

Environmental Impacts of Phosphate Rocks on the Water Quality of Rivers

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Abstract: One of the important natural sediment rocks impacting aquatic environment is Phosphate Rocks (PR). PR comprises from several chemical compositions such as heavy metals. Mining and transportation of PR nearby or through the rivers may expose them to pollution. Some elements such as salts and heavy metals may be leached out into the water, when PR is in contact with water due to dipping in water streams, precipitation events, or changes in water table. In this study via experimental lab work, PR leachability was investigated when it immersed in Nile River. The research work focused on evaluating the release of some constituents, including phosphors, cadmium, chromium and lead of PR on the water quality of Nile by using leaching experiments. In these experiments, the potential impact of changing conditions, such as liquid to solid ratio (L/S) and phosphate content in PR on long-term leaching of phosphor and heavy metals. Results revealed that phosphors and lead were released in high concentrations, while cadmium and chromium leached out in very low concentrations. PR leachate out 32 mg/L of phosphorus into Nile water, which it is too much more than the allowable values for natural streams, i.e. 0.5 mg/L. Therefore, if phosphate rocks are submersed intentionally or unintentionally into Nile river water, this will lead to environmental risks in the area of PR submersion.

Keywords: Phosphate Rocks, leaching tests, Water quality, Nile River

الخلاصة: تعتبر صخور الفوسفات (PR) من أهم صخور الرواسب الطبيعية التي تؤثر على البيئة المائية. يتكون PR من عدة تركيبات كيميائية مثل المعادن الثقيلة. تعدين ونقل PR القريبة من الأنهار أو عبرها قد يعرضها للتلوث. يمكن تسرب بعض العناصر مثل الأملاح والمعادن الثقيلة في الماء، عندما يكون PR على اتصال بالمياه بسبب الغمر في مجاري المياه، أو أحداث الترسيب، أو التغيرات في منسوب المياه الجوفية. في هذه الدراسة عبر العمل المختبري التجريبي، تم التحقق من قابلية العلاقات العامة للانغماس عند غمرها في نهر النيل. تركز البحث على تقييم إطلاق بعض المكونات بما في ذلك الفوسفور والكاديوم والكروم والرصاص في PR على جودة مياه النيل باستخدام تجارب الرش. في هذه التجارب، التأثير المحتمل للظروف المتغيرة، مثل نسبة السوائل إلى الصلبة (L / S) ومحتوى الفوسفات في PR على ارتشاح الفوسفور والمعادن الثقيلة على المدى الطويل. أوضحت النتائج أن الفوسفور والرصاص تم إطلاقهما بتركيزات عالية، بينما تسرب الكاديوم والكروم بتركيزات منخفضة للغاية. مادة PR تسرب 32 ملغم / لتر من الفوسفور إلى مياه النيل، وهو أكثر بكثير من القيم المسموح بها للمجاري المائية الطبيعية، أي 0.5 ملغم / لتر. لذلك، إذا تم غمر صخور الفوسفات عن قصد أو عن غير قصد في مياه نهر النيل، سيؤدي ذلك إلى مخاطر بيئية في منطقة غمر PR.

1. Introduction

The raw material to produce phosphate fertilizers and other chemicals is Phosphate Rocks (PR), thus there is a high demand worldwide for these materials [1]. However, these rocks comprise of many chemical compounds and dangerous constitutions. PR usually contains heavy metals such as uranium, cadmium and zinc with high contents more than other natural stones, for example, limestone and sandstone [2; 3]. PR contains three types of hazardous elements, which can be recognized as heavy metals, radiation elements and rare earth elements. The first two types are the most alarmed environmental pollutants. The chemical composition of the PR varies from place to the other over the world. For instance, it is reported that in Egypt lead, gold, cadmium, mercury, and uranium in phosphate rock are 4.0, N/A, 2.3, 0.05, and 27.0 mg/kg respectively [4]. While these elements are higher in some places such as in Morocco as PR contains 7.0, 13.0, 3.0, 0.04, and 82.0 mg/kg respectively [5].

PR is considered as a mixed mineral system because it is rich in a calcium carbonate and calcium magnesium carbonate. Some elements such as salts and heavy metals may be leached out into the water, when PR is in contact with water due to dipping in water streams, precipitation events, or changes in water table. Leaching tests are the common tools for evaluating the effect of water contact with solid materials. Four types of leaching tests can be

adopted for inorganic pollutants, namely column and tank tests, availability and static-pH [6]. Main effective conditions in leaching tests are pH, liquid to solid (L/S) ratio and contact time. For PR leachability, Jiang, et al. [7] tested different types of PR wastes in different pH environments. The results revealed that the acidic condition could affect phosphorus leaching more considerably than neutral and basic conditions. The phosphorus leached out under acidic environments was much greater than that under neutral or basic ones. Thorneloe et al. [8] reported that the constituent of potential concern concentration at approximately pH equal 2 can be used as an indicator to estimate the total content of the phosphorus in a PR. Therefore, the content of the phosphorus in the solid stage of different PR could be assessed as 1.39 to 1.62 g/kg. Garrabrants et al. [9] recommended that 5 mL/g of the L/S ratio is the most suitable ratio for leaching behaviors of PR in both short-period and long-period. Jiang, et al., [7] concluded that phosphorus release of the PR in the liquid stage declined with L/S ratio increase.

The main leachability constituents from PR are some heavy metals and phosphorous. Heavy metals, in general, cause serious effects on the health of human being. Cadmium, lead and chromium are the most heavy metals encountered in PR, which they result in growth of autoimmunity disease, which makes immune system of the person to attacks its own cells and cause irreversible brain damage. While, increase pure white phosphorus in environmental surroundings can be a severe hazard to human health. White phosphorus is enormously toxic and exposure to it lead to death. Many dangerous diseases such as kidney damage and osteoporosis can be occurred due to exposing to much phosphate. On the other hand, phosphorus are nutrients for natural parts of aquatic ecosystems. Increase phosphorus with nitrogen from atmosphere supports the bloom growth of algae and aquatic plants, resulting in serious environmental and human health issues, and affecting the economy as well [10].

In this study, the release characteristics of PR submersed in a river water such as Nile River was examined by a tentative lab program. The research work aims to assesses advise influence of some components such as phosphors, chromium, lead and cadmium, of PR on the Nile water quality by employing leaching experiments. These experiments investigated parameter effects such as liquid to solid ratio (L/S) and phosphate content in PR on long-term release of heavy metals and salts into the Nile water. The relatively high L/S ratios were chosen to simulate the Nile water amount in comparison to the immersed solid martial of PR into Nile.

2. Methods

PR used in this experimental work was brought from El Sbeaea region in Aswan governorate, Egypt. PR samples was screened and grinded with size of around 5 mm. Material colour is off-white to light brown. PR samples contains 24, 28 and 30% of P_2O_5 . Figure 1 shows size and shape of PR materials. Leaching experiments include sinking PR samples in distilled water and Nile waters at different three L/S ratios, namely 50, 100 and 200 L/kg. Materials and test procedure are shown in Figure 1. Six test containers were used. Four of them had 24% of P_2O_5 with three different L/S ratios from distilled water and one with natural Nile water. The fifth

and sixth container had a 28 and 30% of P_2O_5 respectively with distilled water. Experimental programme details are presented in Table 1.



Figure 1. Phosphate rock material and leaching tank test procedure

Water samples of 100 ml were collected from the test containers at different intervals namely, 1, 7, 14 and 64 days. Then the same amount of distilled water was added to keep L/S ratios fixed. One sample was collected initially from pure Nile water without PR. All water samples were chemically analysed to determine the phosphor, lead, chromium and cadmium concentrations by using Inductivity Coupled Plasma Mass Spectrometry (ICP-MS).

Table 1: Experimental programme Details

Sample no.	Water type	P_2O_5 (%) in PR	L/S (weight)	Collection time (days)
S0	Nile (N.W)	---	---	0
S1	Nile (N.W)	24	200/1	1,7,14, 64
S2	Distilled (D.W)	24	200/1	1,7,14, 64
S3	Distilled (D.W)	24	100/1	1,7,14, 64

S4	Distilled (D.W)	24	50/1	1,7,14, 64
S5	Distilled (D.W)	28	50/1	1,7,14, 64
S6	Distilled (D.W)	30	50/1	1,7,14, 64

3. Results

Phosphorus leachability was presented as liquid phase concentration (mg/L). All results are average of three readings with a standard deviation, for example, for phosphor and lead concentrations as ± 5.6 and 0.048 mg/l respectively. The experimental results were discussed in the following sections.

3.1 Electrical conductivity (EC)

Electrical conductivity, EC, of acquis systems measures their ability to conduct an electric current and accordingly it increases with the increase in the amount of dissolved ions into water. Experimental results, herein, showed that there is a great increase in EC accompanying PR 24% submersion in the Nile water with time in comparison to the control case, as shown in Figure 2. This indicates to release PR a lot of ions into water and this release continued with time. The figure shows also that the ability of PR leaching is higher in Nile water than distilled water. This is perhaps because the Nile water composition has chemical contents which eager the releasing properties of PR. In addition, results confirmed that increase L/S ratio led to decrease the release of the PR contents into water. In addition, the increase of P_2O_5 in PR increases the release of PR. In fact, there are other chemical compositions of PR controlling leaching properties with P_2O_5 . It is reported that beside P_2O_5 in PR, CaO and SiO_2 are the main contents and there are some minors of other chemical compounds such as CO_3 , Na and Mg. [11]

3.2 Total dissolved solids (TDS)

Figure 3 presents the experimental measurements of TDS values. Results showed a well agreement with the previous results of ECs. Dissolved solids increased with increase in the contact time between PR and water. Nile water contents of the dissolved solids are almost doubled due to PR leachate. TDS values increased with decrease in the L/S ratio. P_2O_5 ratio of PRs had also the same results as EC results.

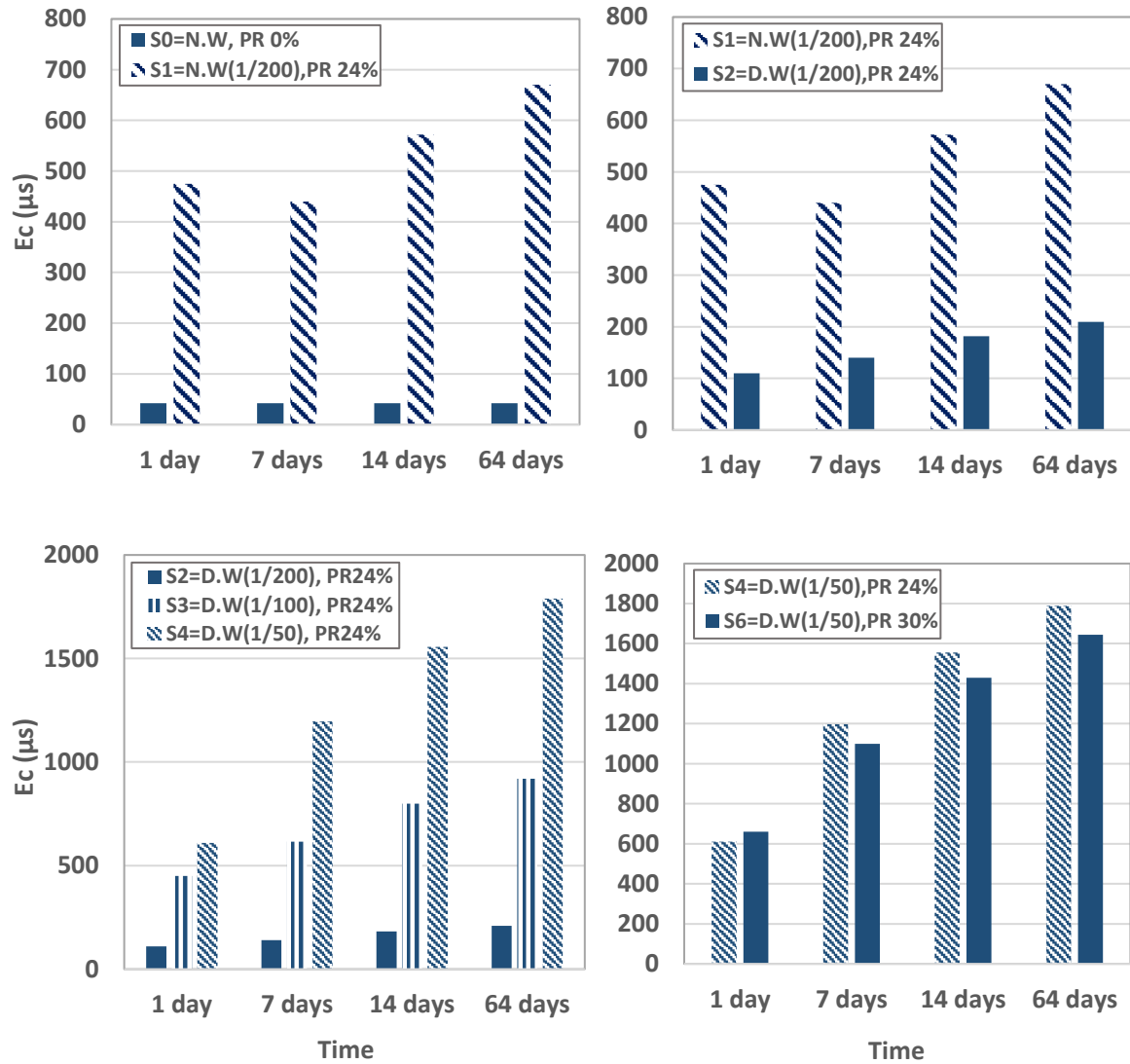


Figure 2. Electrical conductivity readings with time

3.3 Phosphor release

Figure 4 presents the phosphor release concentrations under different conditions. Phosphor results showed that after one day the content of phosphor folded more than ten times of the initial concentration found in the Nile water and the concentrations increased greatly with time. Results showed that there is a small change due to increase L/S ratio in phosphor concentrations and in case of using distilled water as well. The figure shows also that 30% P_2O_5 ratio of PR exposed a high level of phosphor release while 24 and 28% were smaller and having closer values.

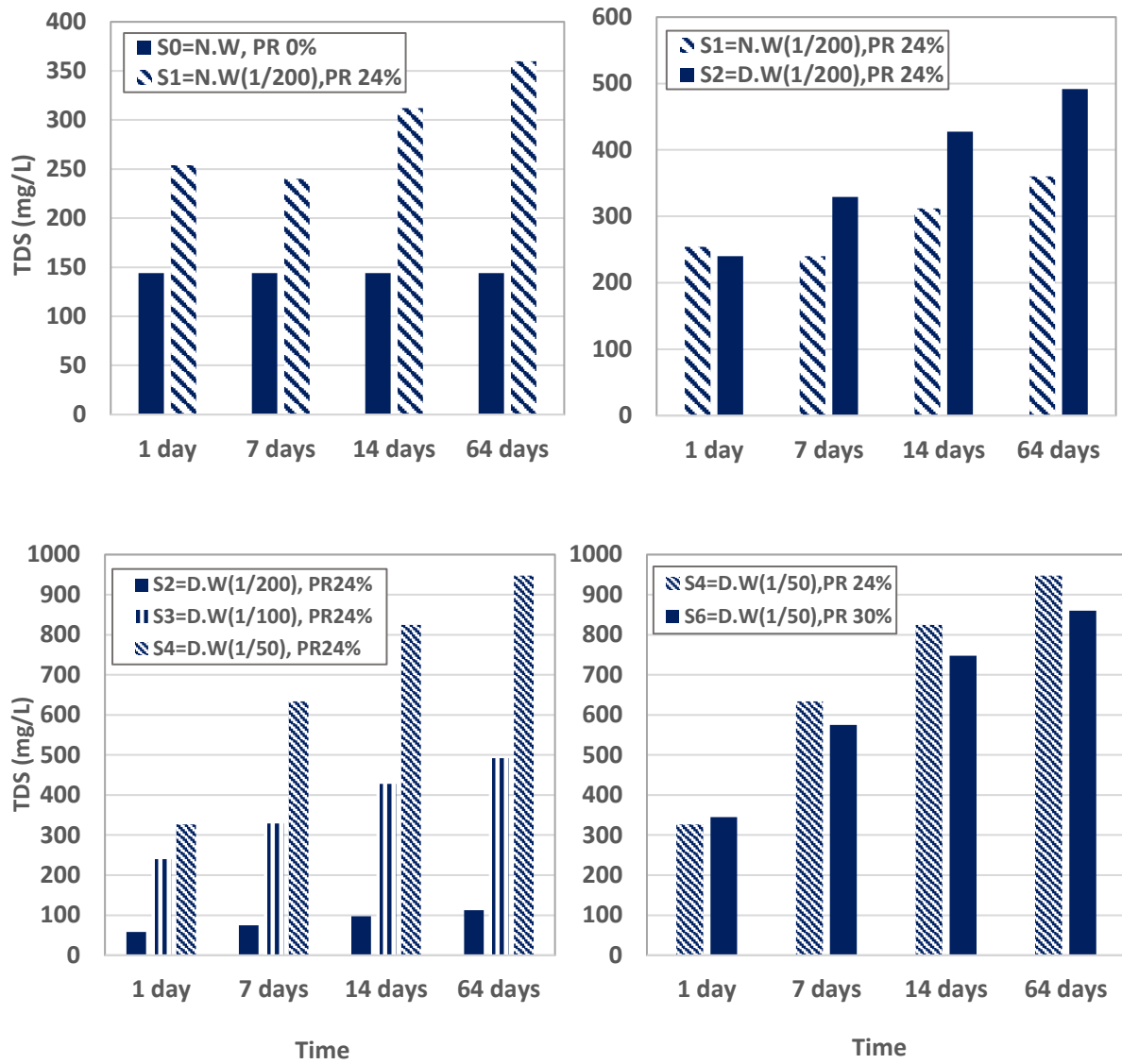


Figure 3. TDS measurements with time

Some studies showed that the solubility of PR is very low, and their leaching out is limited in the neutral pH water and increased with acidic waters [7; 12]. This study shows relatively high leaching properties for PR. This is perhaps due to the grinded PR samples were used and steering conditions applied to simulate the natural movements of water in streams such as Nile River.

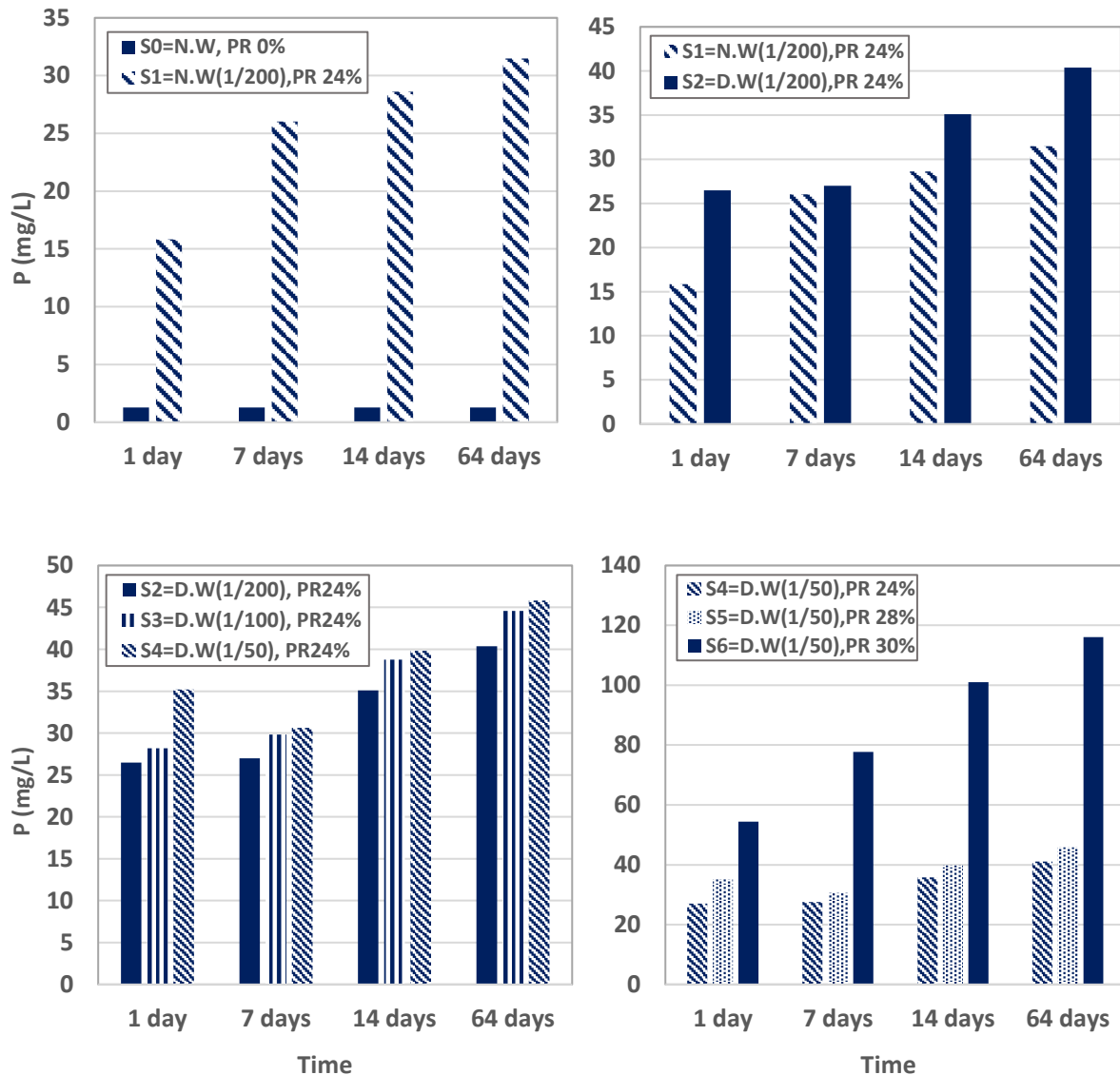


Figure 4. Phosphor release measurements with time

3.4 Heavy metals release

The heavy metals presence in natural streams has become an alarming topic worldwide in for water quality. The emphasis of this threatening concern is indirect harmfulness through accumulation of heavy metals in the aquatic food chain and direct poisonousness to human and aquatic life. Heavy metals such as chromium, lead, copper and zinc exhibit human toxicity at slightly higher concentrations while, cadmium at extremely low concentrations is toxic [13]. The results of this study, herein, showed that lead concentration released from PRs increased by 10% higher than the original content in Nile water after one day and reached 30% raise after 64 days. It increased with time and decreased with increase in L/S ratio. 30% P_2O_5 PR had higher lead release than 24%. Figure 5 presents lead release results.

For chromium and cadmium, which they were not shown in the figure, chromium release ranged between 0.01 to 0.03 mg/l in all samples and cadmium was 0.001 mg/l in some samples and not detected in most of the samples.

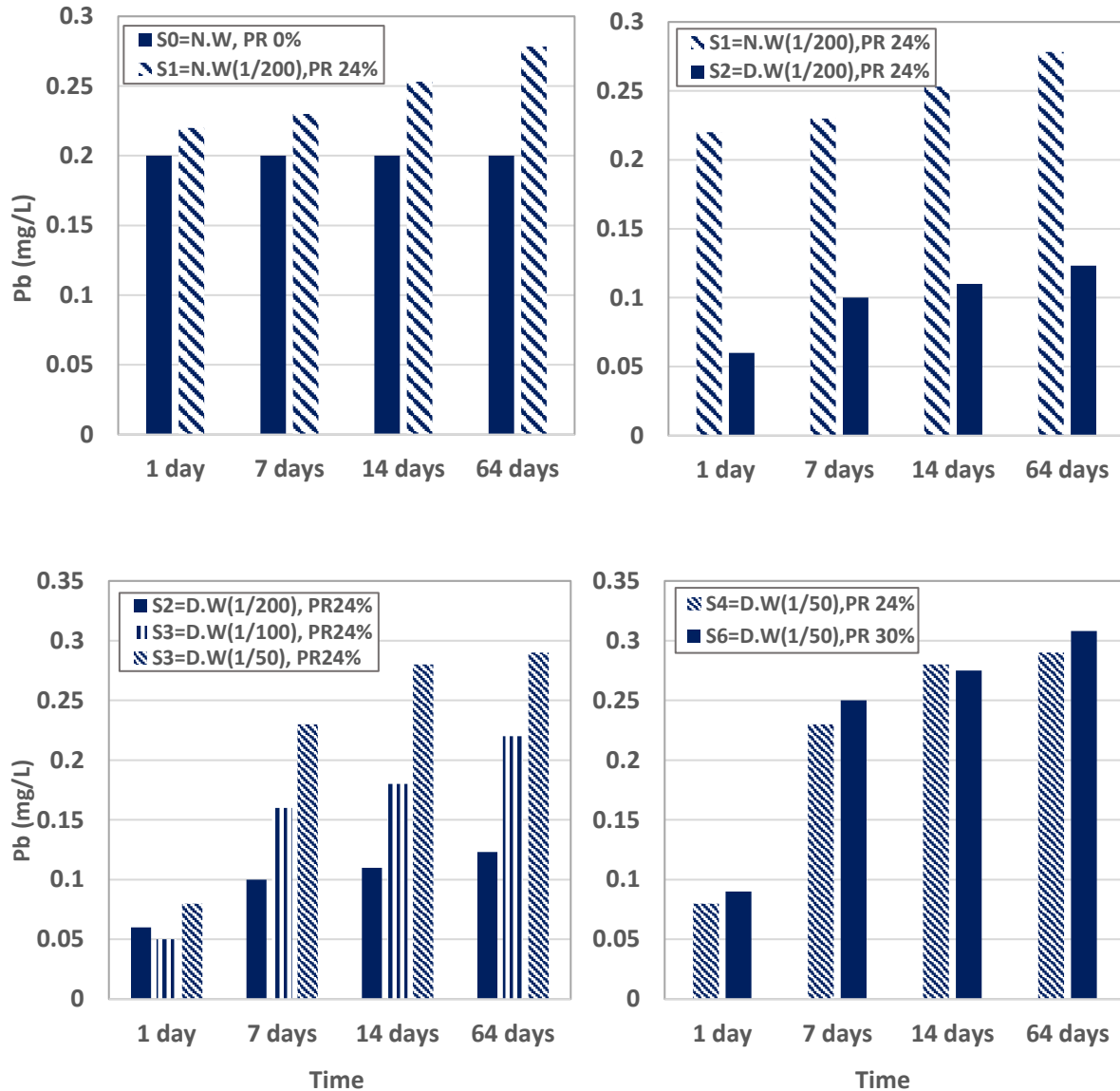


Figure 5. Lead release measurements with time

3.5 Overall Discussion

Phosphorus are nutrients for natural parts of aquatic ecosystems. Increase phosphorus with nitrogen from atmosphere supports the bloom growth of algae and aquatic plants, resulting in serious environmental and human health issues [10]. On the other hand, many health problems to human being are caused by increase phosphorus content, such as kidney damage and osteoporosis. According to the results discussed above, it is important to know if these values exceed the allowable value for drinking water and irrigation streams.

3.5.1 Water quality for Drinking:

World Health Organization [14] determined the allowable values of dissolved ions for safe drinking water as shown in Table 2. The table shows that in case of Nile water under conditions of 24% P₂O₅ PR and L/S ratio of 200, phosphor and lead were exceed greatly the allowable values for drinking water while the other parameter and elements were within permissible values. On other side, for distilled water samples under some extreme conditions of L/S ratios and P₂O₅ ratios in PR, all parameters and element contents close or above the allowable border of these values.

3.5.2 Water quality of irrigation streams: phosphorus element is regularly limited nutrient in freshwater streams. Therefore, if all phosphorus is consumed, growth of the plant will stop. The natural levels of phosphorus usually range from 0.005 to 0.05 mg/L. Increasing its available concentration lets plants to absorb more nitrogen before the phosphorus is exhausted. Consequently, if enough phosphorus is available, high concentrations of nitrates will lead to blooms in algal. Although levels of 0.08 to 0.10 ppm phosphorus may activate periodic blooms, but if total phosphorus levels are below 0.5 ppm, long-term nitrates richness will generally be avoided [15]. In this study, PRs leachate out 32 mg/L of phosphorus into Nile water. Therefore, according to the results of this study, if phosphate rocks are submersed intentionally or unintentionally into Nile river water, this will lead to environmental risks in the area of PR submersion. Similar results reported by Dushyanthaa et.al. [16] as they revealed that when PR incessantly exposed to weathering nearby lakes and streams, it can result in increasing their downstream sediments in both soluble and particulate phases of phosphorus. Thus, more studies are needed to investigate the transportation of these contaminations by the stream flow and self-purification ability of the Nile River in diluting and eliminating the impacts of these high concentrations.

Table 2. Allowable values for drinking water according to WHO (2011)

Parameter	EC (μ S/cm)	TDS (mg/l)	P (mg/l)	Pb (mg/l)	Cr (mg/l)	Cd (mg/l)
The highest reading after 64 days for Nile water sample	650	360	32	0.28	0.025	0.001
The highest reading after 64 days for distilled water samples	1770	940	117	0.31	0.03	0.001
WHO	1500	1000	0.015	0.05	0.05	0.003

4. Conclusion

The results of this study showed relatively high leaching properties for PR as it released significant amounts of different ions into water and this release continued with time.

In case of Nile water under conditions of 24% P_2O_5 PR and L/S ratio of 200, phosphor and lead were exceed greatly the allowable values for drinking water while the other parameters and elements such as chromium and cadmium were within the permissible values.

PRs leachate out 32 mg/L of phosphorus into Nile water, which is too, much more than the allowable values for natural streams, i.e. 0.5 mg/L. Therefore, if phosphate rocks are submersed intentionally or unintentionally into Nile river water, this will lead to environmental risks in the area of PR submersion.

More studies are needed to investigate the transportation of high levels of phosphor concentrations by the stream flow as well as self-purification ability of the Nile River in diluting and eliminating the impacts of these high concentrations.

5. Acknowledgment

The authors would like to thank the technicians in the environmental lab at Faculty of Engineering, Aswan University, especially Mr. Essam and Mohamed said for their help and support in the sample collection and preparation.

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