THE MARCELLUS SHALE AND PUBLIC HEALTH

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Submitted to the Graduate Faculty of

Department of Behavioral and Community Health Sciences

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Master of Public Health

University of Pittsburgh

2010

UNIVERSITY OF PITTSBURGH

Graduate School of Public Health

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It was defended on

April 15, 2010

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University of Pittsburgh, 2010

The Marcellus Shale formation is being harvested for its methane by gas drilling companies in the state of Pennsylvania. The gas extraction method being used is hydraulic fracturing. This operation has public health significance because the chemicals injected beneath the earth's surface during the hydraulic fracturing process are known to have adverse health effects on humans and aquatic life when in their undiluted form. There is much controversy among the communities involved surrounding the use of these chemicals in the Marcellus Shale. Despite communication efforts by government agencies with these affected communities, health concerns continue to run high. A literature review performed in regards to the chemicals found in fracturing fluids and their affects on aquatic life, found eleven chemicals to have adverse affects. A qualitative analysis performed on public comments regarding a proposed EPA assessment on hydraulic fracturing found several common themes. The most prevalent of which were concerns regarding the possibility of hydraulic fracturing affecting water resources and public and environmental health. Themes that emerged from three stakeholder interviews coincided with those found in the public comment analysis. In regards to the issue of hydraulic fracturing and the Marcellus Shale, this paper proposes increased community involvement in government studies, social action methods to help communities achieve the desired change and possible leverage points for interventions to help improve the health of the public and environments involved.

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PREFACE

"Natural gas is such a unique industry… The industry is completely different in terms of monitoring or regulating it… I don't think public-health researchers or the regulatory agencies have gotten their hands around that problem" (Vaughn, 2009, October 4).

The practice of hydraulic fracturing in natural gas production has created a situation teeming with so much complexity that right or wrong solutions are difficult to pin down. This paper will address the need for theory based communication between government agencies and various public and private audiences. Effective qualitative data gathering and message dissemination methods for targeted community's/populations will be explored. The effectiveness and appropriateness of current laws relating to natural gas production activities will also be examined.

Qualitative data will include the analysis of public comments on the EPAs website as well as select opinions from three stakeholder interviews all conducted for this paper in regards to natural gas production. This qualitative data will add insight to the views held by local communities, government and private agencies surrounding natural gas production and its impact on environmental and human health. A literature review performed by the author of this paper on the effects that fracking fluid chemicals have on aquatic life will be included. Also suggestions for additional EPA investigations into the issues surrounding natural gas production will be explored.

1.0 INTRODUCTION

Within the past three years, an activity of much controversy has been taking place within the state of Pennsylvania. This activity is natural gas production through the method of hydraulic fracturing and it has raised concerns by government agencies and residents of Pennsylvanian communities. Some believe that this practice may have an adverse effect and impact on public and environmental health. This natural gas controversy is called the Marcellus Shale (MS).

1.1 BACKGROUND: MARCELLUS SHALE

The MS formation is buried deep beneath the State of Pennsylvania and various neighboring states. This formation contains plentiful supplies of untapped methane. In order to free the methane from the carbonaceous black shale (Phillips energy partners LLC, 2009), gas companies oftentimes employ the method of hydraulic fracturing. Primarily this consists of a fluid being injected at very high pressures into underground wells. This fracturing fluid or “fracking” fluid is a combination of water, various chemicals and sand. Each well requires up to six million gallons of water, usually pumped or trucked from nearby water sources (Marcellus-Shale.us., 2010a). The chemicals are used to address issues such as viscosity, travel distance, sand transport, and ease of degradation. The injection force of the fluid causes fractures in the walls of the shale reservoirs. These fractures are "propped" open by the sand, thus allowing the methane to escape.

The methane then travels back to the earth’s surface through the well, a distance of several thousand feet. Also escaping with the methane is a drilling fluid by-product referred to as flow back, produced water or brine water. This contains a combination of sodium and calcium salts, barium, oil, strontium, iron, numerous heavy metals, soap, radiation and other components (Marcellus-Shale.us., 2010b). In Pennsylvania, this brine water is disposed of by storing it on site in open evaporation pits (Soeder & Kappel, 2009) or it is sent to be treated offsite at a municipal waste water treatment plant (WWTP). In order to treat brine water, WWTPs are required to obtain specialized permits from the Department of Environmental Protection (DEP).

There is a great deal of economic benefit that will be derived from drilling the MS. The coal beds located within the entire MS formation are a major source of natural gas or methane. The latest data estimates gas reserves of up to 500 Trillion Cubic Feet (Tcf) (Engelder & Lash, 2008) compared to the yearly average of total natural gas consumption in the United States which is roughly 23 Tcf (Soeder & Kappel, 2009). A portion of the MS formation can be "found beneath about 60 percent of Pennsylvania’s total land mass" (MSGC, 2010a). Benefits that may result from the practice of MS drilling within the state of PA include an estimated 98,000 Pennsylvanian jobs and a $14.17 billion impact on the state’s economy (Considine, Watson, Entler & Sparks, 2009). Currently there are approximately 56 gas companies within PA that are drilling the MS (MSGC, 2010b).

Despite these economic benefits offered by the hydraulic fracturing of the MS, this is a relatively new procedure and is fraught with controversy. Through prior studies and research, certain chemicals within fracking fluid are known to be harmful to human health and aquatic life. Currently the fracking fluids that are involved with MS development are not regulated under the Safe Drinking Water Act (SDWA). The SDWA has several responsibilities, two of which are allowing: governmental programs to protect public water supplies and sources and; the control of underground waste injection (Tiemann, 2008).

The SDWA was amended in 2005 by the Energy Policy Act to exclude underground injection processes employed by oil and gas companies in their drilling activities unless underground sources of drinking water (USDW) are being affected (Energy Policy Act, 2005). Environmental groups and citizens are concerned by the 2005 SDWA amendment and claim that those drilling the MS and other formations have been granted special privileges by the government in the name of progress, despite unknown environmental and public health impacts.

Potential public health threats have been reported to the Environmental Protection Agency (EPA) in locations proximal to drilling sites in the United States. In response to these past complaints, the EPA performed assessments regarding the impact that hydraulic fracturing has on USDWs in 2002 and 2004 (USEPA-OW, 2004a). Upon completion of their study, they concluded that fracking practices have little potential for adversely effecting USDW when performed correctly. Despite these findings, health concerns continue to run high among environmental groups and many citizens in Pennsylvania in regards to the harvesting of natural gas in the MS.

2.0 HYDRAULIC FRACTURING: EFFECTS ON WATER

Since 2007, Western Pennsylvania residents have been faced with relatively new issues regarding the quality and quantity of their drinking water. They question whether the drilling activities in the MS are having an adverse affect on their water. The chemicals within fracking fluids have raised concerns among those residents living adjacent to MS drilling sites as well as among various environmental groups.

An assessment was performed by the EPA in order to address concerns about these chemicals ability to affect “underground sources of drinking water” (USDW). Additional speculation has focused on the obtaining of the fresh water and the disposal and treatment of the waste water involved with hydraulic fracturing. The lack of regulation concerning the amount of water pumped from local water sources, and the treatment plants ability to remove the amount of organic solids and heavy metals from brine water before discharging it into nearby water sources has been and continues to remain under public scrutiny.

2.1 UNDERGROUND SOURCES OF DRINKING WATER

The Environmental Protection Agency (EPA) performed an assessment regarding the method used by gas companies in fracturing underground coal bed methane (CBM) reservoirs, which for clarification, is not the makeup of the MS but relates because the practice of hydraulic fracturing is implemented. The EPAs assessment was performed in the wake of an Alabama court decision. The court found the need to subject fracking fluids to regulation under the Safe Drinking Water Act (SDWA). This decision however was only effective in Alabama. Fracking fluids are still excluded from regulation under the SDWA in the rest of the United States. After Alabama made this decision, the EPA decided to conduct a second assessment (the first took place in 2002) to readdress the issues concerning fracking fluids.

The basic purpose of this assessment was to take another look at the potential that fracking fluids have for causing contamination to an Underground Source of Drinking Water (USDW). In so doing they were also addressing concerns voiced by individual citizens who felt that their water quality or quantity was somehow being affected by the fracking process. The EPA also acted on Congressional interest and the possible need for additional information before they could make any more policy decisions concerning coal bed fracturing (USEPA-OW, 2004b).

In preparation to conduct this three phase assessment the EPA strategically assembled a peer review panel consisting of seven individuals. Five of the seven peer review board members included three that currently were employed by and two that were previously employed by the oil and gas industry. The other two members consisted of a professor and a lab employee. During the first phase, their charge was to conduct a literature review to discover the potential for USDW contamination from fracking fluid chemicals. From this first phase, the panel was to derive whether faze two and three were warranted. Phase two consisted of water quality field investigations near coal bed fracturing sites. If the data substantiated further study, phase three would then explore areas where fracking fluid injection should be regulated under the SDWA.

Among the many chemicals studied by the EPA, some were known to be hazardous causing damage to the kidney, liver, heart, blood, brain and Central Nervous System in their undiluted form. The chemicals in question however are much diluted when used in fracking fluid. However, not all hazardous chemical concentrations were revealed to the peer review board. Diesel was the EPAs largest concern regarding its use within fracking fluids. Diesel consists partly of benzene, toluene, ethylbenzene, and xylenes (BTEX compounds). These BTEX compounds are in fact among those regulated under the SDWA.

These BTEX compounds are the only chemicals within fracking fluid that fall under SDWA regulation. The EPA doesn't believe that the other chemicals have high enough concentrations within fracking fluid to pose a significant threat to USDWs. Therefore, concerning Diesel use, the EPA made an agreement with the three largest gas companies in the U.S. The voluntary agreement states that the gas companies will not use Diesel in their fracking operations. This voluntary agreement cannot be enforced and can be rescinded by the parties involved at any time.

Community outreach efforts amounted to public information meetings and telephone interviews in regards to complaints from concerned citizens. The resulting leads from these interviews did help the EPA to better understand these citizens' complaints and concerns. The EPA also held public information meetings that were held, among other reasons, to help educate the communities on the assessment results.

The EPA concluded with their assessment. They found that fracking fluids are injected into underground sources of drinking water and that the fluids contain carcinogenic and toxic substances. In the EPA's opinion however, the SDWA does not cover the injection of fracking fluids into the earth, because the injection of fluids underground is not the purpose of these operations. The primary function or purpose of these wells is to produce methane from coal beds. (This opinion was overturned by the court in Alabama as noted above).

2.2 AQUATIC LIFE

I performed my graduate practicum at the Center for Healthy Environments and Communities (CHEC) in Pittsburgh, PA throughout the spring, summer and fall of 2009. CHEC's mission is "to improve environmental health in Western Pennsylvania through community-based research" (CHEC, 2010). During my practicum, they were approached by an environmental law firm with a request to perform a literature review regarding the chemical effects of fracking fluid on aquatic life. It was my responsibility to perform the literature review on this topic. What follows is a synopsis of the fracturing chemicals used in MS drilling and a description of their reported effects on aquatic life found in existing literature (for search methods, please see *Appendix A*).

5-chloro-2-methyl-4-isothiazolin-3-1 has a negligible risk to aquatic life due to the chemicals rapid metabolism into less toxic products (Williams & Jacobsen, n.d.).

Benzene is a Polycyclic Aromatic Hydrocarbon (PAH), which form a large group of organic compounds and are composed of two or more fused benzene (aromatic) rings (Neff, 1979). PAHs are nearly ubiquitous (defined as being "existing or being everywhere at the same time" (Ubiquitous, 2010)) trace contaminants of freshwater and marine sediments worldwide (Neff, Stout & Gunster, 2005) and tend to accumulate in sediments (Allen, 2008), particularly near areas of intense human activity (Neff, 1979 & 2002), causing continuous PAH exposure of benthic organisms (bottom dwellers within a body of water). However, sediment-sorbed PAHs have only limited bioavailability to marine organisms, which greatly reduces their potential toxicity (Salazar-Coria, Amezcua-Allieri, Tenorio-Torres & Gonzalez-Macias, 2007).

A number of PAHs are considered hazardous to aquatic organisms (Connell & Miller, 1981a & 1981b; Miller & Connell, 1980; Miller, 1982). Due to hydrocarbons high stability they tend to be preserved in fish (Grimmer, 1983). For example, nine months after an oil spill when natural waters contained neither benzene nor its derivatives, benzene derivatives were identified in the fish, and also in sturgeon species and bivalves which were collected near the spill site (Levshina, Efimov & Bazarkin, 2009). It is important to note that there are clear differences between fish species in their response to PAHs (Aas, Beyer, Jonsson, Reichert & Andersen, 2001; Eggens et al., 1996; Ploch, King & Di Giulio, 1998). Results from one species can therefore not be directly extrapolated to another (Hylland, 2006).

Due to metabolism, tissue residues of PAH are generally low, but metabolites can be found in bile (Aas, 2000). Causality was indicated between exposure to petrogenic PAHs (from sediment) and (1) increased content of bile metabolites, (2) induced hepatic cytochrome P-4501A or CYP1A (a widely accepted environmental biomarker; when evaluated in target tissues of a biosensor species, it detects the biological effects of several xenobiotic groups, which are chemical compounds not produced by, and foreign to, a living organism; these xenobiotic groups include: oil compounds; dioxins; PCBs and; PAHs that are present in aquatic environments.), (3) elevated concentrations of DNA adducts in liver, and (4) increased prevalence of neoplasia (cancer) in liver (Collier et al., 1992; Collier, Anulacion, Stein, Goksoyr & Varanasi, 1995; Collier, Johnson, Stehr, Myers & Stein, 1998; Johnson et al., 1998; Johnson et al., 1999; Landahl, Johnson, Stein, Collier & Varanasi, 1997; Myers et al., 1994; Myers et al., 1998b; Myers et al., 1998c; Stein et al., 1992).

Benzene is an emerging and less known contaminant which is believed to pose a new threat to our environment (Belpaire et al., 2009). In contrast to its homologues toluene and xylene, which have a “similarity of nucleotide or amino acid sequences” (Homology, 2010), benzene is extremely resistant to biological oxidation and tends to accumulate in living organisms, thus being a very toxic cumulative poison (Henderson et al., 1989; Medinsky, Sabourin, Henderson, Lucier & Birnbaum, 1989).

It was revealed by Akaishi et al. (2004) that benzene exposure is known to affect acetyl cholinesterase, an enzyme that promotes the splitting of the neurotransmitter acetylcholine (Acetyl cholinesterase, 2010), and gill morphology in fish. The combination of which can result in decreasing chemosensory reception (relating to the sensory reception of chemical stimuli (Chemosensory, 2010)) with probable consequences to homing, feeding behavior, avoidance of predators (Babcock, 1985; Birtwell, Fink, Brand, Alexander & Mcallister, 1999; Silva, Medina, Fanta & Bacila, 1993) as well as death if AChE is fully inhibited (Soliman, El-Elaimy & Hamada, 1995).

Among benzenes, toxicity tends to increase with the level of nitrogenation (Nipper et al., 2001). Nitrobenzene compounds were extremely toxic to daphnia and carp (HungYen, HsiungLin & ShungWang, 2002). Aminophenols are said to be the metabolites, “a metabolic waste usually more or less toxic to the organism producing it” (Metabolite, 2010), of nitrobenzene as well as other xenobiotics and that they caused death and DNA damage of Zebrafish depending on the concentration used and life stage of the fish (Sun et al., 2004). Lastly, Lamellar gill epithelia, a thin membrane covering the gill (Epithelium, 2010), developed excessively or hypertrophied (Hypertrophy, 2010), and swimming capacity was reduced when Rainbow Trout fry were chronically exposed (54 days) to 0.2 mg/l of Linear alkylbenzene sulfonates (LAS), a surfactant group sometimes present in coastal marine waters (Christoffersen, Hansen, Johansson & Krog, 2003), even though this was considered the "no observed effect concentration" (NOEC) (Hofer & Bucher, 1995).

Boric acid and borates form very stable complexes with organic chemicals such as *alpha*-hydroxy carboxylic acids (Black, Barnum & Birge, 1993) indicating the possibility of decreased bioavailability and toxicity (Dethloff, 2009). Boron was relatively non-toxic (96-hr "lethal concentration for 50% mortality" or LC50s was greater than 100 mg/L) to two species of Salmon (Hamilton & Buhl, 1990). Chronic studies with freshwater fish have generally reported NOECs in the range of 1–25 mg B/L (Birge & Black, 1977; Black et al., 1993; Butterwick, De Oude & Raymond, 1989). Laboratory studies on a limited number of freshwater invertebrates have reported NOECs in the range of 6–18 mg B/L (Gersich, 1984; Gersich & Milazzo, 1990; Hickey, 1989; Howe, 1998; Lewis & Valentine, 1981; Maier & Knight, 1991).

The rank order of nine individual inorganics, from most to least toxic, ranked boron second least toxic. A comparison of 96-hr LC50 values with reported environmental water concentrations from the San Juan River revealed low hazard ratios for boron (Hamilton & Buhl, 1997). Moderate hazard ratios for boron were revealed when 96-hr LC50 values were compared with a creek which received irrigation drain water in a study by Hamilton (1995).

Dethloff (2009) mentions a concern about the effects of elevated Boron concentrations because phytotoxicity, reproductive effects, and growth effects had been observed in laboratory studies (Howe, 1998; IPCS, 1998). The most sensitive species and life stage in laboratory tests was determined to be embryo–larval rainbow trout, with a "lowest observed effect concentration" (LOEC) of 0.1 mg B/L (Birge & Black 1977). Subsequent studies conducted by Black et al. (1993) suggested that rainbow trout chronic toxicity might be reduced in natural waters; effect concentrations were reported between 0.75 and 1.0 mg B/L. Field observations have suggested that even this value might be conservative, given that healthy trout populations have been observed in waterways with Boron concentrations equaling or exceeding 1.0 mg/L (Goldstein, Hubert, Woodward, Farag & Meyer, 2001; Howe, 1998; Loewengart, 2001).

Acute 48-hr median LC50s for the water flea, Daphnia magna, were 130 mg B/L as was a 24-h median “effective concentration for 50% mortality” (EC50) for Ceriodaphnia dubia (water flea), which is often more sensitive than Daphnia magna (Gersich, 1984; Hickey, 1989; Lewis & Valentine, 1981; Maier & Knight, 1991). The 48-hr LC50 for Chironomus decorus (midge or water flea) was much greater, 1376 mg B/L (Maier & Knight, 1991). Representative species of other aquatic organisms, including plants, invertebrates, fishes and amphibians, usually tolerate chronic exposure of up to 10 mg B/L without adverse effects (Eisler, 1990).

*DBNPA (2,2-Dibromo-3-nitrilopropionamide)*is a biocide that can consist of highly toxic organic chemicals, such as isothiazolins (Latorre, Rigol, Lacorte & Barceló, 2005).

Diesel fuels, home heating oils, and engine oils (crankcase oil; middle distillate fuels) may contain PAHs from benzene through fluoranthene which has four aromatic rings (Neff, Stout & Gunster, 2005). In a study performed by Mos, Cooper, Serben, Cameron & Koop (2008), it was found that diesel represents an acute toxicity risk at the time of spill to fish and a sub acute hazard of a gradual mortality from anoxia or a “deficiency of oxygen resulting in permanent damage” (Anoxia, 2010), increased susceptibility to disease, and possibly, endocrine disruption. The endocrine system consists of “glands, hormones, and cellular receptors that control a body’s internal functions and may cause developmental or reproductive disorders” when disrupted (Endocrine Disruptors, 2010). Schein, Scott, Mos & Hodson (2009) mention that embryonic and larval stages of salmon and herring demonstrated both exposure and chronic toxicity "in situ", which means "in the original position."

The coincidence of spawning and oil deposition in spawning shoals resulted in induction of the biomarker CYP1A, blue sac disease of larvae which causes an "abnormal accumulation of liquid between the membranes surrounding the yolk sac" (Aquafarmer, 2010), and recruitment failure or the inability to produce viable offspring (NWSRI, 2010), which effects were associated with PAH fractions exposure (Carls, Rice & Hose, 1999). A reduction in plasma cortisol concentrations was observed in fish and eels (Alkindi, Brown, Waring & Collins, 1996; Pacheco & Santos, 2001a & b), suggesting that the water-soluble fraction of petroleum derivatives might interfere in the fish stress response. (Simonato, Guedes, & Martinez, 2008) Reports have been made concerning gill and liver damage due to lesions (Simonato et al., 2008; Martinez, Nagae, Zaia & Zaia, 2004; Khan 1998 & 2003; Engelhardt, Wong & Duey, 1981; Myers et al., 1998a) possibly leading to a loss in the fish's ability to maintain homeostasis which is the ability or tendency of an organism or cell to maintain internal equilibrium by adjusting its physiological processes (Simonato et al., 2008).

Acute exposure of a fish species to diesel water soluble fraction caused significant physiological stress (Simonato et al., 2006; Machala et al., 1997). PAHs are potential stressors causing increased mortality and malformations in fish (Colavecchia, Backus, Hodson & Parrott, 2004). Fish exposure to PAH, as studied by Dizdaroglu, Jaruga, Birincioglu & Rodriguez (2002), can cause oxidative stress, which as explained by Kohan & Nyska (2002) occurs when radical production exceeds the antioxidant capacity of a cell. PAH exposure can also affect the fish's immune system (Holladay et al., 1998), endocrine regulation (Gozgit, Nestor, Fasco, Pentecost &

Arcaro, 2004; Lintelmann, Katayama, Kurihara, Shore & Wenzel, 2003; Navas & Segner, 2000) and development (Rhodes, Farwell, Hewitt, MacKinnon & Dixon, 2005).

Ethoxylated octylphenol was not found during the literature review; however, one of its components, octylphenol, was discovered in a potency study regarding various chemical effects on fish. This study suggested that concentrations greater than 1 μg/l of octylphenol in receiving waters pose a danger of endocrine disruption (Johnson & Jürgens, 2003).

Ethylene Glycol (EG) and Propylene Glycol (PG) have relatively low aquatic toxicity (Kent, Andersen, Caux & Teed, 1999) and do not bioaccumulate in the tissues of biota (all plant and animal life in the area) due to their rapid biodegradation in aquatic ecosystems (Sills and Blakeslee, 1990; Verschueren, 1983; Budavari, O'Neil, Smith & Heckelman, 1989; Howard, 1990; ATSDR, 1993).

EG is miscible in water and insoluble in benzene, chlorinated hydrocarbons, and oils (Budavari et al., 1989; ENVIRO TIPS, 1985). Invertebrates such as Ceriodaphnia dubia are slightly more sensitive than fish in regards to reproduction and survival when exposed chronically to EG (Beak Consultants, 1995; Pillard, 1995). Fathead minnows exposed to EG based deicing fluids showed that gills and renal tissues were affected (Hartwell, Jordahl, Evans & May, 1995). Fish and American eels were found to have kidney damage as well (Evans-David, 1974). EG has been reported to be estrogenic in rainbow trout (Ren, Meldahl & Lech, 1996).

PG is relatively nonvolatile and is miscible in water and slightly more soluble than EG in most other solvents (Kent et al., 1999). The Fathead minnow (Pimephales promelas) "25% Inhibition Concentration" (IC25) value was reported at 65.45 ml/L EG (Pillard, 1995). A study by Bass (2003) found that hatching failure for EG & PG was found to be 60% and 48% at

10ml/L concentrations respectively as well as 100% hatching failure in 100 ml/L for both chemicals. The same study also found that organisms which died during exposure period without hatching exhibited developmental abnormalities including failure of eye and fin development and necrosis of head and tail regions. Calculated EC50 values for EG and PG were 9.33 and 26.42 ml/L respectively (Bass, 2003). “Estimated no effect values” were 2ml/L for EG and 5 ml/L for PG (Canadian Council of Ministers of the Environment, 1999). Chronic LC50’s for adult fish were 28.7 to 44.9 ml/L for EG and <11.1 to 49.2 ml/L for PG (Arco, 1990; Pillard, 1995).

2-Ethylhexanol was found to be relatively hydrophobic and thus likely to partition or break apart into the sediments (Horn, Nalli, Cooper & Nicell, 2004).

Ferrous sulfate Hepathydrate did not show up in the literature review, however a component of this chemical has been studied which is the Fenton reagent (ferrous sulfate plus hydrogen peroxide). It was found to induce oxidative stress and significantly reduced GSHT, a non-enzymatic antioxidant that helps get rid of toxins, on PLHC-1 cells in fish liver (Rau, Whitaker, Freedman & Di Giulio, 2004).

Formaldehyde, when applied to microalgae, produces massive destruction of the algae (Chiayvareesajja and Boyd, 1993; Burridge, Lavery & Lam, 1995). Cultures initially collapsed after exposure to 16 ppm formaldehyde. Microalgae tolerance to contaminated environments is relevant because these organisms are the principal primary producers of aquatic ecosystems (Lopez-Rodas et al. 2008). Owing to its solubility in water, formaldehyde can be absorbed via skin and gill thereby promoting adverse local and systemic effects (WHO, 1986). Significant morphological changes of skin and gill filamental epithelium were found, exhibiting a dose response pattern (Bueno-Guimaraes, Ferreira, Garcia & Saldiva, 2001).

Glutaraldehyde (GA), an important biocide, is readily biodegradable in the freshwater environment and has the potential to biodegrade in the marine environment. It tends to remain in the aquatic compartment and has little tendency to bio-accumulate. GA is acutely toxic to aquatic organisms at low doses and is equally toxic to warm water and cold water fish, but is slightly more toxic to freshwater fish than salt water fish. Its toxicity is not appreciably increased with repeated long-term exposures (Leung, 2001; Sano, Krueger & Landrum, 2005). Reproduction of Daphnia magna was inhibited at 4.25 mg/L GA concentration and also reduced at .21 mg/L (CCR, 1990).

Methanol has caused damage to liver and gills of fish (Katsumiti et al., 2009). After a tanker spilled bunker oil, diesel oil and methanol, many birds, turtles, dolphins and invertebrates were found dead, covered with oil (IAP, 2005).

Methyl-4-isothiazolin was not found in the literature review, however a component of this chemical, Isothiazolone, is used as a biocide. Isothiazolone biocides are broad spectrum antimicrobials which are used in a variety of industrial water treatment applications. In aquatic environments, these compounds rapidly biodegrade with half-lives significantly less than 24 hours. Both isothiazolones studied, methylchloro/methylisothiazolone and dichloro-n-octy lisothiazolone would be considered as acute but not chronic toxicants (Williams & Jacobson, n.d.). Like most biocides, these compounds show a significant degree of toxicity to non-target aquatic organisms; however, their rapid metabolism leaves minimal potential for bioaccumulation and results in compounds which are 4-5 orders of magnitude lower in toxicity

(Willingham & Jacobson, 1993). Toxicity against non-target organisms was determined for freshwater algae, fish, invertebrates and select marine organisms (Shade, Hurt, Jacobson & Reinert, 1994).

Propargyl alcohol is an acetylenic alcohol with a lower molecular weight than most and can be quite toxic to marine environments and mammals and very toxic by skin adsorption (Hill, 2000).

2.3 MONONGAHELA RIVER

Speculation has been raised among various agencies and residents regarding brine water treatment and its effects on the receiving waters. In relation to this speculation and future projections that two and a half thousand wells will be drilled in Pennsylvania each year and the amount of waste water a well can produce, an engineering professor stated, "So when you combine, that's a lot of water that…potentially has a serious impact on the environment if not handled properly" (personal communication, November 18, 2009). Also, a greater awareness has developed regarding the need for increased accountability among natural gas drillers when pumping water from nearby water sources. One of the events responsible for this heightened sensitivity was the rise in "Total Dissolved Solid" (TDS) levels in the Monongahela River (the Mon) during the fall of 2008.

On October 10, 2008 the Pennsylvania Department of Environmental Protection (PADEP) received alarms from two industries along the Mon that TDS levels were unusually high (UMRA, 2009; Hopey, 2008a; Litvak, 2008). TDS is a measure of tiny organic and inorganic particles (Bowling, 2008a) that can consist of carbonates, chlorides, sulfates, nitrates, sodium, potassium, calcium and magnesium (Hopey, 2008a; PA-DEP, 2008a & b). They are so small and light that they won't filter or settle out of water (Bowling, 2008b).

TDS are classified as secondary contaminants, meaning that they aren't considered a major public health risk, only causing an unpleasant odor and salty taste to humans (Hopey, 2008a; PA-DEP, 2008a & b). Aquatic life on the other hand is a population that is more at risk health wise due to a decrease in available oxygen caused by TDS which makes it more difficult to breathe.

U.S. Steels' Clairton coke plant and Allegheny Power's electric plant in Masontown alerted the DEP who upon responding found TDS measurements of 750 mg/L, exceeding the maximum standard of 500 mg/L (Hopey, 2008a). This maximum level has been created by state and federal government to control for elevated levels of TDS (Bowling, 2008b; PA-DEP, 2008a). The DEP set up data collection points along a seventy mile stretch of the Mon (Hopey, 2008a, b & c; PA-DEP, 2008a) starting at the West Virginia (WV) border and continuing up to the Youghiogheny River near McKeesport. TDS levels ranging from 500 to 908 mg/L were recorded along these areas of the Mon (PA-DEP, 2008a & b), twice the usual levels from past fall seasons. (Hopey, 2008a) It was found that the Ohio, Allegheny and the portion of the Mon River downstream from the Youghiogheny River had TDS levels below the maximum standard. (PA-DEP, 2008a)

TDS particles are so small that public water suppliers are not "equipped" to filter them out (Bowling, 2008a; Kroeger, 2008; Litvak, 2008) nor are they required to remove them (Hopey, 2008b; Kroeger, 2008). Eleven public water suppliers serving 350,000 people were affected along this seventy mile stretch of the Mon (Hopey, 2008a & c) There were also several reports received by the DEP stating that elevated TDS levels were causing equipment problems for industries employing processes that use river water (PA-DEP, 2008a). Due to this hard water, pipe scaling or the buildup of rust and corrosion products on the inside of the pipe (Answers.com, 2010), and machinery corrosion were sped up (Beveridge, 2008; Bowling, 2008b) and caused significantly higher water treatment costs among industry and utility companies. For example, a coal fired plant in Greene County spent over $200,000 in order to "filter out the contaminants before they could damage (through corrosion) steam boilers and turbines." As for the residential consumers, “hard water” only affected dishwashing aesthetics such as cloud residue and spots on glassware (Hopey, 2008c).

The DEP coordinated with the United States Army Corp of Engineers, WV DEP, PA Fish and Boat Commission and public water suppliers as they responded to the TDS problem on the Mon with an investigation, tests, dilution, as well as precautions and assurances to water consumers (UMRA, 2009; Bowling, 2008a; Hopey, 2008a; Host, 2008; Kroeger, 2008; PA-DEP, 2008a & b).

2.3.1 Possible TDS Contributors

Knowing of nitrates and other pollutants from yards and farms (Bowling, 2008b) but not considering them to be a major cause, the DEP investigated four possible contributors to the increased TDS levels. First, TDS levels at the WV border coming into PA were well above normal values which gave no room for additional TDS discharge into the river on the PA side (Bowling, 2008b; Hopey, 2008a; Kasey, 2008; PA-DEP, 2008a). Second, abandoned mine drainage was explored. The DEP approximated this as the cause for 40% of the solids during this event (Hopey, 2008b) and stated that over the decades this source has had a fairly constant discharge rate (Bowling, 2008a; Kasey, 2008; PA-DEP, 2008a). Third, low flow conditions in the Mon basin could have hampered the rivers ability to dilute TDS (Litvak, 2008).

Two possible contributors to the low flow were drought conditions (Bowling, 2008b) as well as the drilling activities by gas companies in the MS. One gas well can require up to six million gallons of water (Parsons, 2008). These drilling companies pump their water from nearby streams or rivers that are often tributaries of the Mon. Pumping activities are unrestricted in eastern PA and the water is free of charge. In August of '07 and '08, the DEP investigated reports that two streams in Washington County were actually "pumped dry" (Parsons, 2008).

The fourth potential cause was an increased volume of gas well waste water (brine water) being treated by sewage treatment plants and then discharged into the Mon river basin (Bowling, 2008a & b; Kasey, 2008; PA-DEP, 2008a). Sewage treatment plants treat biological waste but are not designed to treat chemical well waste such as brine water from the MS wells. This chemical waste when in large quantities could disrupt the plants treatment processes (Litvak, 2008). Of the nine sewer authorities that were treating well water, only one was capable of removing some metals and suspended solids (not including TDS) whereas the others treated only by dilution (Hopey, 2008b). DEP originally approximated that 30-40% of the TDS problem was due to brine water discharge released by wastewater treatment plants along the Mon (Hopey, 2008a & b).

2.3.2 DEP Actions and Findings

Since many of the wastewater treatment plants could not eliminate TDS, the DEP ordered the treatment plants to reduce the amount of wastewater from gas wells to one percent of their total volume of treated water (Hopey, 2008a; Host, 2008; Litvak, 2008). The DEP instituted the following requirements for treatment facilities to comply with before being allowed a continuation of brine water treatment: adjustments are made for permits and; the completion of a series of tests on incoming wastewater (Litvak, 2008; Parsons, 2008). This order was based on established Clean Water legislation (Litvak, 2008) and ultimately led to the establishment of a new permitting strategy which won't take place until January 2011. Meanwhile the DEP has in place an interim permitting strategy. The DEP then informed the drilling companies that were producing the brine water that they would need to either store their waste, or haul it to a different treatment facility further away (Litvak, 2008). The drillers were also ordered to submit a monthly report regarding the water source that they would be withdrawing from (Parsons, 2008).

A few public drinking water suppliers disseminated TDS information to their customers with their water bill. The fact sheet included the causes and cosmetic effects of TDS on kitchenware, drinking water and ice cubes. Solutions were also included, such as adding vinegar to a dishwashers rinse cycle to reduce spotting (Hopey, 2008b; Kroeger, 2008).

The DEP announced that they did not consider brine water to be the main cause of the TDS problem in the Mon, and cautioned people not to jump to any conclusions regarding drilling and TDS levels (Beveridge, 2008; Bowling, 2008b). WV and PA DEP officials held a public meeting Nov 14 with the Upper Monongahela River Association hosting the meeting (Kasey, 2008). The meeting analyzed the October/November 2008 incident on the Mon River (UMRA, 2009) and it was announced that the incident posed no public health threat. No illnesses due to tainted water had been reported and the lab tests indicated the water contained only secondary contaminants thereby making it safe to drink (Hopey, 2008a; PA-DEP, 2008a & b). It was reported that the Mon was much healthier than it had been during the nineteen seventies and that no significant damage was seen to aquatic life. However, it was also stated that the drop in river flow was the worst on record in seventy years, and conductivity values, as well as other data, were higher than they ever had been (UMRA, 2009). Conductivity is a water purity measure that is dependent on its concentration of dissolved salts. The lower the conductivity is, the purer the water (Stevens, 2008).

2.3.3 Effect on Gas Industry Stakeholders

The vast majority of local sewage authorities had to stop treating brine water. The regulations put forth by the DEP made the cost outweigh the benefit for most authorities accepting waste from drillers. This loss in revenue had many municipalities scrambling to make up the difference using different avenues such as increases in property tax (UMRA, 2009; Litvak, 2008). One of the treatment plants began trying to negotiate a consent order with DEP so that permission might be obtained to treat upwards of half the brine water amount that they had treated previously (Hopey, 2008b).

This rapid decline in operational brine water treatment plants affected nearby MS gas drilling activity immensely (Litvak, 2008). Drilling companies had few options for brine water treatment facilities that they could take their waste to and were hard pressed to find enough storage room due to the amount of wells producing the waste water (at least one company had 800 wells). Some drillers found it necessary to cut down to operating one rig a day instead of two (Litvak, 2008). Faced with this new dilemma, one company felt that it would be forced to close its operation altogether. Due to a company’s disagreement with the DEPs estimate that 30% of the TDS problem was caused by brine water, a consulting firm was hired to review the DEPs information and conduct testing of their own (Hopey, 2008b). This assessment was relatively thorough and its findings did not support the DEPs previous estimate. Rather, it suggested that brine water treatment had contributed very little to the elevation in TDS levels on the Mon (Tetra Tech NUS Inc., 2009)

3.0 DISCUSSING THE NEED FOR CHANGE

The events and studies previously reviewed are a testament to the reality of the communities affected by the hydraulic fracturing of the MS. The reality that will be discussed is that there are many unknown impacts from these operations and many gaps in regulations and studies that still need to be filled.

3.1 UNDERGROUND SOURCES OF DRINKING WATER

The EPAs assessment was quite thorough regarding the possible danger posed to underground sources of drinking (USDW) water by the hydraulic fracturing of CBM reservoirs. Many quantitative and some qualitative measures were taken, however there were still many weaknesses. The lack of impartiality among the assembled peer review board members that conducted the study for instance.

A more diverse and appropriate peer review board would have been more consistent with the Federal Advisory Committee Act. This act states that when forming a federal advisory panel, citizens and other interested parties should be included (Wilson, 2004). Staff employed by the EPA with expertise in this area of study would have been a good choice for one or two panelist positions. For some reason, the EPA went against its own policy when forming this review board. Their policy requires that the peers be able to give an objective and independent evaluation without conflicts of interest. Separating personal interests so as not to influence the assessment outcomes, seems to be a very slim possibility with the chosen peer review board members selected for the 2004 assessment.

Also, only one out of three possible phases was conducted and; some post assessment actions did not match up with the assessment findings. From a community needs assessment standpoint however, the ultimate weakness was the insufficient time invested in garnering community involvement and other qualitative methods.

As I have analyzed various studies along with the EPA assessment on hydraulic fracturing issues, it seems that insufficient communication is a prevalent cause concerning the lack of community buy-in when it comes to the assessment results for the EPA and others. There is a significant gap between the concerns voiced by individual citizens, communities and/or groups regarding hydraulic fracturing issues and the actual study results that have been conducted by the EPA. This makes one wonder if: the results from conducted studies have been more optimistic than reality warrants concerning the negative impacts of hydraulic fracturing or; the concerns regarding hydraulic fracturing voiced by community's or environmental groups are too cautious or lacking in merit.

3.2 AQUATIC LIFE

The following chemicals were found to be harmful to aquatic life in some way: Benzene; a component of DBNPA; Diesel; a component of Ethoxylated Octylphenol; Ethylene Glycol; Propylene Glycol; a component of Ferrous sulfate Hepathydrate; Formaldehyde; Glutaraldehyde; Methanol; a component of Methyl-4-isothiazolin and; Propargyl alcohol.

Although some of the fracking fluid chemicals were found to be harmful to aquatic life in various ways, it should be noted that they are present in less concentrated doses than those utilized in the reviewed studies. Also, among the literature reviewed, not one study was specifically related to MS natural gas production. However, the hydraulic fracturing of the MS has only been in effect for a few years. Therefore, it is unlikely that sufficient time has passed for the conducting of studies relating to this relatively new field of natural gas production and its health impacts.

For a better idea of the effects that these chemicals have on aquatic life when used in fracking fluid, the concentrations of each chemical within the fracking fluid would need to be calculated and then compared to the concentrations used within the reviewed literature. Presently, the concentrations within fracking fluid are unknown to the public because under federal law, the concentrations are considered proprietary information, known only to each individual gas company.

In regards to the deal made by the EPA with the three largest drilling companies in the United States, Diesel tends to be more controversial than the rest of the chemicals due to its well known adverse affects on aquatic life and the fact that it is regulated under the SDWA. There is speculation that this agreement may have stemmed from: an effort to "pacify" the communities involved since no major effects were found to USDW in the assessment or; political pressure in an attempt to keep fracking fluid regulation out of the SDWA.

Regardless of whether or not the chemicals used in fracking fluids are dangerous to the public and environments health when used in hydraulic fracturing, there is a need for increased transparency regarding the chemical amounts involved with this practice. This would most likely help to alleviate some of the concerns voiced by communities or groups. It would also allow for more informed studies to be conducted concerning the potential health effects of hydraulic fracturing.

3.3 MONONGAHELA RIVER

“It…seems like…we didn’t really tackle the TDS problem…until we started violating the water quality standard”, reflected an attorney in reference to the Mons ability to assimilate these secondary contaminants (personal communication, April 14, 2010).

The order to reduce the amount of brine water that sewage plants treated was a decision made in the face of many unknowns. Whether this order was necessary for recovery and future mitigation remains disputable especially among the drilling companies that were involved.

The DEP’s “inter-rim” strategy for brine water treatment currently being followed allows dischargers to continue discharging unless there is a water quality violation. WWTP’s that are treating brine water were given this two year “inter-rim” period to enable them to conform to the new TDS regulations. In order to conform to these new regulations, current WWTP’s have had to construct new facilities that meet the required limits set for brine water discharges despite the heavy TDS loads found within. These heavy loads ranged from three hundred thousand to nine hundred thousand milligrams per liter of TDS, higher levels have not been seen during the career of an environmental attorney interviewed (personal communication, April 14, 2010).

As it stands right now, the intakes at public water supply plants have a maximum TDS level that they can accept. When the new regulations (found in chapter 95 of PA Code) are in place come January 2011, that acceptable intake level of 500 ppm TDS (found in chapter 93 of PA Code) will instead be applied to the discharge pipe of those WWTP’s handling brine water disposal (personal communication, April 14, 2010). There is concern if these plants will be able to remove enough solids during treatment in order to meet this future regulation. Some feel that this will be a major problem for a lot of people because 500 ppm total dissolved solids are relatively small number when compared to the discharges currently coming from industrial facilities (Personal Communication, November 18, 2009).

In relation to the Mons' low flow problems and previous to this incident, the DEP in Western PA did not require accountability by drillers regarding their source of water. Eastern and Central PA, however, require that federal permission be sought before pumping large volumes of water from freshwater sources. Environmental groups have pressed the PADEP for more accountability among gas drilling companies and their use of "our" water (Parsons, 2008). These types of regulations if enforced by Western PA might help maintain normal river levels thereby helping to mitigate future TDS events or increases (Parsons, 2008).

The outcomes of this incident raise a few questions among the communities affected. The PADEP had made an estimate concerning the contribution of brine water treatment to the rise in TDS levels. A private firm also studied the situation and came up with a significantly lower estimate than the PADEP. Laying aside the issue of "who is right and who is wrong", this situation creates much confusion and uncertainty among involved community members. In situations like this, effective and clear communication is needed from the government agency involved. Appropriate measures were taken by the PADEP for disseminating information to the public about the incident such as through the media and the community meeting that was held. However, the need for further communication efforts to educate and inform affected parties is illustrated throughout the aforementioned events that surround the hydraulic fracturing of the MS.

4.0 WORKING TOWARDS CHANGE

The incidents and studies previously discussed have caused a lot of commotion among the Pennsylvanian communities and government agencies involved. It has been opined that many residents have been taken by surprise in regards to the impacts from MS drilling operations (personal communication, April 14, 2010). These impacts, however, are subject to debate among various parties. The debate on the public health and environmental impacts surrounding the hydraulic fracturing of the MS has resulted in much needed steps towards a greater increase in transparency around these issues.

4.1 RECENT CHANGE

Quite recently, changes have been implemented that will help address the concerns of communities more fully. For example, the EPA has established a hotline and email address for citizens or groups to report concerns regarding the natural gas drilling of the MS. The DEP has hired a significant amount of staff to help solely with MS issues and they have built a new Oil and Gas office closer to drilling sites. They will also be posting online the specific status and production information for each MS gas well for public viewing.

A current proposal by the DEPs Department of Oil and Gas would require gas companies to make available the chemicals used and more importantly the amounts used for each well they are drilling. Also, a plan for another EPA assessment is currently being finalized for later this year. It will focus specifically on the potential that the practice of hydraulic fracturing has for adversely affecting an USDW. Many of these new developments and regulations are in response to the public's desire for more transparency regarding the development of the MS.

4.1.1 Public Comments Regarding 2010 Assessment

In regards to the previously mentioned 2010 assessment on hydraulic fracturing, the EPA's Science Advisory Board Environmental Engineer Committee Hydraulic Fracturing Research Plan Review was held on April 7 of 2010. During this review, the EPA accepted public comments focused on the hydraulic fracturing study. These comments were to be reviewed and considered by the EPA as possible areas to explore during their assessment.

Upon being analyzed, these public comments produced several recurring themes (for more in depth theme descriptions, please see *Appendix B*). The majority of comments focused on water quality and the feeling that the United States is trading one natural resource (water) for another (methane). Other environmental issues followed, with concerns for remediation of natural resources and roadways, both affected by drilling activities. Feelings were also expressed concerning the unknown impacts caused by hydraulic fracturing and the need to proceed with more caution concerning its use in natural gas production. Government involvement was hit upon; asking for more appropriate regulations and transparency in regards to hydraulic fracturing activities as well as politically unbiased assessment results. Air quality and human health being affected adversely were both voiced as concerns. Trailing these themes were questions concerning whether economic benefits truly outweigh the costs as well as desires that the government increase community participation. These themes help to illustrate the fears and worry that aforementioned events have caused among various groups and communities.

4.1.2 Alternative Fracking Fluids

A project is underway that will help address the issue of brine water treatment through the creation of alternate forms of fracking fluid. This will allow drilling companies to reuse these fluids at other wells. The Department of Energy has funded a partnership between the University of Pittsburgh and Carnegie Mellon University for the purpose of solving issues related to both natural gas production and mining operations.

During an interview, one of the professors involved with this study explained that brine water's high salinity upon returning out of the gas well, causes the common fracking agents to break down, thereby excluding its reuse at the next well. Designing alternative fluids that would avoid this breakdown is one goal of this project. Another reason for not reusing brine water was its components barium, strontium and calcium. Drillers will not reuse brine water containing these components because of the possibility that these chemicals will precipitate out and plug the wells (personal communication, November 18, 2009).

Which brings into the forefront, the other part of the project, removal of these chemicals through the use of acid mine drainage (AMD) which is a large contributor to the Mons TDS problem. AMD contains a high amount of sulfates, which when mixed with brine water, would cause the chemicals in brine water to precipitate out thereby helping to create a more reusable fracking fluid. This project will ultimately help cut down on fresh water withdrawals during the fracking process aiding in conservation efforts of Pennsylvanians precious fresh water supplies (personal communication, November 18, 2009).

5.0 PROPOSAL FOR CHANGE

There is a lot of anger, fear and frustration among communities regarding what is taking place with the MS. A Clean Water Advocate with PennEnvironment believes that more of an effort is needed to disseminate information to communities and decision makers (personal communication, April 23, 2010). Realistically, these problems that have been presented in regards to the drilling of the MS will most likely continue as a source of concern in the years to come. Despite these concerns, the gas companies are likely to keep drilling as well.

Yet it is believed by the individuals interviewed at the law clinic and PennEnvironment that a more unified consensus among these parties regarding the potential dangers of hydraulic fracturing could be realized by an improvement in communication and community outreach (personal communication, April 14 & 23, 2010). For these improvements to be realized however, solutions to strengthen communication and education efforts between communities and government agencies need to be addressed.

5.1 COMMUNITY ASSESSMENT

When embarking on a new adventure such as MS natural gas production, it is felt by an environmental attorney that the government needs to make sure they are out there in the community "justifying what they are doing" and creating "better informed citizens" possibly through involvement with the various agencies such as the DEP (personal communication, April 14, 2010).

Greater community involvement will be focused on for this proposal through expansion of the EPA's smaller qualitative assessment process into a community needs assessment. This will hopefully lead to greater community buy-in for future assessment results. A needs assessment involves members of the community and those conducting the assessment. The needs of the community are explored and qualitative research often takes place. Qualitative research is "any type of research that produces findings not arrived at by statistical procedures or other means of quantification" (Strauss & Corbin, 1998). Data gathering can take the form of in-depth interviews, observations or even videotapes. These data can be quantified during analysis but usually remain interpretive.

A needs assessment "may be utilized as a central method to facilitate the modification of social systems so they become more responsive to human needs" (Costa & Garcia, 2001). Sometimes the government and communities can work together to assess various health issues. The communities involved with natural gas issues and concerns are all to use to getting the "run-around" by gas companies and sometimes government agencies. Costa & Garcia (2001) discuss the need for empowerment and social action techniques for groups such as these:

> Needs assessment methodology, if it is to respond to a commitment to the powerless and to the fostering of social change, must (a) emphasize techniques that, singly or in combination, facilitate grouping and mobilizing people; (b) foster collective activities; (c) facilitate leadership development; and (d) involve residents in the entire research process. These characteristics are essential so that the technique can facilitate consciousness-raising.

The framework that this needs assessment will utilize is called 'Mobilizing for Action through Planning and Partnerships' (MAPP). This model is offered through the National Association of County and City Health Officials in cooperation with CDC (www.naccho.org). The community participates in an assessment that helps to build their capacity and identify their needs. These visioning processes are divided into 4 sections which include themes and strengths, health system, health status and forces of change. Upon assessment completion, all participants are better able to envision their community's desired outcome through an illustrated community roadmap, developed from the assessment results. The MAPP process will allow the EPA to empower the communities as well as educate them on the assessment process and ultimately the results (Gilmore & Campbell, 2005).

This assessment could take place in the communities affected by the MS drilling as well as other locations where hydraulic fracturing fluid is being injected into or adjacent to, an USDW (as was previous studied by the EPA's 2004 assessment). Rather than just focus on possible health impacts from fracking fluids, as the EPA did before, other community concerns will also be addressed. For example, possible methane migration into drinking wells and the consequences of "cloudy water and objectionable odors" related to citizens wells (Wilson, 2004) will be explored. Including concerns from the communities that are related to natural gas drilling but not necessarily specifically to fracking fluid will help nurture the belief that "the government" cares more about the welfare of communities when carrying out their responsibilities.

Face-to-face interaction between the EPA and communities during the planning of and process of the assessment, will allow for greater community buy-in to the study results. The community will have a deeper sense of ownership for both the research and its conclusions. (Costa & Garcia 2001) This will allow for government agencies to communicate more effectively with communities while researching the issues surrounding natural gas drilling. Increasing the voice of participating communities is important for this assessment. To ensure that this goal is met, there will need to be a greater interaction between communities and the EPA's peer review panel. As previously stated, The Federal Advisory Committee Act encourages citizens to participate in panels such as this (Wilson, 2004).

The assessment will include various activities and methods allowing for a higher level of community participation throughout the process. Since this issue borders social action, Freire's "education for critical consciousness" could be implemented as described in Hancock & Minkler (1997). This method would allow community members to reflect upon changes or improvements that they feel are appropriate regarding their community issues with natural gas production. Also, delBecqs nominal group process is an effective tool for large community meetings. During this process, smaller groups form from the larger group and facilitate discussion through a smaller, less threatening, more informal atmosphere (Hancock & Minkler, 1997). Photo voice, another participatory action research method as described by Wang and Burris in Lopez (2005), can be used to enhance an individual community member's ability to relate their experiences. Community members upon receiving cameras can take pictures involving natural gas drilling and how it affects their lives. They can then share these pictures with fellow community members as well as government agencies and policy makers.

The last section of the MAPP assessment process addresses 'forces of change' which "identifies forces affecting the community or the local public health system." This will provide the opportunity to discuss the legal regulations surrounding natural gas drilling practices and how one would achieve or influence desired changes.

5.2 LEVERAGE POINTS

Donello Meadows article on leverage points applies very well to the health issues surrounding the MS and is great for facilitating discussion regarding desired changes and how to go about them. Leverage Points "are places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in everything" (1999). Systems are too complex for leverage points to be common sense. It is very hard to tell what the consequences will be when making a change in a complex system. There are two “points of power” within a system, the “physical” aspects and the “control” aspects. The control points of power are the most effective areas for intervention. Therefore, the control area of leverage points will be applied to the issues concerning natural gas production in the MS.

Within the Meadows article the point was made that growth, due to its benefits, is encouraged, while the costs are sometimes completely ignored. One of the issues with hydraulic fracturing is that this practice is relatively new in natural gas production meaning the long-term health effects are widely unknown. During the interview with the environmental attorney, they voiced their opinion that Pennsylvania has been “beta-tested” by the natural gas industry in contrast to New York (NY) and their more cautious approach to MS development. NY’s state laws requires a moratorium on these new practices to allow ample time for evaluating possible health impacts associated with new practices. Pennsylvania however does not have those kinds of laws and has as a result discovered the impacts of hydraulic fracturing through personal experience (personal communication, April 14, 2010).

Therefore, an area of leverage to intervene would be the growth rates of the drilling operations themselves. "There's more leverage in slowing down the growth of the system so technologies and prices can keep up with it, than there is in wishing the delays away" (Meadows, 1999). Perhaps by slowing the growth rate, the potential long-term health effects may have more time to catch up. This would help in mitigating the possible harmful health effects on communities that are sometimes associated with a drilling boom.

A negative feedback loop gives a system the ability to correct itself. When a goal is met, a negative mechanism responds by turning off the positive mechanism. When the goal is no longer met, the positive mechanism comes back on to help meet the goal once more. One of the negative feedback loops employed around natural gas production are environmental laws and regulations. One set of laws is the SDWA. Its goal is to protect our drinking water from various industrial operations. The EPA monitors for excursions from this goal and can respond with the affixed penalties when industries don't observe the SDWA. When parts of this law are stripped away or "amended", its ability to accomplish its intended goal is hampered. Instead, this needs to be taken in the other direction so as to strengthen SDWA’s ability to protect environmental and public health.

Another leverage point is the "structure of information flows". In essence this creates a new loop that delivers information to places and people that it didn't go to in the past. It's creating a better awareness of actions and consequences. Obviously, this type of leverage point would be unpopular with those causing the actions and consequences due to the potential for public backlash or pressure to change. The application of this tactic would work very well in the MS Drilling issues especially if the DEP s proposal to post specific chemical concentrations for each well passes. If the amount of chemicals used in fracking fluid had to be posted publicly, maybe drilling companies would show more responsibility for the possible harm they are causing environmentally. One example of this increased responsibility would be an added investment to spend more time on researching "environmental friendly" versions of fracking fluid such as the previously mentioned DOE funded project.

The last two leverage points that I will discuss are the “power to change the rules” of a system and the “power to alter (add, change, evolve etc) the structure” of a system. Targeting the people with the power to change things is a high point of leverage. For instance, the former Vice President of the U.S., Dick Cheney was once a CEO of Halliburton, one of the largest gas companies involved in the MS. Dick Cheney chaired the 2005 Energy Bill which amended the SDWA to exclude gas companies’ practice of hydraulic fracturing from government regulation. As one could imagine, this “use of power" has caused quite a bit of controversy among environmental groups and other communities involved.

Of course it would be nice to use the most effective leverage points such as the changing of an entire paradigm to the “protecting of human and environmental health”. If all of the activities, laws and programs surrounding the MS derived from this paradigm, the situation would be vastly different. There are definitely current laws and measures with this paradigm in mind, the SDWA being just one of them. These laws that help to maintain a paradigm are also influenced by other paradigms however. For example, the need to be more “self-sufficient as a nation” in regards to natural gas drilling in U.S., seems among other reasons, to have caused the most recent SDWA amendment as discussed previously.

6.0 CONCLUSION

As illustrated through the MS issues previously discussed, it seems that much can be gained by a more proactive approach, rather than reactively triaging problems (personal communication, April 14 & 23, 2010) that arise as a result of ignorance and greed. Perhaps as time goes on, the shift into the paradigm to “protect human and environmental health” will continue to snowball, especially if the following advice from Thomas Kuhn is followed. In regards to bringing about a change in paradigms he stated, “You keep pointing at the anomalies and failures in the old paradigm, you keep speaking louder and with assurance from the new one, you insert people with the new paradigm in places of public visibility and power.” (Meadows 1999) Many hope that the health of the public and the environment, which are ultimately inseparably connected, will be considered more fully and cautiously in endeavors such as the harvesting of the MS.

APPENDIX A

LITERATURE REVIEW METHOD

A list of the chemicals that are commonly found within fracking fluids was obtained on the Pennsylvania Department of Environmental Protection website. http://www.dep.state.pa.us/dep/deputate/minres/oilgas/FractListing.pdf

Using the list of chemicals obtained from this website, a meeting was held with a librarian from the Falk Library of Health Sciences at the University of Pittsburgh. The librarian gave advice and instruction in regards to searching for the chemicals and their existing literature. This literature search then utilized major databases of research information from peer reviewed journals, books and dissertations. Alternative names for each chemical were found using the website for the Agency for Toxic Substances Database Registry (ATSDR).

The databases searched include: PubMed, CINAL, OVID, AGRICOLA, EMBASE.com, Google Scholar, the website of the U.S. Environmental Protection Agency, and the ATSDR website. Initially these searches included terms associated with aquatic life and MS drilling. These included: Ecology, Ecological, Ecotoxicology, Aquatic, Fish, Bird, Daphnia (water flea), Shrimp, and Marcroinvertebrates. Search terms used were ecotoxicology AND specialty chemicals OR aquatic OR Aquatic Life. Ecotoxicology AND Aquatic Life; MS Drilling AND

Ecotoxicology AND Aquatic Life. There were no studies associated with the above search terms in any of the databases presented previously

At this point, the search was expanded to include names of chemicals used in the fracturing process along with the search terms used above such as: specialty chemicals OR aquatic OR Aquatic Life. Many of the chemicals in the list of fracturing chemicals were not found at all in the literature related to toxicity and aquatic life, some were not found with the other search terms used simultaneously, and others were found with those terms but deemed irrelevant. The relevant information that was found in the literature related to specific fracturing chemicals with application or in reference to aquatic life, however, literature was not found in regards to MS drilling specifically.

APPENDIX B

QUALITATIVE DATA COLLECTION & ANALYSIS

S*takeholder interviews* were conducted for this thesis after the 17 of November, 2009 under IRB approval number PRO09110103 entitled "Pittsburgh Regional Environmental Threat Analysis" (PRETA). These interviews were conducted with an attorney from University of Pittsburgh's (Pitt) Environmental Law Clinic, a professor from Pitt's Department of Civil and Environmental Engineering and a Clean Water Advocate from PennEnvironment, a research and policy center. Interview questions centered on themes such as: regulations and laws pertaining to issues surrounding the drilling of the MS; government communication; community involvement and; possible solutions to environmental health impacts. These interviews reflected many themes that were prevalent in the public comments below. All interviews have been cited as "personal communication" using agency name only.

Public Comments were analyzed for this thesis. The EPA accepted these public comments for a meeting held regarding their 2010 Hydraulic Fracturing study. These comments are public information and can be viewed on the EPA's website at http://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/4CAA95A38952145F852576D3005DAA17?OpenDocument under the title "SAB Environmental Engineer Committee Hydraulic Fracturing Research Plan Review." The amount of public comments received totaled seventy.

The commenter's consisted of but are not limited to: scientists; political figures; business owners; community members; environmental groups, alliances, associations & counsels; local, state & federal government agencies and companies from the oil & gas industry. Some of these public comments were made by individuals on behalf of up to thousands of group members or citizens. Out of the seventy comments, 56 were reviewed. Those not reviewed were comments submitted by companies from the oil & gas industry or they were duplicates of previously reviewed comments. The comments were then read and recurring themes or keywords were identified as well as subgroups to that theme. If a key theme or subgroup was referenced in a paper, it was recorded once per paper. The results from the 56 public comments are as follows. **8** major themes were identified, some of which had sub groups. There were **377** total theme hits. **135** (35.8%) for *Water Quality*- general concerns; private wells; public/municipal water supplies and; aquifers. Withdrawals, contamination and spills affecting natural water ways and; adverse affects on aquatic life and fish kills. Testing of wells; owners unable to afford testing and; drillers should test wells. The disposal of, a WWTP's ability to treat, and a drillers ability to store Brine water. **55** (14.6%) for *Other Environmental*-concerns on remediation; natural resources; landscapes; soil; trees; agriculture; cattle being harmed or dying; animal health in general and; road damage. **49** (13%) for *Hydraulic Fracturing*-general concerns of safety; relatively unstudied; the accelerated development of and; possible consequences. Cautious approach needed or moratorium. Alternatives for current fracking fluid chemicals. **47**(12.5%) for *Government Involvement*-appropriateness, changes and additions to current laws and regulations; best management practices; mistrust of and political/gas industry influence on EPA 2004 assessment; transparency through FRAC Act and chemical amount disclosure. **35** (9.3%) for *Air Quality*-general concerns; greenhouse gas; asthma and; cleaner than coal myth. **28** (7.4%) for

Human Health-including concerns over present and future possible adverse affects. **16** (4.2%) for *Economic*-concerns for benefits outweighing costs and; who will suffer most. **12** (3.2%) for *Community Participation*-general desire for; law suit threats; avenues for complaints. 377 total theme hits

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