4.15 phosphorus

32P (half-life of 14.3 days) is a radioactive isotope of phosphorus that is used to help understand the biological and chemical processes in plants. It is chemically identical to other isotopes of phosphorous and can be substituted in biological and chemical reactions. For example, a phosphate solution containing 32P (which has the identical behavior of non-radioactive 31P) can be inserted into the roots of a plant, and its movement can then be tracked throughout the plant with the use of a Geiger counter. This movement detection study helps scientists to better understand how plants use phosphorous to reproduce and grow [128, 129].

At the molecular level, 32P can substitute for 31P in nucleotides of DNA or RNA (ribonucleic acid, a single stranded molecule that regulates genes). Radioactive probes can be created to help identify the presence, absence, and quantity of genes in a system [130, 131].
32P has been used as a tracer to help determine phosphorus nutrient cycling in eutrophied lakes (lakes rich in organic and mineral nutrients commonly leading to the excessive growth of phytoplankton, a self-feeding water organism) (Figure 4.15.1). In one experiment, phosphoric acid labeled with 32P was added to a lake that had been experimentally eutrophied. 32P was measured in microphytoplankton (plankton visible only with a microscope), phytoplankton, and zooplankton (tiny animals that live suspended in fresh or salt water), and the amount of incorporated 32P was determined [129].

33P has been used to better understand phosphorus dynamics in the environment at the sediment-surface level. Phosphorus is a necessary nutrient for many biota (the plant and animal life of a particular habitat, region, or geological period). Understanding bioavailability and sorption (bonding) of this nutrient to particles in soil is important for understanding ecosystem health. Organic and inorganic phosphorus substrates isotopically labeled with 33P can be tracked within a sediment system to determine their transport properties and availability to biota [132].

Fig. 4.15.1: Partitioning of 32P among water layers, the sediments, and outflow during the 105 days following addition of 32P to the upper layer of stratified Lake 227 (northwestern Ontario) to trace the lake's phosphorus cycle during lake stratification and fall overturn (modified from [129]).
4.15.3 Phosphorus isotopes in industry

$^{32}$P was added to tires in the 1950s by Goodrich Laboratories to help determine the location and depth of tire wear in performance tests [133].

4.15.4 Phosphorus isotopes in medicine

Beta emissions from the radioactive isotope $^{32}$P can be used in drug therapy of cancerous bone masses. By injecting a patient with a $^{32}$P pharmaceutical, tumors and other cells can be targeted for cell death, which also helps to alleviate pain [134, 135]. For example, Polycythemia vera is the condition of having excess red blood cells in the bone marrow, and $^{32}$P can be used to treat this condition by reducing the number of red blood cells. However, there is no cure for this condition [136]. Using a $^{32}$P labeled bio-silicone product, $^{32}$P has been used as the radioactive target in brachytherapy of solid tumors in the lung [137]. Depending on the type of $^{32}$P-labeled compound (antibody or pharmaceutical drug), when ingested or injected into the body, specific body parts (blood, tumors, joints, or bones) can be targeted for visualization and imaged using a gamma camera. This is useful for imaging cancer sites and for treatment monitoring of oncologic patients [130, 131, 135].