THE POTENTIAL OF BRYOPHYTES IN PHYTOFILTRATION OF HEAVY METAL CONTAMINATED WATER

PRELIMINARY COMMUNICATION

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ABSTRACT:
Bryophytes are a group of plants vital to many ecosystems and biogeochemical cycles and are well known bioindicators and biomonitoring tools. However, they have been deemed industrially less important than vascular plants and their potential for applications other than as biomonitoring tools has been overlooked. In recent years, however, bryophytes, and in particular mosses, are starting to gain attention as viable phytoremediation agents. Studies indicate that some moss species have the ability to uptake heavy metals such as Pb, Cd, Zn, Cu, As, and Cr from contaminated water. Tested mosses could both adsorb and absorb significant amounts of specific heavy metals without adverse effects on the plant. Results suggest that moss biomass, either dry or wet, could be used as a bio-sorbent in filtration of heavy metals. The review of available literature shows a promising prospect of moss to be used in phytofiltration of heavy metals. Existing knowledge on this topic could be the basis for further research which is needed.

KEYWORDS: moss; heavy metal; phytofiltration; bio-sorbent

INTRODUCTION

Bryophytes are a group of plants vital to many ecosystems and biogeochemical cycles. They were the first plants to evolve from water plants, namely green algae, to terrestrial plants and pave the way for other plants to develop in terrestrial environments. There are three major gorups of bryophytes: mosses, liverworts and hornworts. This paper will focus on mosses. Although they are deemed industrially less important and often overlooked in favor of vascular plants, there are several strong points of mosses that indicate that these plants may be a usefull tool in environmental engineering.

Mosses inhabit a variety of ecosystems and microecosystems, in many of which vascular plants can not survive. Mosses adapt well to nutrient poor environments and harsh conditions. The key difference between mosses and bryophytes in general and vascular plants is that the former lack a root system, meaning they absorb nutrients through their whole surface. Moss leaves also lack a cuticle layer which makes their cell walls easily accessible to metal ions and in turn facilitates ion-exchange over a large surface [1]. These characteristics allow moss species to absorb and accumulate large amounts of heavy metals and other pollutants both inside and outside of their cells. The extracellular pollutant concetration shows the current pollution levels, while the intracellular fraction shows an average pollution over a period of time [2]. Beacause of this, mosses proved to be valuable tools for in situ biomointoring and have been used as such for decades. Their potential for applications other than air pollution monitoring, however, has been overlooked up until recently. Recent studies have been conducted researching mosses for applications other than in biomonitoring and this paper aims to concisely present the promising results of those studies.

DISCUSSION

The ability of mosses to accumulate pollutants from air is well known, but scientists are proposing that this ability could be applied to other media as well. For example, Nduka and Umeh [3] showed that a non-specified terrestrial moss displayed the ability to uptake heavy metals from aqueous solutions. Precisely, moss could absorb ions Pb^{2+}, Cd^{2+}, Zn^{2+} and Ni^{2+} and showed a particular tolerance to Pb^{2+} and Cd^{2+}, theorizing that the use of moss could be feasible for waste water treatment.

Some moss species, like *Bryum capillare, Funaria hygrometica* and *Ceratodon purpureus,* are known hyperaccumulators for heavy metals, specially for Fe, Pb, Cu, Mn and Zn [4]. Vukojevic et al [4] also showed that mosses are able to accumulate heavy metals from coal ash landfill and showed potential for remediation of ash deposit sites because they bind surface ash and prevent it from being blown away. Mosses do not absorb nutrients from soil since they lack a root system, but they do facilitate growth of vascular plants on soils which would not likely sustain their growth otherwise [4].

Aquatic moss biomass from the species *Taxiphyllum barbieri* showed capacity to accumulate heavy metals Pb, Cd, Zn, Cu, As, and Cr [5]. *T. barbieri* was especially suitable for the phytofiltration of Pb (>100 g/kg DW in 6 h), Cd (about 4.3 g/kg DW in 6 h) and Cr (about 19.4 g/kg DW in 6 h) from contaminated water. It was noted that lighting conditions while growing moss influenced the hue of moss and also the absorbancy efficiency for specific metals. In the same study, Papadia et al [5] asserted that due to their resistant thalli, mosses could also provide some mechanical filtration and support the growth of desirable bacteria. It is important to note that the interrelationship of multiple heavy metals in one medium and its effect on removal pathways in moss are unclear.

Although the application of mosses for phytofiltration of contamintated water still is a very under-researched topic, there are several studies implicating its potential. For example, one study [6] indicated that *Warnstorfia fluitans* removed up to 82% of As from the water in the form of arsenate without toxic effect on the plant biomass, which was comparable to As accumulation capacity of A-hyperaccumulating vascular plant *Pteris vittata*. The same study found that of the As taken up, over 90% was bound to the tissue, and arsenic was both absorbed and adsorbed by the moss, and twice as much As was found in living parts than in dead moss tissue. These results propose that *W. fluitans* could be suitable for use in the phytofiltration of As-contaminated waters.

The same moss species, *W. fluitans* also exhibited the ability to remove nitrogen from polluted water, especially when used in conjuction with other materials such as woodchip [7]. In a hybrid bioreactor combining moss and woodchip, 48% of dissolved inorganic nitrogen on average was removed from mine-influenced water in cold climates. The hybrid bioreactor showed significantly higher removal rates than bioreactors using solely woodchip or moss [7].

Another study showed that the moss species *Bryum muehlembeckii* and *Sphagnum perichaetiale* presented great efficiency in removing Fe and Cr in dry biomass form, both removing at least 95% of Fe and Cr present in aqueous solution [8], comparable to removal rates of Cr by activated carbon [9] which is commonly used for contaminant removal.

Another recent study even presented evidence of the abitility of moss *Sphagnum palustre* L. to retain polystyrene nanoparticles [10].

Itouga et al [11] report that protonema of the moss *Funaria hygrometica* adsorbed Pb with a maximum adsorption capacity of 74.1%, mainitaining stable adsorption within a pH range from 3 to 9 of test solutions. Adsorption of Au, Cr and Tl by *F. hygrometica* was also efficient [11]. Therefore authors suggested that *F. hygrometrica* could be a biomaterial for the bio-sorbent filtration of metals.

Aforementioned studies show that the tested moss species in dry or wet biomass forms can be applied as phytoremediation agents and bio-sorbents of metals from contaminted water. Although existing methods of heavy metal removal from contamintated water using vascular plants are efficient, the presented studies show that other phytogenic options could be auspicious as well.

DISPOSAL OF PHYTOREMEDIATION PLANTS

Since vascular plants are established in phytoremediation, all existing methods of disposal and utilization methods of phytoremediation plants pertain to vascular plants. Theorizing that the end product of phytoremediation is biomass regardless of whether the phytoremediation agent was a vascular plant or a bryophyte, disposal methods applied to vascular plants could also be applied to mosses.

FUTURE DIRECTIONS

Although there are a number of studies reporting on various moss species' ability to uptake and retain metals, the extact mechanims through which this is achieved are little understood. In general, it is accepted that the lack of cuticle on moss leaves allows easier ion-exchange and due to the lack of root systems, moss adsorb metals through their whole surface. However, specific characteristics and genes involved in heavy metal uptake and resistance need further research. Itouga et al [11] propose that the high adsorption capacity for Pb of *F. hygrometica* could be linked to phosphoglyceric acid (PGA) found in *F. Hygrometica* cell walls, PGA being found to have similar adsorption capacity to chitosan [12].

Mentioned experiments studied short-term uptake of mosses. With mosses being slow growing plants, long-term uptake and uptake in different growth phases of the plant should also be investigated. Research is also needed on behavior of moss in presence of multiple contaminants, as well as to what degree a moss bed could provide mechanical filtration to wastewater.

Since it was shown that different lighting conditions during moss growth influence heavy metal absorption capacity [5], studies optimizing moss cultivation conditions to maximize uptake would be beneficial.

It was also proposed that moss species could be genetically modified to further enhance heavy metal uptake capacity and minimize negative effects on the plant [13], which could be a possible.

Development of microplastic removal methods from soil and water is imperative and the possibility to use moss for this purpose is compelling.

Comparison to established biosorbents and phytofilters taking into consideration environmental impact is also necessary.

Since the potential of bryophytes for phytofiltration of heavy metal contaminated water has only recently been noticed, existing research is scarce but promising.

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