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Review

Review on the Evaluation of the Impacts of Wastewater Disposal in Hydraulic Fracturing Industry in the United States

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Abstract: This paper scrutinized hydraulic fracturing applications mainly in the United States with regard to both groundwater and surface water contamination with the purpose of bringing forth objective analysis of research findings. Results from previous studies are often unconvincing due to the incomplete database of chemical additives; after and before well-founded water samples to define the change in parameters; and specific sources of water pollution in a particular region. Nonetheless, there is a superior chance of both surface and groundwater contamination induced by improper and less monitored wastewater disposal and management practices. This report has documented systematic evidence for total dissolved solids, salinity, and methane contamination regarding drinking water correlated with hydraulic fracturing. Methane concentrations were found on an average rate of 19.2 mg/L, which is 17 times higher than the acceptance rate and the maximum value was recorded as 64.2 mg/L near the active hydraulic fracturing drilling and extraction zones than that of the nonactive sites (1.1 mg/L). The concentration of total dissolved solids (350 g/L) was characterized as a voluminous amount of saline wastewater, which was quite unexpectedly high. The paper concludes with plausible solutions that should be implemented to avoid further contamination.

Keywords: surface water; groundwater; methane gas; salinity; total dissolved solids; contamination

1. Introduction

The number of natural oil and gas well services in the USA up to 2019 was over one million (U.S. Energy Information Administration (EIA) 2019) [1–3]. Natural gas extraction by hydraulic fracturing as well as horizontal drilling has advanced the U.S. gas economy by altering the global energy markets in the country, leading toward reasonable natural gas and oil prices [4–8]. Hydraulic fracturing, also known as fracking, is a method of drilling used for extracting petroleum, mostly oil, and gas deep in the soil. In the process of fracking, a mixture of water and sand as well as chemical additives are thrust into wells under high pressure to make cracks and fissures in rock formation [9–11]. Throughout the hydraulic fracturing process, up to four million gallons of water-based mixture fluid is injected into a single well to begin and increase fractures as well as to transport the proppant, of which 10–70% is recovered as flowback afterward [12–16].

Apart from flowback water, produced water, which is the largest quantity of waste product, is also generated during the hydraulic fracturing process. In 2009, more than 70 billion barrels (annually) of produced water was reported globally, among which, the U.S., itself produced 21 billion barrels.

In the formation of produced water, there are two processes that are involved. At the beginning, the underground water near the oil and gas deposits reaches into the extraction region due to pressure abatement. The second process commits, while injecting the water into the subsurface oil fields to explore oils to the surface. During the hydraulic fracturing oilfield exploration, these two processes merge to produce wastewater [17]. In the fracturing industry, the volume of produced water (PW) increases with the age of the gas and oilfields. Produced water (PW) contains 80% of the waste and residuals generated during the hydraulic fracturing exploration. Produced water has distinctive characteristics, having inorganic and organic components along with dissolved and dispersed oils and grease components. Naturally, produced water contains heavy metals, dissolved gases, treating chemicals, radionuclides, scaling products, and microorganisms that create the microbial corrosion process into the pipes, etc. [18,19].

Although hydraulic fracking was first introduced in the early 20th century, up to the mid to late 1940s, it was not commercially used. To raise the productivity of shale gas from unconventional sources like coalbeds, shale, and tight sands as well as in the application for extraction from conventional sources, this is a standard procedure. For drilling, almost 90% of all oil and gas deep wells use the hydraulic fracturing technique in the United States. The availability of data, however, is insufficient to prove this estimate [20]. Dealing with hydraulic fracturing, wastewater disposal, and the overuse of fresh water in each well are currently the major concerns with hydraulic fracturing [21–23]. Depending upon the rock formation and other biological and physical parameters, the hydraulic fracturing process varies from well to well. Approximately 17,000 m^3/day of fresh water is used in each well for the drilling process [24]. Due to the high levels of radioactive materials, extremely toxic metals, and salinity, which are often present in the waste fluids, therefore, ensuring the safety of the disposal of large amounts of liquid as the waste correlating with shale gas and oil production has become a largescale challenge [25–31].

The reasons for the problems faced during different states that have been reported: contamination of drinking water, leaks in wastewater storage ponds, dumping a petroleum based product in the stream, dumping toxic products in the stream, pit leaks and corroded tanks, hundreds of oilfield spills and thousands of waste disposal, hydraulic fracturing drilling, significant increases in the acceptance levels of methane, total dissolved solids (TDS), salinity, ethane, propane etc. The impact of the problem ranged from water discoloration and malodor to posing adverse health risks for humans, plants, and animals. For example, individuals experienced rash and in one state, it was reported that young children with their parents were adversely affected with neurological symptoms [28–32].

Hence, the strategy of this study was to present some effective research findings concerning the hydraulic fracturing with respect to both the surface and groundwater contamination. Existing outcomes on the topic fall within a broad spectrum. There have been some assessments that carefully validate that hydraulic fracturing has no connection to groundwater or surface water contamination, and that even the reduction of freshwater resources and that regulations are too stringent [32–36]. On the other hand, studies propose a definite interrelationship of hydraulic fracturing to groundwater contamination and the depletion of freshwater resources and that the regulations are not strict enough [37–40]. This paper will present a summary and evaluation of the environmental impacts of hydraulic fracturing wastewater disposal or spills in shale or natural gas well reservoirs, with examples from multiple basins. The basic objectives of this report are as follows: (i) summarize research findings linking the impact of hydraulic fracturing operations on both surface and groundwater quality; (ii) address specified case studies on operational incidents; and (iii) propose research findings for possible solutions regarding the impact of operations.

2. Literature Review

There are five stages of the hydraulic fracturing water cycle (Figure 1) and each stage has its own designated activity involving water that upholds hydraulic fracturing. The steps and major activities include: (i) the first stage, to produce the fluid mixture for hydraulic fracturing, the systematic approach of the withdrawal of water resources (groundwater and surface water) is called water acquisition; (ii) chemical mixing is the second stage where the mixture of a water, proppant, and additives at the fracturing well site is made for hydraulic fracturing; (iii) the third stage, which is called the well injection stage, is where the hydraulic fracturing fluid is injected and the movement of the fluid is monitored carefully when it goes toward the set rock formation; (iv) handling of produced water where the on-site collection of water is maintained, particularly the handling and transportation of water for reuse, recycle, and restoration as well as pipeline breaks during the produced water transport can sometimes significantly contaminate the sources of water and nearby land resources; and (v) wastewater disposal and reuse is the final stage where the disposal of produced water and the hydraulic fracturing wastewater reusing activity is monitored. The last engineering step includes the disposition of wastewater through underground injection, wastewater treatment supervised with reuse, or whether it is in an allowable situation to discharge to surface waters or water bodies, and finally continue with the disposal through percolation or evaporation pits [41].

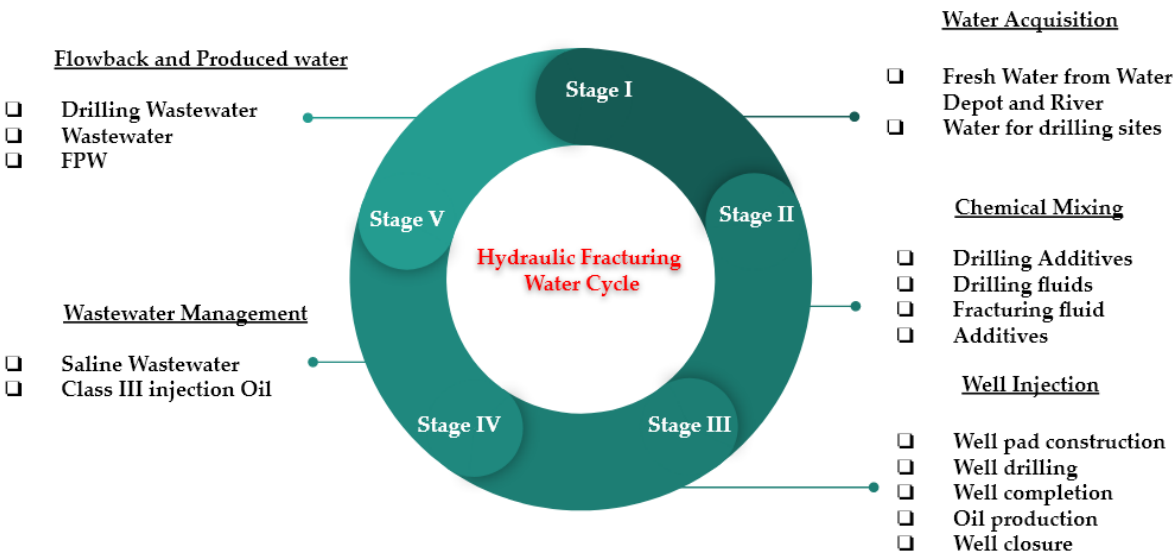

Figure 1. The five stages of the hydraulic fracturing water cycle and the consumptive and non-consumptive water use for oil production [41,42].

Due to the consumptive and non-consumptive water use for oil production from the Bakken shale potential water impacts, North Dakota is presented in Figure 1. It is evident that the impacts on water resources could be affected due to the oil development through the possible ways: as a result of poor well casing or wastewater storage design; hazardous chemicals and produced water will infiltrate into the ground from evaporated or percolation pits in Stages I, II, and III; meanwhile, water and land resources can be contaminated due to pipeline breaks during wastewater transportation; untreated or unmanaged wastewater can contaminate receiving water bodies at Stage IV; and both surface water and groundwater contamination can occur mainly due to surface spills as well as leakage during treatment, storage, and treatment at Stage V and later on.

This paper only focused on the final stage of hydraulic fracturing, which impacts the wastewater disposal on the environment. Impacts on drinking water resources is one of the key factors with respect to the hydraulic fracturing process. Discharges of partially treated or sometimes totally untreated wastewater into the surface and leaks, unwanted spills, and percolation affiliated with pits cause major damage. Other components of impacts include improper and mismanagement of handling residuals, sludge from the pits or tanks and leaching as well as runoff from different aspects of wastewater practices regarding the hydraulic fracturing process. These directly affect the surface and ground water contamination. Unlined pits and compromised liners cause major damage to the environment.

The constituents with the greatest attention with regard to the environmental impact in this paper included total dissolved solids (TDS), methane contamination and salinity as well as several organic and inorganic constituents of concern [3,40,43–46].

The literature review provides findings and opinions on hydraulic fracturing with respect to both the surface water and groundwater quality. The review of this literature utilizes peer-reviewed journal articles, official websites, and government (e.g., the U.S. Environmental Protection Agency) publications to convey objective information on hydraulic fracturing impacts with respect to these topics. Multiple tables have been created to explain the whole scenario of current hydraulic fracturing issues. The tables were selected based on different variables, namely, state, year, informer, location, company owned, source, reason, impact, and the level of impact. Incidents from Texas, Arkansas, Colorado, Michigan, Wyoming, New Mexico, North Dakota, New York, Pennsylvania, Virginia, West Virginia, and the other states were also added to make this table. The data were collected for the years from 2007 to 2018. Since thousands of companies have been involved in hydraulic fracturing activities, it is difficult to obtain the available information of all the company's wastewater disposal activities. However, from the available data, founder or company names have been given in the tables.

3. Discussion

3.1. Impacts from Wastewater Disposal

Tables 1 and 2 represent a comprehensive scenario of the current hydraulic fracturing incidents. The tables were selected based on different variables, namely, state, year, informer, location, company owned, source, reason, impact, and the level of impact. The risks associated with the outstanding utilization of the hydraulic fracturing process vary greatly from one state to another according to the geology of the reservoir and the hydrogeological conditions of the overlying aquifer systems [47]. Informer names like the house owner or landowners were also added to the tables. The name of the companies responsible for their well are also listed. Thousands of companies have been involved in hydraulic fracturing activities, but it is difficult to obtain the available information of all the company's wastewater disposal activities. Many hydraulic fracturing companies have been banned while doing their job and others have been given citations or warnings for the greater good. The reasons for the problems faced in different states that have been reported are: contamination of drinking water, leaks of storage ponds that were used for deep well injection, dumping a petroleum based product in the stream, dumping toxic products in the stream, pit leaks, and corroded tanks, hundreds of oilfield spills and thousands of waste disposals, hydraulic fracturing drilling, methane or stay gas contamination due to the similar properties of methane products like ethane and propane contamination as well as a high level of iron and the presence of manganese, etc.

The tables summarize the causes for the associated issues. Potential reasons are contamination from hydraulic fracturing fluids consisting of salts and hazardous chemicals, contamination from produced water constituents, aquifer contamination through natural gas drilling wells, leakage in cement casings, abandoned wells with constituents left inside, deep inside the formation waters, or produced water where gas and saline flows, and contamination through the leaking of fracturing wells. The concentrations of benzene products like xylene and toluene are recorded in the table. Gasoline and diesel products have a significant impact that is also addressed in the table. Methane, ethane, different hydrocarbon products and byproducts, and after measuring the water quality, high pH presence were also monitored and reported in the table.

Table 1. Ground water contamination.

Location	Event	Impact	Level of Impact	References
Center Ridge, Arkansas	Dumping toxic products in the stream (2008)	Water smelled bad, had sediment in it with color turning into brown and the water pressure changed.	High salinity (3500–25,600 mg/L) as well as VOCs	[48]
Silt, Colorado	Well blow-out that makes ground water contamination, four nearby natural gas wells (2001)	Wastewater from industry made the contamination on drinking water during hydraulic fracturing, the color of the drinking water turned into gray, reported to have a very strong smells, water pressure was lost while having bubbles.	High salinity (111,000–120,000 mg/L)	[20]
Huerfano County, Colorado	Pump house exploded, methane seepage developing from some wells (11 natural-gas wells) within a mile distance (2007)	Methane gas seepage arising from more than 11 natural-gas wells less than a mile, Several trees like Cottonwood and Pinyon were found dying, along meadowland; Divide creek, which is situated in western Colorado runs along 60 acres of area, was found bubbling.	Methane concentration found 64 mg/L	[49]
Las Animas County, Colorado	Production of Methane at an escalating rate (2010)	Three monitor wells on the ranch on Las animus County are the source of contamination, it had a history of running clear water for years, now, it is reported that the water turned graying brown with murky in about 500 gallons to be approximate.	The average concentration of methane was 28–35 mg/L	[50,51]
Granville Summit, Pennsylvania	Significant increases of methane, as well as hydrocarbons like ethane, propane, manganese and iron (2012)	Clarity and color has changed dreadfully in water, drinking water had reported to have a foul odor, not only that but also contained prominent levels of methane gas, and might matured into volatile. Furthermore, several properties near the creek began to witness bubbling all around at their water.	High salinity (60,000 mg/L) with concentrated methane (64 mg/L)	[52]
Bradford County, Pennsylvania	Gas well Blew out, methane and other contaminate concentration was really high in level (2011)	Ground water Contamination happened, tap water turned gray and hazy, rashes at a very high level was seen with oozing blisters, and due to the nausea and severe headaches, one poor child was hospitalized for nosebleeds (torrential) which was for a long time	High salinity (180,000 mg/L) with concentrated toluene 110 mg/L	[53]
Susquehanna County, Pennsylvania	Wastewater from wastewater treatment well creates methane gas contamination as well as salt and chemical contamination from hydraulic fracturing fluids and/or formational waters (2010)	One child had neurological symptoms consistent with exposure to toxic substances.	Methane concentration >64 mg/L	[53]
Bradford Township, Pennsylvania	Due to brine spilled, drinking water of at least seven families has been contaminated (2009)	One household contained 2-Butoxyethanol or 2BE, a common drilling chemical, which is known to have caused tumors in rodents.	High Salinity (150,000–180,000 mg/L)	[54]

Table 1. *Cont.*

Location	Event	Impact	Level of Impact	References
Hickory, Pennsylvania	After starting the Natural gas well Drilling, Pipe Blowout (2009)	Water became cloudy and foul-smelling. Measurement have found, a chemical named Acrylonitrile which was used in hydraulic fracturing process.	Methane concentration >64 mg/L	[55]
Bradford County, Pennsylvania	Methane gas contamination near the shallow aquifer that started from the targeted shale gas pattern through leaking well casing (2010)	The color of Water turned black and developed into combustible from the methane contamination	High Salinity (60,000 mg/L) with concentrated methane (64 mg/L)	[56]
Wise County, Texas	Pipe leaks, unlined pit (2010)	Water became flammable	Methane concentration 34 mg/L	[57]
Tarrant County, Texas	Pipe Blowout, pit malfunctioning (2010)	One of the property owner's water turned significantly dark black and presence sedimentation or sand has been observed	pH found 5.6	[58]
Virginia	Shallow aquifer contamination by methane gas had spotted, there was leaking in hydraulic fracturing oil and gas wells casing (2007)	Murky water with oily films had been noticed, black sediments, methane, and diesel odors. Individuals experienced rashes from showering	Methane concentration ranges from 34–64 mg/L	[54]
Buchan, Virginia	Ground water contamination by methane gas that begun from intermediate geological formations through annulus leaking of either shale gas or conventional oil and gas wells (2010)	Black sediments, Methane and diesel odors.	pH reduces from 7.5 to 4.5 with a high salinity 60,000 mg/L	[58]
Dickenson, Virginia	Methane gas contamination of injection wells through leaking (2009)	Individuals experienced rashes from showering	Methane contamination of 34 mg/L	[54]
Jackson County, West Virginia	Pipe Blowout, pit malfunctioning, aquifer contamination (2011)	The property owner informed of having "a peculiar smell and taste" in their water and suffering from the neurological symptoms was reported by the parents as well as children	Chloride (Cl^-) concentration >60 mg/L	[58]
Marshall County, West Virginia	Methane Contamination (2010)	Fracturing well has reported getting some gas in it. Some families also lost their source of drinking water in that well.	Concentrated methane concentration found 34 mg/L	[58]
Small town of Pavillion, Wyoming	Poor cementing and casing leak (2011)	The color of the drinking water had turned black with a very bad smell and taste, Individuals who admitted in hospitals reported that the reason was water contamination.	Total Dissolved Solid (TDS) > 250,000 mg/L	[28]

Table 2. Surface water contamination.

Location	Event	Impact	Level of Impact	References
Bee Branch, Arkansas	Significant drinking water contamination in nearby fracturing well (2008)	Domestic water found smelling really bad, water color turned yellow as well as filled with silt	TDS = 250–350 g/L and salinity > 35 g/L	[59]
Pangburn, Arkansas	Drinking water contamination due to natural gas well (2007)	Very light and kind of slick, water turned muddy and contained particles and composed pieces of leather.	Significant amount of Iron (Fe), Manganese (Mn), Bromine (Br) were found	[60]
Bee Branch, Arkansas	Nearby drilling well Leaks of wastewater storage ponds that likely were worked as a deep well injection (2009)	Not only the water pressure changed but also the drinking water significantly turned cloudy and grey and had bad odors.	TDS = 250–350 g/L and salinity > 35 g/L	[59]
Center Ridge, Arkansas	Nearby natural gas well Dumping a petroleum-based product in the stream (2007)	Changes in water pressure had recorded and water color turned red or orange and clay was observed in it after hydraulic fracturing had started	TDS > 400–600,000 mg/L and salinity > 35,000 mg/L	[59]
Rapid River Township, Michigan	Senske Well near the Rapid river area had a significant change in static water level (lowered by around 11 feet) (2013)	People had to experience a drop in water pressure as well as discolored water	Benzene = 0.01 mg/L,	[59]
Seneca County, New York	Contamination of drinking water had been noticed due to the unwanted disposal of partially treated wastewater to neighboring streams (2007)	Water color turned grey and had a lot of sediments in it	TDS >110,000–120,000 mg/L and salinity > 40,000 mg/L	[61,62]
Allegany County, New York	Contamination of drinking water due to the leaks found in the storage ponds of hydraulic fracturing well (2009)	The water turned "foamy, chocolate-brown".	TDS > 110–120 g/L and salinity > 40 g/L	[61,62]
North Dakota	There was a combustion activity in one of the oil pitch in North Dakota, Pit leaks and corroded tanks, Hundreds of oilfield spills and thousands of waste disposal (2011)	After hydraulic fracturing had started, serious health symptoms not only in humans but also in livestock and pets was noticed	TDS = 300 g/L and salinity = 47 g/L	[63]
Bainbridge Township, Ohio	An blowout of a fracturing well and because of that almost 22 drinking water wells got contaminated (2007)	The frac communicated directly with the well bore and was not confined within the "Clinton" reservoir	Benzene = 0.01–0.05 mg/L	[61,62]

Table 2. *Cont.*

Location	Event	Impact	Level of Impact	References
Allegheny Township in Potter County	Disposal of inefficiently handled wastewater to the nearby water bodies and inflation of contaminant residues in hydraulic fracturing drilling sites	Water turned brown	Fe = 22.3 mg/L, Mn =15.8 mg/L	[61,62]
Washington County, Pennsylvania	Wastewater treatment well, Contamination of drinking water (2009)	Arsenic level was found at 2600 times than the acceptable levels, on the other hand benzene level was found at 44 times above the acceptance level, naphthalene was found five times higher where mercury and selenium were found significant numbers than the allowable limits.	The level of arsenic was 2600 times higher than the acceptable levels, Benzene was 44 times higher, naphthalene five times higher, and last but not least, mercury and selenium were also higher than the official limits.	[59]
Gibbs Hill, Pennsylvania	Brine Spilled, the drilling company had a poor management of wastewater and spilled significantly hydraulic fluids which contaminated the water supply badly (2008)	Due to the spilled, the water had a serious strong fumes, which made burning in peoples lungs and mouths, sinuses even though after showering,	**Strontium (Sr)** = 774 mg/L **Lead (Pb)** = 3.50 mg/L,	[64,65]
Wise County, Texas	Hydraulic fracturing well was nearby the two properties, who's drinking water got contaminated and after having analyzed a carcinogen compound benzene was found double the acceptance level (2010)	The water was hurting people's eyes during showers, and some of their pets refused to drink whenever they offer the water	Benzene = 0.10 mg/L, Toluene > 5 mg/L	[66]
Grandview, Texas	Surface water contamination, Water testing found toluene and other contaminants (2007)	Strong odor had been found with the change on water pressure as well as skin irritation with rashes and dead husbandry	TDS >400–600 g/L and salinity > 35 g/L	[59]
Johnson County, Texas	It is reported that hydraulic fracturing wells nearby Scoma home, had benzene and petroleum by-products which made the water contaminated (2011)	Drinking water turned orange-yellow color, foul odor with very bad taste	Toluene = 5 mg/L, Benzene = 0.01 mg/L, Xylene = 15–20 mg/L	[67]

Table 2. *Cont.*

Location	Event	Impact	Level of Impact	References
South Texas, Texas	Surface water contamination, Surface spills (2009)	Water pressure changing had observed by a property owner as well as water color changes had been noticed. Fish were dead, abnormal milk production by husbandry as well as new born babies with unusual birth signs	TDS > 600 g/L and salinity > 30g/L pH reduces from 7.5 to 4.5 Conductance found > 1500 mS/cm	[61,62]
Northeast, Texas	Blew out some casing, higher level of benzene was fond which is also a carcinogen element, 2010	Bad smell and discolored water had been observed which smells like diesel	Benzene = 0.1–0.7 mg/L	[61,62]
Texas	Drinking water contamination, although the hydraulic fracturing well was abandoned long ago (2011)	Drinking water became foamy, oily with bad odors were reported	TDS >110–120,000 mg/L and salinity > 40,000 mg/L	[61,62]
Johnson County, Texas	Carbon, Hydrocarbons as well as diesel fuel elements was found in surface waters where hydraulic fracturing were performed nearby the residents house	Foul odor with bad taste, slick to the touch and oily feeling had been reported.	Pb = 10.50 mg/L were present in the water	[68]
Denton County, Texas	This county had a significant surface water contamination. After the testing hazardous metals such as Chromium, Calcium, Cobalt, Arsenic, Lead, Manganese, Vanadium etc. were found with high numbers than the acceptable level (2008)	In 2008, it was reported that the water started to contaminate soon after that county had permitted to do hydraulic fracturing activity. Grey water with sediment had noticed in the drinking water sample	Cl = 120,000 mg/L, Br = 558 mg/L, Na = 45,000 mg/L, Mn = 16.7 mg/L, Zn = 12.5 mg/L, Pb = 0.6 mg/L, Fe = 19.2 mg/L	[63]
In Wetzel County West Virginia:	Contamination of drinking water, leaking (2010)	Residents had informed that there had been unusual health symptoms such as mouth sore and rashes with illness in their husbandry	TDS >250 g/L and salinity = 30–40 g/L	[54,69]
Powers Lake, North Dakota	Saline Wastewater, Brine spills (2016)	Missouri River and lake gets contaminated	TDS level = 300.0 g/L and level of salinity = 47.0 g/L	[63,70]

On the other hand, a significant amount of TDS, conductivity, pH, alkane products (methane, ethane, and propane) have also been reported. The TDS content of produced water was recorded as a seven times higher level of saline content than the usual seawater, although this depends on the formation of the shale, which ranged below seawater (concentration around 25,000 mg/L). Shale formations can have higher TDS values that can range by almost an order of magnitude [71–73].

Due to the leak, spills, and unwanted release of hypersaline content, the inorganic quality of surface water becomes significantly contaminated. This incident is very common in the flowback and produced water stage. The flowback and produced water brines consist of a higher concentration of salts like chlorine and bromine. It also contained alkaline earth elements like barium, strontium, etc. Metalloids like selenium, arsenic, etc. as well as radionuclides (e.g., radium) are also present as a dangerous constituent of flowback and produced water. In the treated wastewater effluent, sometimes, the concentration of chemicals stayed at a higher level than anticipated. For example, the concentrations of Cl, Br, Ca, Na, and Sr, which is considered as a major element, could vary even a full length sampling of the two-year period [74]. The result could range up to a 6700 times higher level than the concentrations previously measured upstream at the water body sites. In our study, from Tables 1 and 2, the chloride effluent in wastewater concentrations ranged between 55,000 and 98,000 mg/L (around 2−5 times higher than the seawater concentration). Additionally, major supervision is needed for epidemiological studies to determine the possible adverse health effects of hydrogen fluoride [75–79].

3.2. Potential Solutions and Future Directions

Given the highlighted risks regarding gas and oil development using hydraulic fracturing, in the U.S., mitigation techniques are a major necessity to pinpoint, evaluate, and alleviate the possible risks affiliated with the procedures of transportation, wastewater handling, in site storage, and disposal of drilling or fracturing related fluids that need to be in place. Hence, we scrutinized several conceivable ideas that could be relevant to some of the addressed issues.

Methane gas contamination has been observed and mentioned in previous peer review journals, where drinking water resources were affected the most in locations less than 1 km from the active drilling sites [60]. Imposing a safe zone of 3 km (or around 2 miles) between future or already installed shale gas and oil drilling sites and previously existing drinking water wells could mitigate the risk of methane gas contamination. Second, there is always a toss-up situation in a sense as to whether shale gas development is directly responsible for producing the methane gas in drinking water resources or whether natural gas occurs naturally in the drinking water. Baseline monitoring should be addressed as compulsory work in this particular case so that it can also be incorporated with geochemical techniques. For example, collecting the data of major and trace components in surface and ground water, recording the methane concentration accordingly, measuring the stable isotopes of methane for satisfactory identification of the chemicals that are in use and the composition of isotopes for the regional or local aquifers mainly in the areas of shale gas and oil development should be the priority. Chemistry of the production gas, followed by the baseline data with data generation, must become accessible not only to the researcher or scientific community, but also to the locals as well as used to assess the cases where surface or ground water contamination has a higher possibility of occurring.

Third, data transparency and sharing, along with full acknowledgment of all the chemicals used as hydraulic fracturing chemicals must be ensured to create an open space for scientifically discussion of ideas and proper solutions that might mitigate future legal and social confusions. For the sake of wastewater management, implementation of a zero liquid discharge policy for treated and untreated produced wastewater and enforcing sufficient wastewater treatment technologies might mitigate surface and groundwater contamination. Best management practices have become a necessity for establishing a variety of fracking operations and lengthy processes at natural oil and gas production locations, which includes secondary containment management, fluid transfer or transportation, waste collection, and unwanted or accidental spill control and cleanup.

Frac pad liners or containment pads, berms on hand, and fully covered storage units should be a priority by creating a borderline to prevent the migration of fluid and sediment [80]. Spill containment berms can easily be fit under leaking valves, storage vessels, and machinery. Oil-absorbing booms can be handy for securing spills that might crack the boarders of frac pad liners or containment pads, which can prevent spilling for a longer time if the property is ultra-violet resistant.

According to the case studies in the USA, transferring, disbursing, and blending chemicals develop spill potential even though the containers are on the containment pads. Restricting the entrance of workers and vehicles as well as leaving hydraulic fracturing drilling locations by capturing fracturing liquid everywhere and generating slip hazards by cleaning minor spills with the containment decks before these materials could be properly vacuumed. To boost the coverage and sump capacity, decks can be used separately or connected to other decks or by expanding portable containment pools under hose connections where leaks might occur as well as other locations to stop leaking. Pools can fill up the leak quickly and some of these can hold more than 300 gallons [80]. This is very handy as most of the pools can be dredged to be cleaned and restored for further use.

To reduce groundwater and drinking water contamination, waste and other chemicals at each well location need to be perfectly handled. By using drum funnels, the violation of hazardous waste regulations can be avoided. To collect non-bulk liquid waste drum funnels are good options. These drum funnels can easily clamp to manage liquid containers whether it is closed and in compliance. These funnels have extra vents that can regulate vapor emissions and really shorten the fluid transfer time. There are some solid waste drums that have open head options, and using secure lids for these can be used as a preventive measure as these drums can be opened and closed regularly. On the other hand, lid gaskets maintain an unyielding seal and diminish volatile emissions.

To remove high amounts of TDS, mechanical vapor compression (MVC) is a very unique and effective technology compared to other existing methods [81,82]. Desalination of produced water by MVC minimizes the higher complexity of treatment and emissions of the waste stream [82]. This technique is very economical and can recover oil almost four times compared to the other techniques [83]. Membrane distillation (MD) is another desalination technology that is specifically suitable to desalinate higher salinity sources, especially produced water [84–88]. MD is an advanced separation technique that separates the feed stream from the microporous membrane that is hydrophobic [85,86]. To get the best out of MD, pre- and post-treatment steps should be maintained and monitored carefully [87,89]. Forward osmosis (FO), which is a separation process, removes TDS from the produced water [90,91]. Compared to the other existing technology, it is very advantageous due to its osmotic pressure driven methodology [92]. FO membranes are good for removing TDS and TOC from high salinity produced water [93].

In the membrane distillation process, a mixture of microbubble treatment after filtration was tested as highly efficient for removing heavy metals [56,94–96], although pretreatment is necessary before discharging the heavy and radioactive material to advanced treatment. The removal of radium and metals such as calcium, barium, strontium, and barium has been proven by mixing the flowback and produced water with acid mine drainage technology, and by doing so, precipitating newly formed solids such as barite [69,97–101]. Arsenate and selenite can be removed by zero-valent iron mechanism [102,103].

Biosorption on hydraulic fracturing water wastes and by-products has been analyzed as a legitimate substitute to the current techniques practiced for hazardous and toxic metal ions and organic nutrient removal from wastewater streams [104]. Sugarcane bagasse, rice husk, watermelon rind, walnut tree sawdust, banana peels, etc. are some of the adsorbents that can be used to properly remove heavy and toxic metals like Cu (II) Ni, Cd, and Pb [105,106]. On the other hand, sugarcane bagasse, sawdust, wheat straw cotton stalk, and banana peel are good adsorbents to remove organics and nutrients like gasoline, n-heptane, ammonia, phenol, and phosphate, etc. [107–109]. Another lignocellulosic material, Spanish broom, has made a useful impression for the scientific community as an adsorbent to remove mercury from contaminated water sources with a removal efficiency of

86% [104,110–112]. Endocrine disrupting compounds, for example, Bisphenol-A, etc. can also be removed using surface modified cellulose fibers [113].

4. Conclusions

Inconsistent reporting on how spills occur within a state will lead to contrasting decisions between inquiries or studies because it varies from analyst to analyst. The hydraulic fracturing spill data disclosed here are not necessarily covered by the integrated life span of the hydraulic fracturing well; the spotlight is only on spills occurring near the fracturing well pads, during the transportation of additives to a well pad, and the transportation of generated wastewater for disposal by truck or injection lines. It is crucial to put the proper planning in the right place and for a mandatory supply of materials or products ready to control and clean up the hydraulic fracturing spills. Downplaying the spill response interim and scaling down the environmental and social impacts, while advancing and closely maintaining spill prevention regulations and countermeasure planning to restrict releases to nearby waterways. However, even after using the best hydraulic fracturing wastewater management options, the severity as well as the frequency of the environmental impacts are unidentified and unquantified. Characterization of wastewater and sampling has to be done in a significant way so that it can resolve the concerns of the analyst. The amount of wastewater generated and its proper nature requires a necessary careful consideration of handling, after extraction treatment, reuse, recycle, or disposal to secure water bodies and water resources. Decisive and persistent waste generation data collection and baseline data reporting for researchers and the public should be accessible for the greater good. Along with improved endeavors to define and characterize the quality of wastewater for both treated and untreated samples, methodical and efficient monitoring exercises should be practiced to detect the impacts on drinking water resources.

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