Research Article

***Cryptosporidium* Removal from Runoff by Active Carbon Filter with Coal Gangue**

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Transport of *Cryptosporidium* in runoff will contaminate the surrounding water body. *Cryptosporidium*-sized microspheres and inactive *Cryptosporidium parvum* oocysts removal using an active carbon (AC) filter with/without coal gangue from the runoff was evaluated. Chemical composition of coal gangue was determined, and its performance as a water treatment material was tested. Results showed SiO₂ was the dominant chemical component of coal gangue. Removal was only 20% for microspheres and 24% for oocysts by AC filtration alone. The removal for both was increased to more than 98% by addition of coal gangue powder to the filter. Furthermore, gangue reuse turned commercially worthless material to a water treatment material as well helping prevent gangue from occupying agriculture/industry land.

1. Introduction

Coal gangue makes up 10% to 25% of the amount of coal yield in China, which turns to industrial wastes congregating like huge mountains in coal mining areas. In mining, gangue is the commercially worthless material and thus distinct from overburden, the waste rock or materials overlying an ore or mineral body that are displaced during mining without being processed. More than 1,600 coal gangue mountains with approximate 45 million tons of gangue are found in China. The number of gangue mountains is still increasing with the accumulation of 1.5 to 2 million tons/year. Gangue reuse rather than dumping as tailing will help to manage the waste in coal mining area and may later find a commercial use. So far, there is no reuse research on coal gangue as a water treatment material to remove *Cryptosporidium* from water.

Cryptosporidium is one-celled intestinal parasite with diameter of 4–6 μm and has been reported for contamination of water worldwide [1–3]. Transmission of *Cryptosporidium* via runoff to surface water is relatively common. However,

there is limited research on *Cryptosporidium* removals from runoff so far.

AC filters are effective for removal of multiple contaminants from water body [4, 5]. They are easy to install and less maintenance is required. The runoff in research area contains multiple pollutants, such as protozoan pathogen *Cryptosporidium* and polycyclic aromatic hydrocarbons. Here, AC filter was selected due to its large specific surface area with high adsorption. However, *Cryptosporidium* removals by AC filter were low indicated by the preliminary experiments. In this paper *Cryptosporidium*-sized microsphere and inactive *Cryptosporidium parvum* oocyst removals from runoff were evaluated by AC filter with/without coal gangue powder, intending to enhance the AC filter performance.

2. Methods and Materials

2.1. Experimental Methods. Figure 1 shows the lab-scale AC filter and runoff treatment system. AC filter height was 0.5 m and diameter was 0.5 m. The filtration rate was 20 m/h.

TABLE 1: Chemical composition (percentage) for coal gangue.

Composition	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	C
Content	30%–60%	20%–30%	2%–10%	1%–4%	1%–2%	1%–2%	20%–30%

TABLE 2: Heavy metals in coal gangue and soil (mg/kg).

	Cd	Pb	Hg	Cr ⁶⁺	As	Cu
Gangue	0.1 ± 0.02	25.2 ± 0.25	0.1 ± 0.02	53.1 ± 0.12	8.2 ± 0.17	23.8 ± 0.1
Soil	0.1 ± 0.02	14.7 ± 0.35	0.1 ± 0.03	52.5 ± 0.87	16.9 ± 0.15	18.2 ± 0.25

FIGURE 1: Experimental setup (100 g gangue powder was added).

The filter was backwashed every 24 hrs. Online data could be recorded and downloaded from a computer. A control experiment without gangue powder was conducted. Duplicate experiments were conducted and triplicate samples were collected.

Gangue and soil samples were collected from a local coal mining area. It was crushed into small grain (10–30 mm) and then ground into powder (5 μ m) by a grinding machine (LHE-1000, Zhengyuan Company, Shandong, China). The gangue powder was stored in dry basket for use. Chemical composition was tested by X-ray Fluorescence (XRF, EDX8800E, 3V Instrument Co., Ltd, Suzhou, China). The gangue powder solution (volume ratio of powder/water = 1:2) was fed previous to experiment by circulation pump.

The use of polystyrene microspheres as an oocyst surrogate has been done by multiple researchers, and it was used in this study [6–13]. Microspheres with diameter of 4.5 μ m were used as the surrogate (Fluorobrite™ Carboxylate YG 4.5-micron microspheres, Cat. #16592, Polysciences, Inc., Warrington, Pennsylvania, USA). Heat-inactivated *C. parvum* oocysts were used. Oocysts were heat-inactivated at 55°C for one hour prior to seeding. The concentration for both stocks was 4×10^{11} #/L. Samples were passed through 2.5 μ m pore size filters. Each polycarbonate filter was mounted on a glass microscope slide under an epifluorescent microscope at 100x magnification. *C. parvum* samples were concentrated by centrifugation twice at 4,000 $\times$ g at 4°C for 15 minutes followed by two microcentrifugation steps at 15,000 $\times$ g at 4°C for 5 minutes and detected under 200x magnification [14].

Approximately 10^7 (1.82 #/mL) microspheres and oocysts were fed. Filter influent and effluent samples were taken for removal calculation. Runoff combined with microspheres

FIGURE 2: *Cryptosporidium*-sized microspheres (1.8 #/mL) and *Cryptosporidium* oocysts (1.8 #/mL) removal by active carbon cartridge filter with and without gangue powder (GP).

and oocysts were fed. Duplicate experiments were conducted. Triplicate samples were taken for each.

3. Results and Discussion

Collected gangue chemical composition is shown in Table 1. Varieties of mineral substances were found in coal gangue, which contains SiO₂, Al₂O₃, Fe₂O₃, CaO, MgO, Na₂O, K₂O, SO₃, P₂O₅, C, N, H, and so forth. The max-composition was SiO₂ which took up 30% to 60%, while Al₂O₃ (20% to 30%) took the second place, followed by C, MgO, and Na₂O. In addition, heavy metal concentration in coal gangue and soil was compared and shown in Table 2. Cadmium, lead, mercury, chromium, arsenic, and copper were found in coal gangue. Similar heavy metal concentration was observed between gangue and soil. The metal concentration in coal gangue and soil was below the Chinese Environmental Protection Agency limits (GB15618-1995).

Figure 2 shows the microspheres and oocysts removal with and without gangue powder addition on the surface of the AC filter. Average removals were 23% (varied from 16% to 34%, standard deviation = 0.07) and 24% (varied from 14% to 26%, standard deviation = 0.05) for microspheres and oocysts by AC filter, respectively. The average microsphere and oocysts removals were 99% (varied from 97% to 99.9%, standard deviation = 0.01) and 98% (varied from 95% to 99%, standard deviation = 0.02) by AC filter with gangue powder on its surface (duplicate experiments and triplicate samples). Removals of microspheres and oocysts were similar demonstrating that the microsphere was an adaptable

Cryptosporidium surrogate. There is rare research on *Cryptosporidium* removal from runoff. The removal as high as 99% can be comparable with the removals of *Cryptosporidium* by sand filter with coagulation [15]. However, the mechanism was different from coagulation followed by sand filtration. The potential reason of gangue powder enhanced AC filter performance is similar to membrane filtration.

4. Conclusions

AC filter could remove 23% of *Cryptosporidium*-sized microspheres and 24% of oocysts. The AC filter with gangue powder achieved 99% microspheres and 98% oocysts removal. The results indicated AC filter with coal gangue powder could remove microspheres or oocysts from runoff efficiently. Using coal gangue to treat runoff was an effective way to reuse coal mining waste material as well as to deal with the gangue accumulation and stealing agriculture land issue.

Competing Interests

The authors declare that they have no competing interests.

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References

- [1] J. R. Harris and F. Petry, “*Cryptosporidium parvum*: structural components of the oocyst wall,” *The Journal of Parasitology*, vol. 85, no. 5, pp. 839–849, 1999.
- [2] L. Putignani and D. Menichella, “Global distribution, public health and clinical impact of the protozoan pathogen *Cryptosporidium*,” *Interdisciplinary Perspectives on Infectious Diseases*, vol. 2010, Article ID 753512, 39 pages, 2010.
- [3] P. Lu, T. Yuan, Q. Feng, A. Xu, and J. Li, “Review of swimming-associated *Cryptosporidiosis* and *Cryptosporidium* oocysts removals from swimming pools,” *Water Quality Research Journal of Canada*, vol. 48, no. 1, pp. 30–39, 2013.
- [4] D. Vial and G. Doussau, “The use of microfiltration membranes for seawater pre-treatment prior to reverse osmosis membranes,” *Desalination*, vol. 153, no. 1–3, pp. 141–147, 2003.
- [5] Y. Wang, F. Hammes, and T. Egli, “The impact of industrial-scale cartridge filtration on the native microbial communities from groundwater,” *Water Research*, vol. 42, no. 16, pp. 4319–4326, 2008.
- [6] J. E. Amburgey, *Improving filtration for removal of Cryptosporidium Oocysts and particles from drinking water [Ph.D. thesis]*, Georgia Institute of Technology, Atlanta, Ga, USA, 2002.
- [7] J. E. Amburgey, A. Amiratharajah, B. M. Brouckaert, and N. C. Spivey, “Effect of washwater chemistry and delayed start on filter ripening,” *Journal of American Water Works Association*, vol. 96, no. 1, pp. 9–110, 2004.
- [8] J. E. Amburgey, A. Amiratharajah, M. T. York, B. M. Brouckaert, N. C. Spivey, and M. J. Arrowood, “Comparison of conventional and biological filter performance for *Cryptosporidium* and microsphere removal,” *Journal of American Water Works Association*, vol. 97, no. 12, pp. 10–91, 2005.
- [9] T. J. Brown and M. B. Emelko, “Chitosan and metal salt coagulant impacts on *Cryptosporidium* and microsphere removal by filtration,” *Water Research*, vol. 43, no. 2, pp. 331–338, 2009.
- [10] X. Dai and R. M. Hozalski, “Evaluation of microspheres as surrogates for *Cryptosporidium parvum* oocysts in filtration experiments,” *Environmental Science and Technology*, vol. 37, no. 5, pp. 1037–1042, 2003.
- [11] M. B. Emelko and P. M. Huck, “Microspheres as surrogates for *Cryptosporidium* filtration,” *Journal of American Water Works Association*, vol. 96, no. 3, pp. 12–105, 2004.
- [12] M. B. Emelko, P. M. Huck, and B. M. Coffey, “*Cryptosporidium* removal by filtration: a review,” *Journal of American Water Works Association*, vol. 97, no. 12, pp. 101–115, 2005.
- [13] S. Y. Li, J. A. Goodrich, J. H. Owens, G. E. Willeke, F. W. I. Schaefer, and R. M. Clark, “Reliability of surrogates for determining *Cryptosporidium* removal,” *Journal of American Water Works Association*, vol. 89, no. 5, pp. 90–99, 1997.
- [14] P. Lu, *Enhanced removal of Cryptosporidium parvum oocysts and Cryptosporidium-sized microspheres from recreational water through filtration [Ph.D. thesis]*, University of North Carolina at Charlotte, Charlotte, NC, USA, 2012.
- [15] P. Lu and J. E. Amburgey, “A pilot-scale study of *Cryptosporidium*-sized microsphere removals from swimming pools via sand filtration,” *Journal of Water and Health*, vol. 14, no. 1, pp. 109–120, 2016.