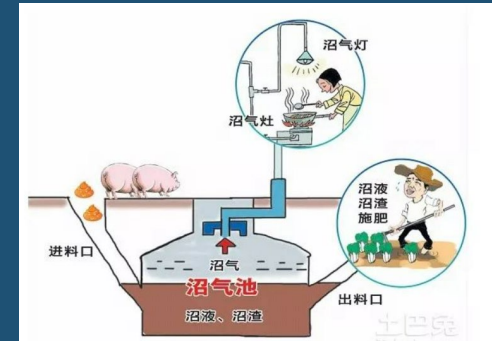
- Total cases: 143 (all “major accidents”)
- Fatalities: 266
- Injuries: 219
- Total property damages: unknown, but huge

Victims

- Male : female = 5.5 : 1
- Minimum age: 3-year-old
- Maximum age: 75-year-old

Cases in two digester types:

- ~73.2% at household digesters
- ~26.8% at industrial digesters



Household digester

<https://www.sohu.com/a/323140642120034261>



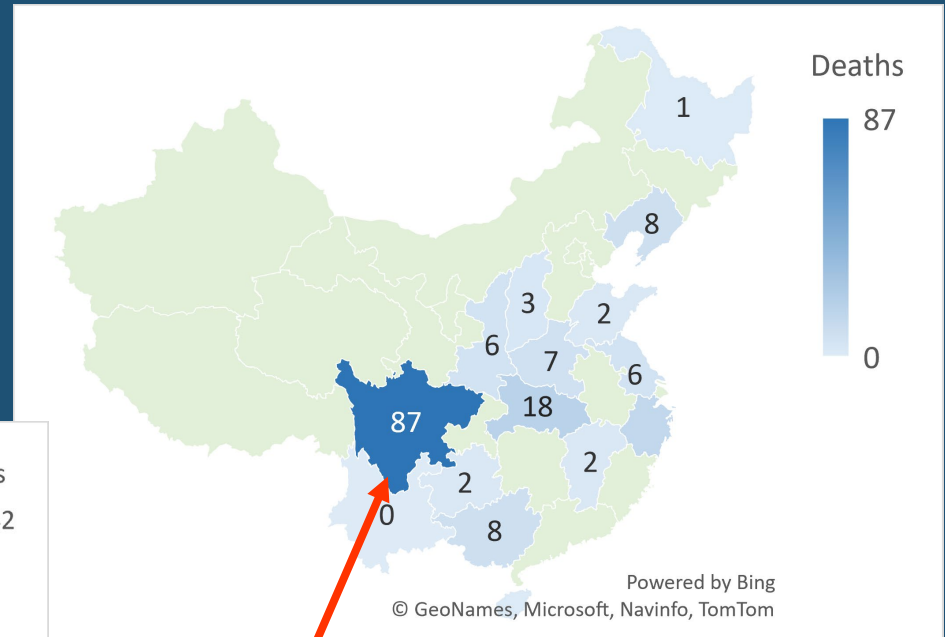
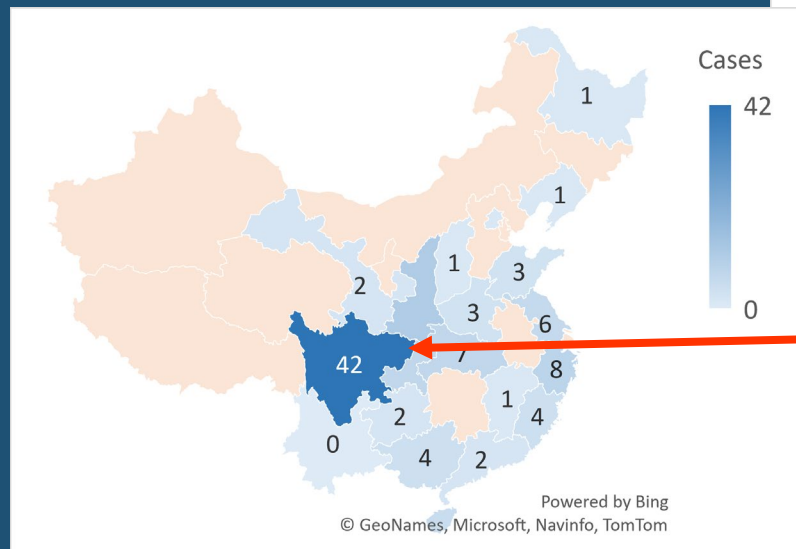
Industrial digesters

Ni, Unpublished data. Do not cite.

Geographical Distribution

Cases in five countries and one region

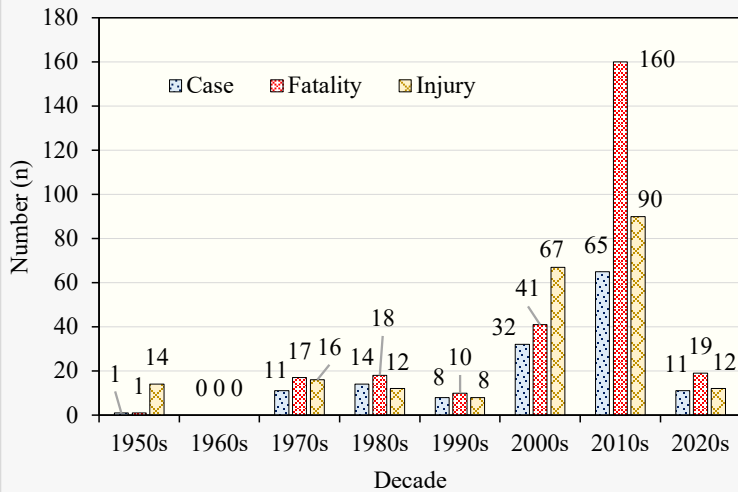
- China: 111 (77.6%)
- Vietnam: 12 (8.4%)
- Thailand: 11 (7.9%)
- India: 7 (4.9%)
- Malaysia: 1 (0.7%)
- Taiwan: 1 (0.7%)



Sichuan Province in China had the largest numbers of cases and deaths.

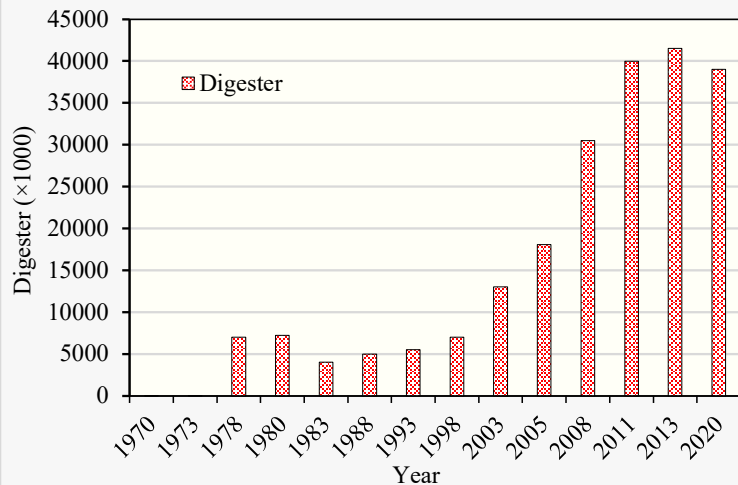
Ni, Unpublished data.

Chronological Distribution



Cases & damages in 8 decades.

- An increasing trend.
- Highest in the 2010s.
- 11 cases in recent <3 years.



Number of digesters in China.

- Shows some similar patterns with Asian cases.

Ni, Unpublished data.

Acute Poisoning and Explosion

- Poisoning by inhaling hydrogen sulfide (H_2S), 80.6% of all cases.
- Explosions by welding or other work at digesters, and fires by inappropriate use of biogas for cooking, and a lightning strike, 19.4% of all cases.

Incidents occurred while:

- Maintaining and repairing digester systems.
- Rescuing other victims in digesters.
- Rescuing animals fallen into digesters.
- Recovering lost items (such as cell phones) from digesters.

Ni, Unpublished data.



Poisoning in 2018, China.

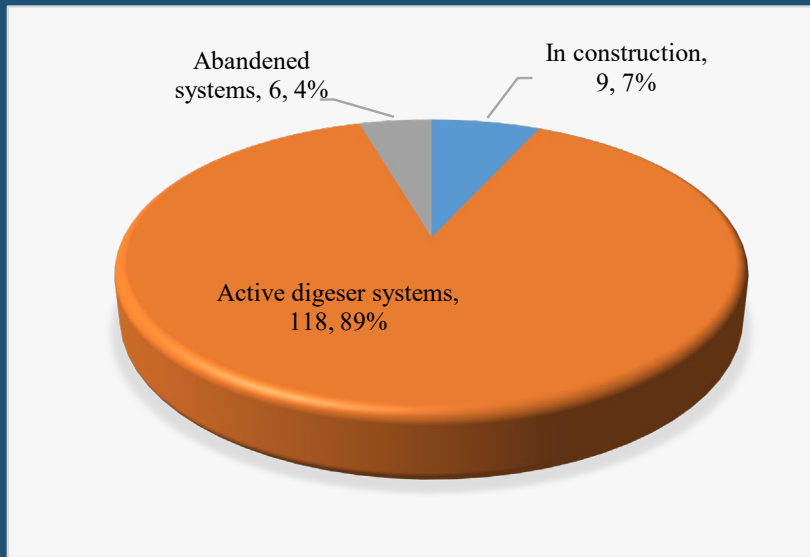
https://www.sohu.com/a/233521492_420076



Explosion in 2013, India.

<https://www.indiatvnews.com/news/india/>

Status of Digesters at Incidents



Incidents occurred:

- 89% at active digester systems.
- 7% at digesters in construction.
- 4% at abandoned digesters.

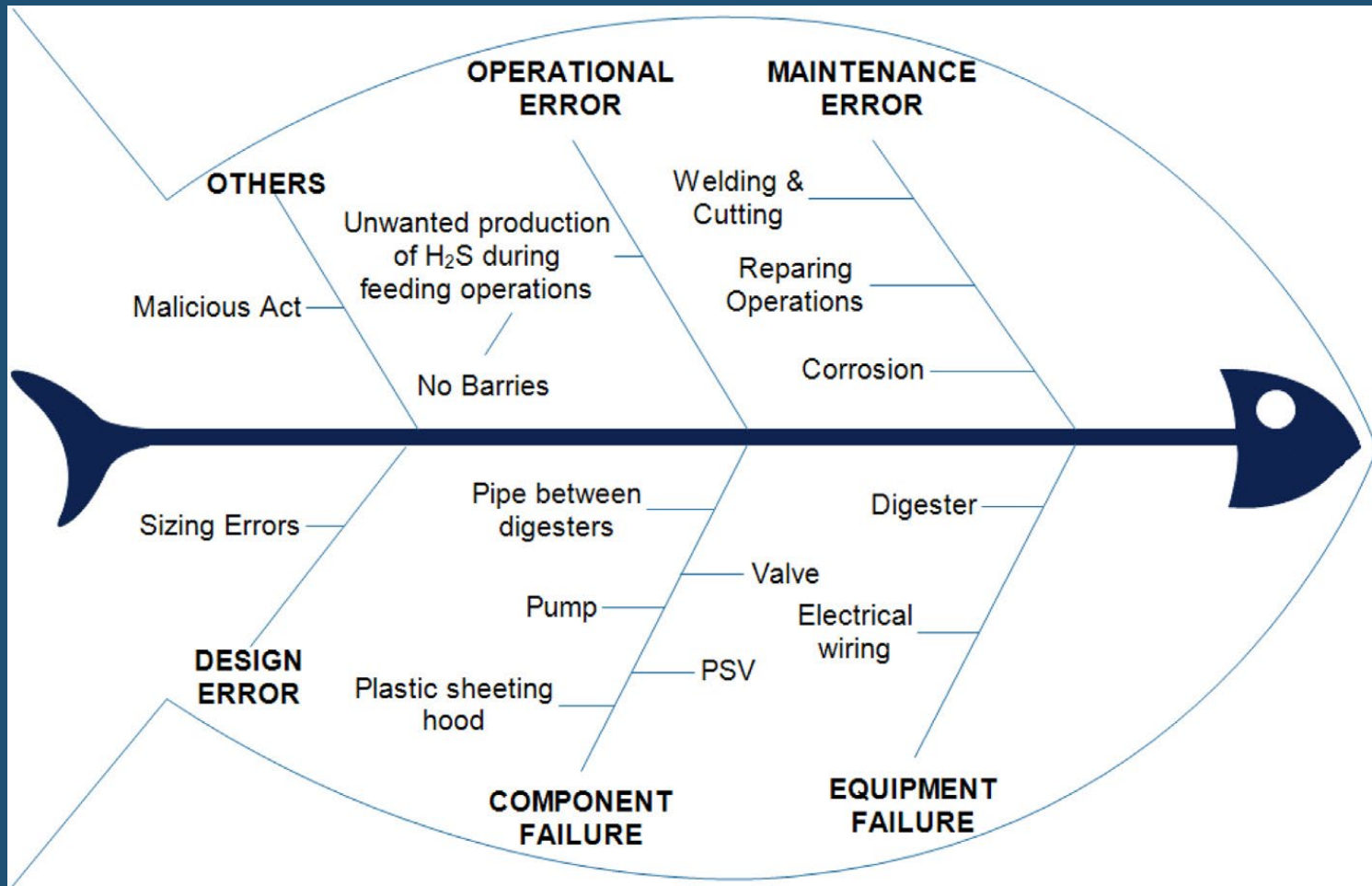
Ni, Unpublished data.

An abandoned household digester in China that claimed 3 lives



Chen, 2015. Deyang Evening News.

Summarized Causes



Casson Moreno et al. 2016. *Renewable Energy*. 96, 1127-1134.

Economic Impact

- Property damage
- Medical expense
- Loss due to death, burial costs
- Loss of earnings or business
- Loss of employment and benefits
- Replacement service loss
- ...

Two examples

- An incident in Thailand (2/25/2011 Chaiyaphum Province):
~ US\$ 670,000.
- An explosion in China (2018):
US\$ 584,495, but not clear if the deaths of three workers were included.



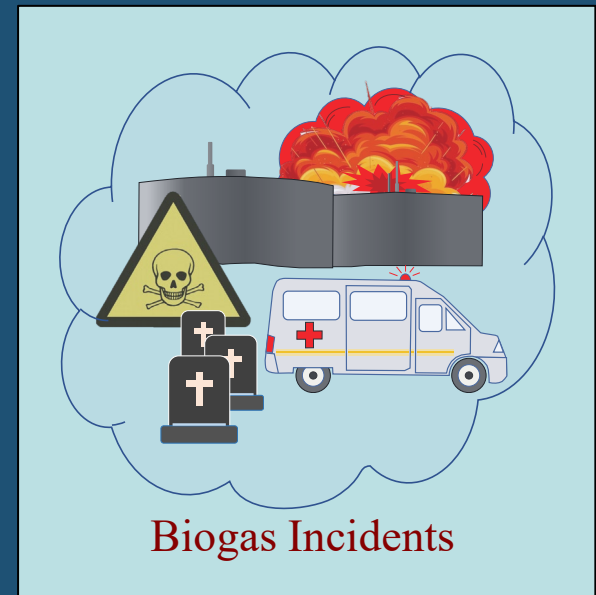
Three people in a family died in this covered lagoon digester in 2019 in Thailand.

https://www.thairath.co.th/news/local/south/1580255?fbclid=IwAR3wGctDO7UxZxeY3_IPkBRTwwK9krGoxGAF18qrW532YAn7whIm41eBs_I

Individual and Family Impact

Death and/or injury causes:

- Emotional trauma and mental health problem.
 - Suffering from injuries.
 - Loss of family supporter and social welfare.
 - Decrease in quality of life.
 - Altered family dynamics and relationships.
-
- No systematic study was found.



Social Impact

- Shock waves in local community and beyond.
 - Negative images of biogas technology.
 - Depression of employees and work fellows.
 - Political turmoil.
 - Follow-up safety measures.
-
- No systematic study was found.

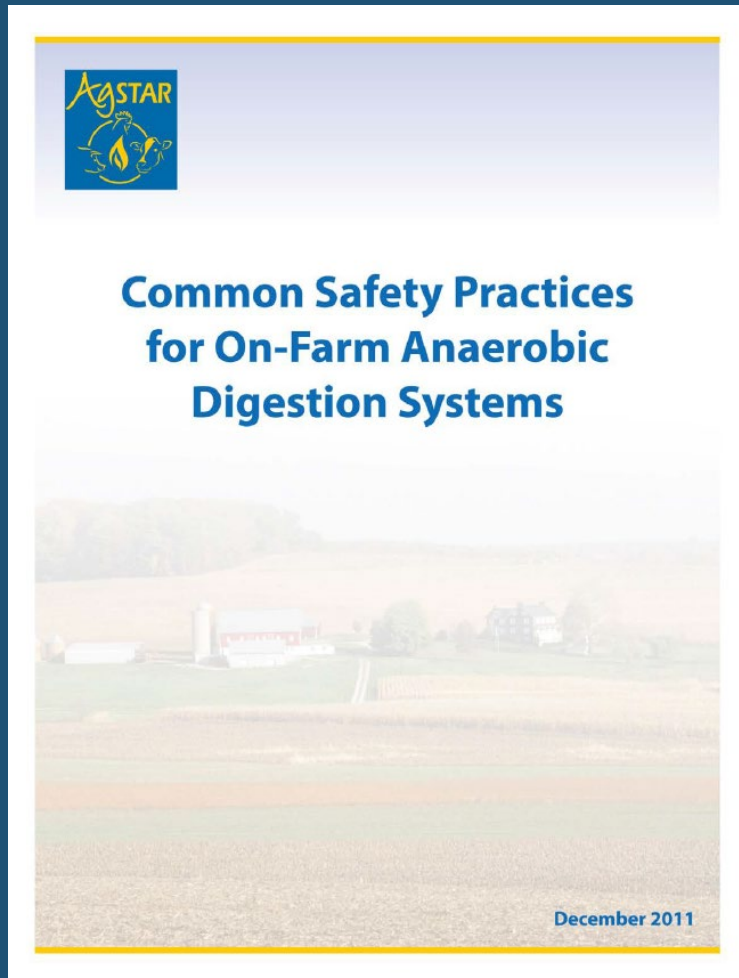


<https://www.lcasp.org.vn/vi/news/phong-tranh-su-co-tu-ham-biogas-314.html>
<https://www.lcasp.org.vn/vi/news/phong-tranh-su-co-tu-ham-biogas-314.html>

Key Recommendations

- A high level of safety is built into the processes.
- Ventilation systems are fit for purpose.
- Take account of potential for biogas accumulation.
- Process control systems in biogas handling areas are fit for purpose.
- Safe vehicle movements are factored.
- Give more attention to integrating and optimizing design and control systems.

AgSTAR – AD Safety Practices



AgSTAR Biogas Toolkit

The U.S. Environmental Protection Agency (EPA) Biogas Toolkit serves as a centralized knowledge hub for biogas project stakeholders. The toolkit is designed to allow stakeholders to search and browse for information and resources that meet their specific project needs.

<https://www.epa.gov/agstar/biogas-toolkit>

Conclusions

- Actual cases are believed more than what were reported.
- Cases in Europe, USA, and Asia had their own characteristics.
- Most of the cases in Europe and USA were explosion and fire.
- No much detail is available for the U.S. cases.
- Acute hydrogen sulfide poisoning caused most of the deaths and injuries in Asia.
- Most accidents occurred during maintenance and repair of digesters.
- The accidents resulted in large impacts, which need more studies.
- Safety practices are critical to mitigate the risks.