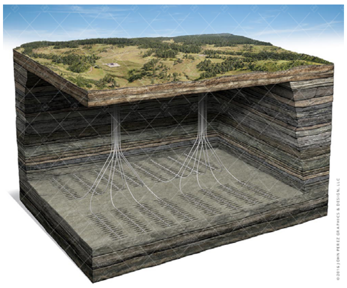

A BRIEF LOOK ON THE ENVIRONMENTAL EFFECTS OF SHALE GAS EXTRACTION

by Fatih Temiz

ABSTRACT

Shale gas can still be considered as one of the hot topics today. Some people believe in the pros of the subject, whereas some others stand on the cons' side. Each party is firmly supporting their own side of the story. It is possible to express that there is more to the researches that are needed to determine the math about shale gas. The question of "Are we experiencing a shale gas revolution or is it another earth polluting source of energy?" is yet to be answered.

"Shale gas can still be considered as one of the hot topics today. Some people believe in the pros of the subject, whereas some others stand on the cons' side."

INTRODUCTION

Geology, current technology, accessibility, transportation alternatives, demands, and effective prices all affect the hydrocarbon market. Natural gas extraction takes its share from recent world events as well. It was 1821 when the first natural gas well was dug in the state of New York in the US (New York Department of Environmental Conservation, 2007). It was not until 1930s that horizontal drilling took place and the year was 1947 when the hydraulic fracturing started in the United States (Stevens, 2012). Shale gas is among the unconventional sources of energy (like coal-bed methane and tar sands) and extraction technologies had their development in progress in 1970s (Clark, 2012).

"An environmental impact and a sustainability assessment are required for any place developing shale gas industries."

Next, it is possible to find in-depth reports about hydraulic fracturing and shale gas extraction. Starting with the report of Stockholm International Water Institute (SIWI), it summarizes the current situation about this hot issue. The report starts by saying it is not yet known if the world is experiencing a so-called shale gas revolution. The total amount of shale gas reserves is difficult to assess and it is still discussed if shale gas can secure energy consumption of countries in the years to come. Like the oil boom in the past, countries such as the USA have started taking advantage of shale gas by taking advantage of this source of energy with the addition of clusters of work opportunities around. Whereas, dread of the possibility of environmental problems sets other countries back from fast exploitation of their shale gas reserves. Hydraulic fracturing is the technology associated with shale gas extraction; there are some findings that this technology brings environmental problems to areas where fracturing is done without regulations. Next, this process's effects are felt in water. Water usage in water-scarce areas of shale gas reserves puts further distress in the hydrology of the area. Additionally, when there is not enough water to run the shale gas production, then this water is needed to be carried from a distance (Hoffman et al., 2014).

The fluid used in hydraulic fracturing is mostly water and the proppant (sand or similar particulate material suspended in water) used – up to 99.5% – and between 5% and 2% is made up of the chemicals used (usually proprietary). The difference in the concentration is due to the differences in the local geology. Correspondingly, acid is an addition to "unclog" the gas reservoir and biocides are used to stop microorganisms from forming in the fractures. Then, more chemicals are added to stop corrosion and scale buildup; viscosity enhancers and chemicals reducing friction are also in the blend (Hoffman et al., 2014).

An environmental impact and a sustainability assessment are required for any place developing shale gas industries. According to European Union's (EU) environmental and public health assessment for the industry, vigorous regulations are needed since the risks are greater than those of conventional natural gas. EU endorses member states to prepare sustainability assessments before permitting shale gas production. Public health assessment, short and long term environmental impact analysis, effects to community and economy need to be considered (Dernbach and May, 2015).

There was mixed feelings from the environmentalist's point of view. Shale gas is supposedly a better alternative than coal. However, the chemicals used during the extraction process pick up some frowns. More to add to the public worries, the composition of these chemicals are usually protected due to commercial reasons.

There are two major prospective basins of shale gas in Turkey – the Thrace Basin and the Southeast Anatolia Basin – as shown in Figure 1 below. These two basins are studied and undergone for exploring oil and natural gas by the state-owned Turkish Petroleum Corporation (TP) and other privately owned local and international companies. U.S. Energy Information Administration (EIA) provides the following map of shale gas reservoirs of Turkey.

TP is leading the hydrocarbon exploration activities in Turkey. The Salt Lake Basin and the Sivas Basin still need to be further explored. There have been limited studies on these two basins. As it can be seen in the map, some large metropolitan areas in Turkey are located in the locality of shale gas basins – Istanbul, Ankara, Edirne, Konya, Sivas, Gaziantep, Hatay, and Diyarbakir. Therefore, the obscurity of the safety or danger of shale gas is a matter of concern.

"Shale gas is supposedly a better alternative than coal. However, the chemicals used during the extraction process pick up some frowns. More to add to the public worries, the composition of these chemicals are usually protected due to commercial reasons."

Figure 1. Shale Gas Assessment of Turkey. (Source: EIA, 2015).

“In the USA, currently, shale gas production is rapidly increasing. It has come to a quarter of the nation’s total natural gas production. Yet, concerns are growing.”

In the USA, currently, shale gas production is rapidly increasing. It has come to a quarter of the nation’s total natural gas production. Yet, concerns are growing. In 2010, a movie showed tap water being set on fire and in 2012, a gossip claiming hydraulic fracturing could intoxicate drinking water of New York was caught up. However, due to unease from public, countries such as France and Bulgaria forbid hydraulic fracturing. Nevertheless, Australia gave the green light to hydraulic fracturing (Clark, 2012).

Breakthroughs in horizontal drilling techniques combined with developments in fracking technology gradually increased the economic feasibility of shale gas and American production started soaring around 2005. This – combined with rising energy prices and increasingly vast estimates of global reserves – led to growing an interest in the unconventional energy source around the world.

“Harmful emissions also include VOCs such as BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) that escape from the equipment used. Benzene is a compound that is known to cause cancer in humans. Natural gas production areas experience higher concentrations of benzene.”

And about the public concerns; popularized method of unconventional gas production surely worries large numbers of the public. Possibility of spillages and leakages, increased wastewater production, water distress and water withdrawals, air pollution, plummeted water quality, impact to the surrounding ecosystems, increased traffic (especially heavy duty machinery and trucks), chemicals used, aesthetic worries, erosion, and earthquakes are some of the probable problems coming to one’s mind while thinking about hydraulic fracturing. This paper will try to bring pros and cons to the reader as it is mostly a literature and press review what opinions and facts are available regarding the subject.

AIR POLLUTION AND THE CLIMATE CHANGE

Air pollution is caused by leakages, maintenance exhausting (as in pneumatic valves, storage tanks, during dehydration etc.), routine processes and transferring the natural gas. Greenhouse gases and the natural gas itself (the composition varies) go into the atmosphere (Alvarez and Paranhos, 2012) and methane (CH_4) makes up majority of the mixture of natural gas; also, methane is the main air pollutant resulting from the natural gas industry.

Succeeding, volatile organic compounds (VOC) and nitrogen oxides (NO_x) cause ozone pollution near the surface of earth. In areas extensively extracting natural gas the concentrations of VOC and NO_x may become significant – the biggest producers of ozone precursors in Colorado (according to Colorado Department of Public Health and Environment) and in Texas (Alvarez and Paranhos, 2012). Additionally, in the Haynesville Shale formation (stretching between Arkansas, Louisiana, and Texas) air pollution models propose rising of ozone pollution due to ozone conveyance near natural gas production fields (Kemball-Cook et al., 2010). Harmful emissions also include VOCs such as BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) that escape from the equipment used. Benzene is a compound that is known to cause cancer in humans. Natural gas production areas experience higher concentrations of benzene. This was observed in Texas (Whitelet and Doty, 2009) and in Colorado (Coons and Walker, 2008).

Particle pollution also rises in the air because of these operations. With the handling of proppants, silica dust becomes an issue. Silica dust causes silicosis when it hits the lungs of people (Hoffman et al., 2014).

Some of the hazardous air pollutants found in the neighborhood of natural gas and oil wells are H_2S (hydrogen sulfide) and hydrocarbon compounds.

Compressor engines produce formaldehyde in their exhaust gases. Likewise, formaldehyde is a hazardous air pollutant and it was reported that a 37%-solution of 30 mL caused death in adult humans (Centers for Disease Control and Prevention, 2016).

Concerns were born as the unconventional natural gas production increased. The issue is on the table for only two decades, so, still, further research is needed. Air emission problems were analyzed and it was seen that people residing within 800 m (0.5 miles) from unconventional natural gas wells carry a bigger health risk than people living further than 800 m (0.5 miles) from these developments. The same study reported 67% more excess cancer risk for people living within the 800 m (0.5 miles) radius of natural gas wells than the people residing outside the circle – increasing from 10 per one million residents to 6 per one million residents (Mc Kenzie et al., 2012).

On the contrary, Sierra Research Inc.'s report on health risk assessment suggests that excess risk cancer risk and non-cancer health hazard indices did not show a significant difference according to their calculations when compared with Environmental Protection Agency's (EPA) data for given areas (Walther, January 2011).

There is a growing public opinion against fracturing and shale gas production. People living around natural gas development sites claim to be suffering from being nauseated, feeling lightheaded, and even claim their noses bleeding (Shogren, 2011). The reporter also adds that people cannot locate the exact source of the pollution although they are feeling the downsides.

Moreover, another news story includes people having muscle spasms because of the natural gas industry. The complaining parties also show their dead farm animals and claiming it is the natural gas industry's fault (Olsen, 2011). Olsen interviews the officials and they say the health issues are taken seriously. Dr. Adgate from Colorado School of Public Health co-authored a report on the air quality of the region and states that the air quality impacts are difficult to verify (Olsen, 2011).

As it is mentioned above, both story lines hint there is "something" there but nobody can put a finger on it. There is still ambiguity in both public and scientific worlds.

Furthermore, there is still this debate – Is shale gas good or bad for global climate change? One side of the story sticks to their claims of shale gas emits less CO_2 than burning oil or coal. On the other hand, the environmentalists stand by their statement that this might not be so. The latter claim is based on studies suggesting vast methane gas leakages into the atmosphere. Additionally, the environmentalist side says this production does not guarantee to cut coal consumption. But then again, the pro-shale gas flank advocates for the idea that shale gas will lower greenhouse gas emissions and will slow down effects of global climate change till there is a full scale solution (Clark, 2012).

Like every industrial activity, any drilling activity pollutes the air. Exhaust gases from the heavy machinery and trucks with the addition of lifted dust are risks to human health. It is reported that ozone levels near some shale gas wells are competing with major cities with pollution problems. Methane pollution rises with back flows and well testing; also by flaring the excess amount of gas (Hoffman et al., 2014).

Advocates of shale gas are in favor since it produces half the CO_2 of what coal produces and 2/3 of CO_2 what oil burning does. In the total balance, when considering the methane leakages during production of shale gas, using shale gas as an energy source still has a large impact on the atmosphere. While we are cutting down our CO_2 emissions, this process emits a more powerful greenhouse gas i.e. methane. Although, a life cycle analysis is yet needed to assess the combined effect of shale gas to the atmosphere, a report written in 2013 states a promising improvement in 190 hydraulically fractured natural gas wells in USA have managed to lower their methane emissions by 99% (Hoffman et al., 2014).

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In the report titled "Can Shale Gas Help Accelerate the Transition to Sustainability?" it is inscribed that in ten years between 2005 and 2015, the greenhouse gas emissions dropped by 10%. Replacing highly polluting energy sources with natural gas contributed to this improvement. The same report also adds that by switching coal with natural gas the USA is showing promise of reaching its goal (lowering its greenhouse gas emissions by around 17%) of the 2009 Copenhagen Accord under the United Nations Framework Convention on Climate Change. This was possible by building new combined-cycle natural gas plants that emit only 1/3 of CO_2 gas produced by coal power plants. Up till now, methane leakage is a big step back in the positive contribution to lowering greenhouse emissions (Dernbach and May, 2015).

WATER POLLUTION AND HYDROLOGICAL PROBLEMS

While boring for shale gas, multi-layered steel casings are used to protect underground aquifers of water. This minimizes – if not eliminates – physical and chemical contact between shale gas and the chemicals used with the underground water bodies. Adding to the problem, there are tens of thousands of new shale gas wells are projected on the reserves. These new wells will be closely located and will withdraw massive amounts of water from the system. Depletion of fresh water and contamination of these water resources cannot be sustained forever. A drastic finding by Prof. Ingraffea of Cornell University states that all natural gas wells leak sooner or later, some of this happens immediately and some in a few years (The Water Footprint of Shale Gas Development, September 10, 2012).

"Depletion of fresh water and contamination of these water resources cannot be sustained forever. A drastic finding by Prof. Ingraffea of Cornell University states that all natural gas wells leak sooner or later, some of this happens immediately and some in a few years."

Water quantity and water quality are likely to be altered in the surrounding area of shale gas extraction. Roads and well infrastructure cause disturbance to the surface structure. These disturbances alter hydrology and sediments and these may change sedimentations and nutrient weathering in the water bodies. A horizontal hydraulic fracturing well consumes great amounts of water – 15 to 30 thousand tons of water – which is mostly drawn from water bodies in the surrounding area within a short time frame of about a week. This drastic interference changes the system especially during low water flow seasons. Next, this withdrawn water mostly stays inside the fractured well, yet, what is returned from the well must be treated off its added chemicals before being discharged into the water system. Moreover, nitrogen emissions tend to increase as the shale gas wells are developed which may cause deposition in the local area. Following, up to 1/5 of the fluids used during shale gas well development tend to reappear on the face of the earth. Next, this fluid contains up to 1/4 of a million total dissolved solids, toxic materials, and cancer causing chemicals (Gottschalk et al., 2012). Nonetheless, when fracturing finds an already existing fault, then chemicals used in the process would travel along these faults and contaminate freshwater aquifers.

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Garfield County in Colorado is home to shale gas production. Studies were undertaken and possible contact with hazardous emissions is seen in these various studies. Still, this paper underlines that there are no planned observations of surface and sub-surface waters and the authors request a water monitoring scheme of whose results must be made available to public (Witter et al., 2008). On the other hand, it is stated that concentrations lower than regulatory standards in Garfield County in Colorado still cause health problems and if health risks are to be aimed to be lowered this issue should be taken seriously (Glass et al., 2005).

Without misgiving, moving immense amounts of water from the surrounding system will cause problems. This is because of the fact that this water is mostly not recycled back into the water system. Especially, in water-scarce regions the withdrawal of millions of gallons of water will bring distress into the hydrology of the area. Additionally, some

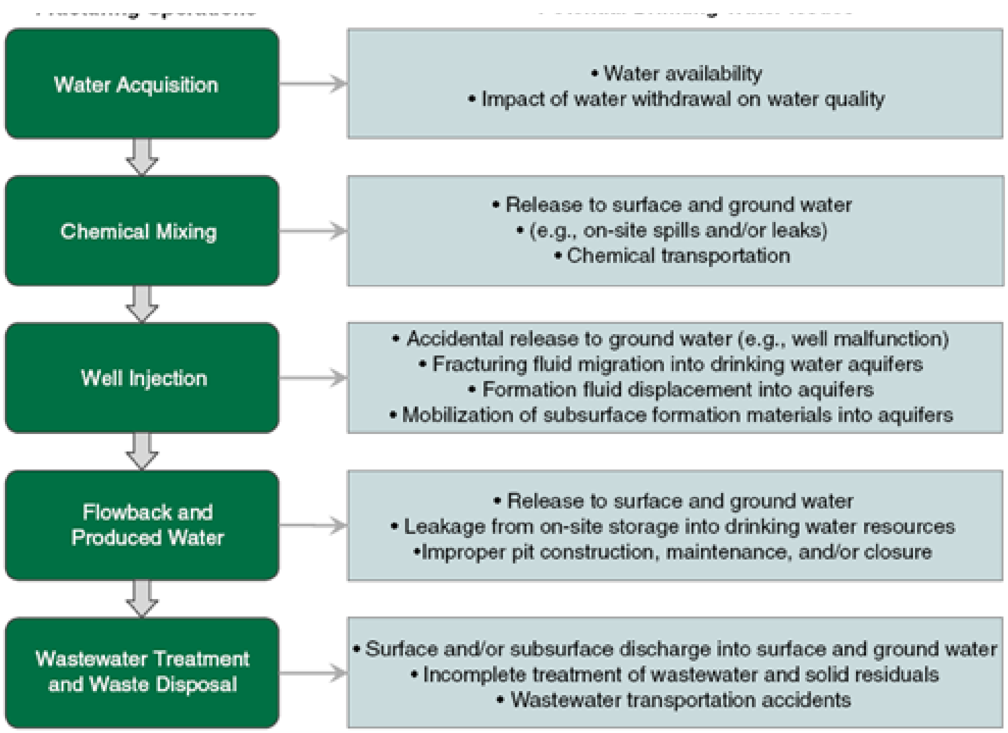

Figure 2. Water Use in Hydraulic Fracturing Operations. (Source: US EPA, 2011).

companies in the US have managed to treat the water they contaminated and reuse it in order to lower their hydrological impact (Energy and Climate Change Committee - Fifth Report, Shale Gas, 2011).

In the figure below, a diagram of possible water pollution issues are presented. It is a brief summary of ways of water contamination.

Once again, different reports come about the safety of hydraulic fracturing for shale gas. For instance, drinking water contamination with the chemicals used during processes or with methane gas is the strongest debate. EPA admitted there is an existing connection in the example of Wyoming community. Though, more recent articles from University of Texas determined that these issues can be lessened by improved drilling operations (Clark, 2012).

In the study "Water Pollution Risk Associated with Natural Gas Extraction from the Marcellus Shale", the authors list trails of water contamination - transportation spills, leaks from well casings, leaks through fractured rock, drilling site surface discharge, and wastewater disposal. These trails of contamination were studied statistically. The biggest cognitive ambiguity was for waste water disposal and the infrequent but severe effect-causing retention pit failures (Rozell and Reaven, 2011).

The same study above suggests probability of contamination by fracture migration is minor to the risk of contamination by wastewater disposal problems. Therefore, the authors call for further research in the area of water disposal pointing out that each well discharges around 200 tons of water that is chemically contaminated (Rozell and Reaven, 2011).

Once again, on the opposition side, The Geological Society states there is no proof of aquifers being polluted by hydraulic fracturing operations since shale gas formations are located hundreds of meters below aquifers (Energy and Climate Change Committee - Fifth

"The biggest cognitive ambiguity was for waste water disposal and the infrequent but severe effect-causing retention pit failures."

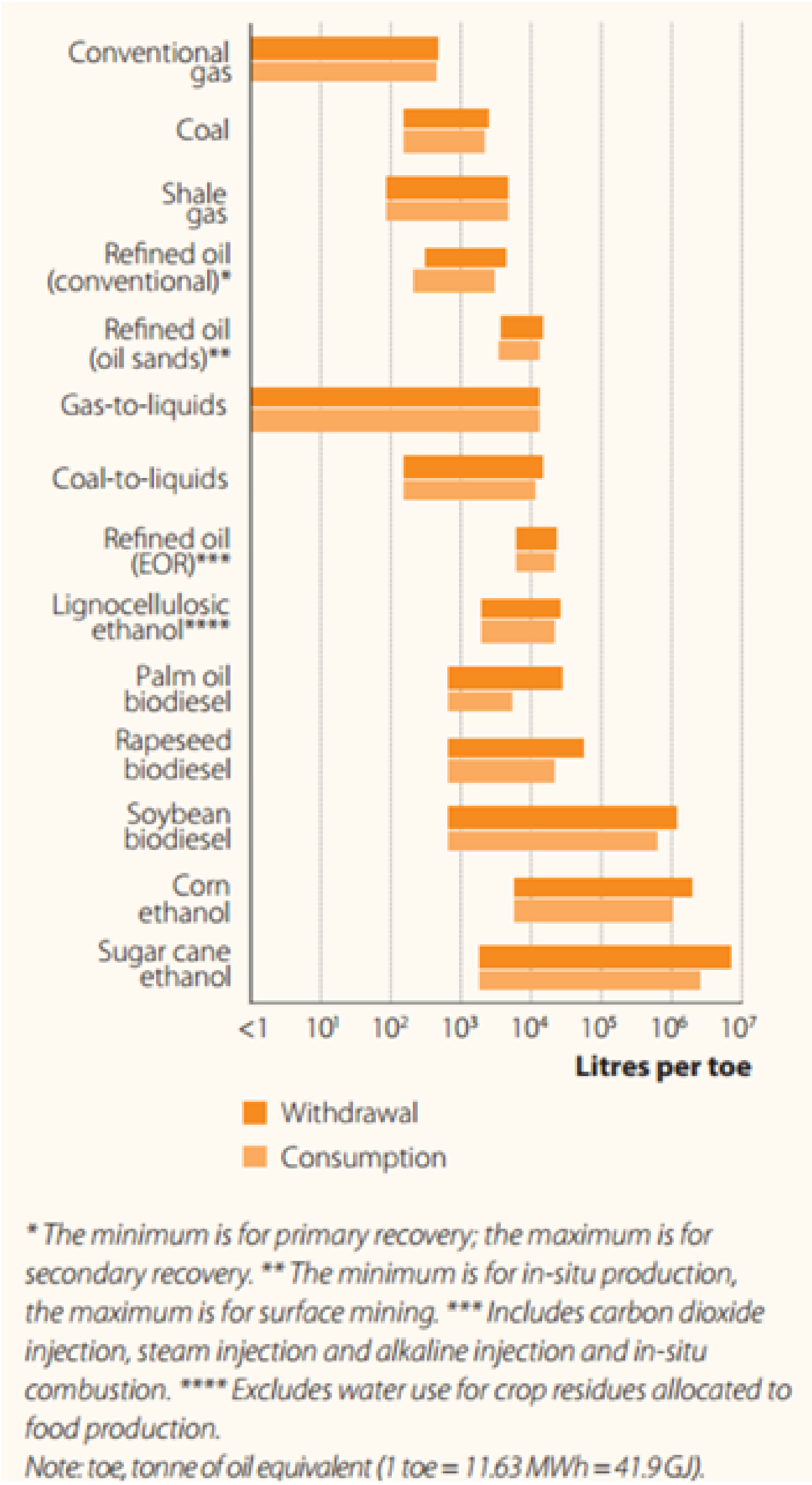

Figure 3. Water Withdrawal and Consumption for Different Fuel Productions. (Source: The United Nations World Water Development Report, 2014).

"the journalist reports EPA's findings of synthetic chemicals and oil (such as methane, ethane, propane, diesel oil, and phenol) remainders in the drinking water supply in a shale gas zone."

Report, Shale Gas, 2011). However, even if fracturing fluids do not reach an aquifer, still their travel outside the aimed area is called "fluid leak off" and is a pollution source.

In addition, in Figure 3, the impact on water by different energy sources is given. The minimum amount of water needed for shale gas extraction is shown to be minimal according to the graph.

Figure 3. Water Withdrawal and Consumption for Different Fuel Productions. (Source: The United Nations World Water Development Report, 2014).

In the Norwegian press (Stavanger Aftenblad, 28.09.2012) the journalist reports EPA's findings of synthetic chemicals and oil (such as methane, ethane, propane, diesel oil, and phenol) remainders in the drinking water supply in a shale gas zone.

Coming back to SIWI's report, it continues by stating that regulations and regulators have been lenient. Noting that, the shale gas industry is exempt from the Clean Water Act, the Safe Drinking Water Act and five more regulations in the USA. Once more, the companies can keep their fracturing fluid formulas secret. Then, there is the potential risk of methane contamination of drinking water. Methane catches more heat than carbon dioxide but it has a shorter half-life in the atmosphere. This leakage can occur if the well and the pipes are not properly built or maintained. Also, the amount of produced waste water that returns alternates between 15% and 300% according to the geological structure; this recovered water is transferred into tanks or pits to be later pumped into deep wells. The flowback water spillages affect well workers and the population in the surrounding area (Hoffman et al., 2014).

It is possible to say that there is a wide spectrum of chemicals used in fracturing fluids. The number can go as high as 750. Due to secrecy of the composition of these fluids it can be a challenge to identify all of them. In Commonwealth of Pennsylvania and State of West Virginia in the USA more than 300 of these chemicals that are used in the Marcellus Shale have been acknowledged. Carcinogenic properties of some of the chemicals are known, besides, these chemicals also affect the endocrine system, the nervous system, the respiratory system and harm the organs. Still, even if non-toxic chemicals were used, the recovered water coming from the underground carries chemicals from the shale formation – sodium, chloride, bromide, arsenic, barium, and radioactive materials that are naturally found in the shale formations. One of the radioactive materials identified was Radium-226 with a half-life of 1,600 years which can cause lymph, blood, and bone cancer (The Water Footprint of Shale Gas Development, September 10, 2012).

SOIL POLLUTION, EARTHQUAKES AND SURFACE RUNOFF

Following, hydraulic fracturing is under operation in countries like Australia, Poland, the United Kingdom, and China. Nevertheless, the British felt many tiny earthquakes in 2011 which put the hydraulic fracturing operations on hold briefly – in April 2012 the UK government advisers admitted these tremors (tiny earthquakes) were associated with these operations, conversely, their report advised these processes could start again (Clark, 2012).

Worries about earthquakes brought new regulations in the USA declaring requirements for horizontal well drillings up to 5 km away from confirmed faults or other earthquake zones to first install seismic detectors before getting their permits. If there are earthquakes recorded greater than the Richter scale of 1.0 in the bed of the shale gas then the hydraulic fracturing will be halted for the foreseeable future. Due to an increase in the number of recorded earthquakes in Middle USA, the states of Oklahoma, Ohio, Texas, and Kansas are looking forward to having more strict legislations and standards for hydraulic fracturing operations (Hoffman et al., 2014).

According to The Wall Street Journal, more than 15 million people in the USA live within a radius of 1.6 km (1 mile) shale gas well drilled since the year 2000. This is more than the population of New York City. Anything

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going wrong in this area almost immediately affects this population due to closeness of houses, schools, farms and other settlements (Dernbach and May, 2015).

Reports also suggest deforestation of shale gas sites is also a problem. This brings wishes for suspension of hydraulic fracturing by the environmental activists (Clark, 2012). When considering ten thousands of wells being drilled close to each other, then, this deforestation problem grows within a confined area and propagates outwards. Besides, approximately 30,000 m2 of land is cleared for one shale gas well pad. There is also extra land usage for roads, storage units, retention pits, vehicle parking, and equipment usage and so on (Cooley and Donnelly, 2012).

The Pacific Institute’s report on fracturing underlines some issues about spillages, leakages, and surface water runoff. According to the report, spillages can happen at any phase of the process. Transportation of chemicals and on-site preparation of fluids are prone to spillages. Storage tanks and retention pits may also leak if not properly handled. Also to mention, human error and deliberate dumping of contaminated fluids may cause disasters in the surrounding. Industrial waste discharges, wastewater impoundment construction regulation violations, and defective pollution prevention applications are among violations of shale gas producers (Cooley and Donnelly, 2012).

“Then again, like every system and technology there are imperfections with fracturing.”

Storm water and surface runoff occur naturally. However, interruptions of fracturing practices upsurges volume and chemical composition of runoff. There is also contamination by contact with the equipment, and storage units (Cooley and Donnelly, 2012). Storm water runoff ends up in water bodies in the surrounding, and when the runoff enters streams they can travel further.

CONCLUSION

Concluding the article, it is vital pointing out that there are always positive and negative views on every aspect of hydraulic fracturing and shale gas extraction. Starting with well boring and well casing… A properly cased well is intact, therefore, if its integrity is sustained, it should possess little risk of contamination of water sources from the casing itself. Still, as mentioned before, all wells are prone to leaking and harming their surroundings.

SIWI’s detailed report makes a good summary. The authors express that there is a requirement for robust policies and an in-depth check list (complying with the most recent and scientific findings) of benefits and practices of the hydraulic fracturing process. Furthermore, there is no doubt that there is a hole on potential effects of hydraulic fracturing and this hole needs to be filled as soon as possible to make sound decisions possible. The effects include water problems, air quality damage, global climate change, increased earthquake occurrence, and negative effects on the human population and the ecosystem. Encouraging newer hydraulic fracturing technologies is necessary in order to improve production and to lessen its reverse effects. Companies should be willing to share the information of their water use and other natural impacts to be observed and measured (Hoffman et al., 2014).

Natural gas capturing technology should be applied to necessary production sites in order to reduce greenhouse gas emission and environmental impact. EPA’s Natural Gas STAR program lists recommended technologies and practices for methane emission lessening. These references list suggested compressors, engines, dehydrators, directed inspection and maintenance, pipelines, pneumatics, controls, tanks, valves, and wells for low-cost and effective methods and technologies in combatting reverse effects of natural gas production (epa.gov, 2015).

Then again, like every system and technology there are imperfections with fracturing. Dr. Jonathan Craig of the Geological Society states that less than 1/3 of the fractures produced contribute to gas production; therefore, he is underlining the necessity of developing improved methods that would be more efficient, thus, using less water and less chemicals. Once more, cooperation of companies extracting shale gas would bring more applicable solutions to waste handling and co-owned wastewater disposal units would cut the distance travelled by the waste itself and energy costs (Energy and Climate Change Committee - Fifth Report, Shale Gas, 2011).

Moreover, the American and the European methods of approach to fracturing are different due to some nuances such as the density of population, strictness of environmental legislations, available land area etc. The European environmental legislations are stricter than their overseas counterparts. The European population density is greater than in remote areas of Texas or Colorado, for example. Hence, in Europe fewer wells are to be developed, improved technologies such as multiwell pad technology are to be used (Energy and Climate Change Committee - Fifth Report, Shale Gas, 2011). It would also be wise to use experience of older and current practices. There is no need to reinvent the wheel at this point; however, this approach may not be approved by companies that see their practices as their intellectual property.

Most importantly, there is deficiency of sound data which is a key obstacle in determining or assessing shale gas and hydraulic fracturing related risks. Business owners strongly prefer keeping their methods and operations secret in order to holding on to their own advantages. Furthermore, the other limitation to assessment of environmental risks is that there are inadequate quantity of peer reviewed articles or academic work. It is also observed that writings about environmental risks about the issue are one sided, written by industry-sided or environmentalist-sided authors. Also, the papers on this issue are not peer reviewed. Thus, it can be said that opinions are told by authors who delay an all-inclusive investigation of environmental and health related risks. Thus, risk minimization is further postponed. As a final point, it is important to note that there are misperceptions in the definitions related to hydraulic fracturing and shale gas extraction. For instance, it is argued by the American Petroleum Institute's (API) constricted description of hydraulic fracturing that there is no connection between shale gas extraction and groundwater pollution. API and other industries deny witnessed proofs of groundwater contamination – as in Commonwealth of Pennsylvania and State of Wyoming (Cooley and Donnelly, 2012).

Overall, further studies in this specific area are necessary to clear out questions over the potential risks caused by hydraulic fracturing and the shale gas extraction. Only after shedding light on the potential risks, we can lower the impact of shale gas risks and proceed to mitigate environmental stress it has been causing.

ABBREVIATIONS

API: The American Petroleum Institute

BTEX: Benzene, Toluene, Ethylbenzene, and Xylene

EIA: U.S. Energy Information Administration

EPA: Environmental Protection Agency of United States

EU: European Union

NOx: Nitrogen oxides

SIWI: Stockholm International Water Institute

TP: Turkish Petroleum Corporation

VOC: Volatile organic compounds

"The European environmental legislations are stricter than their overseas counterparts. The European population density is greater than in remote areas of Texas or Colorado, for example. Hence, in Europe fewer wells are to be developed, improved technologies such as multiwell pad technology are to be used."

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