ASSAY

A NEWSLETTER ABOUT ACID SULFATE SOILS

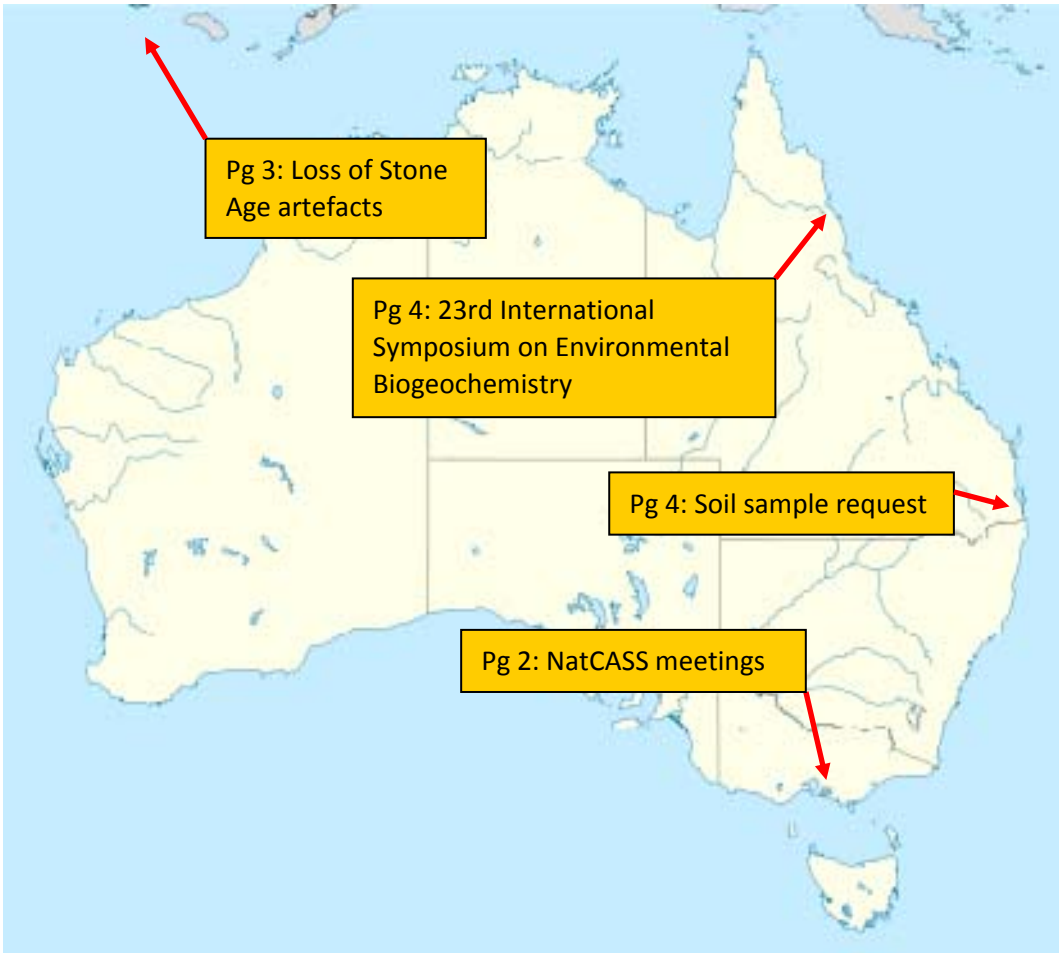
Issue # 70 **May 2017**

Welcome to the latest issue of ASSAY – your national acid sulfate soil newsletter. Since the previous issue regular editor Simon Walsh has moved onto another role. I'd like to take this opportunity to thank him for the time keeping this newsletter running over the last few years and wish him well in his new role. Unfortunately Simon's move means this issue is a little light on stories, but there is a round up on the most recent NatCASS meetings, an interesting take on how drained and oxidised peat bogs are impacting on Stone Age artefacts, request for soil samples, notice of the upcoming 23rd International Symposium on Environmental Biogeochemistry, and of course the most recent research.

Please remember that ASSAY is still open for business! If your organisation would like to invest in maintaining the continuity of our ASSAY flagship while benefiting from some well-placed promotions, please feel free to contact me directly at: scott.nichols@dpi.nsw.gov.au.

Happy reading... Scott

Stories and places…



NatCASS (National Committee for Acid Sulfate Soils): Melbourne - May 2017

Steve Appleyard

The National Committee for Acid Sulfate Soils (NatCASS) met in Melbourne on the 3rd and 4th of May 2017 to finalise preparation of a package of new acid sulfate soil guidance. The new guidance material aims to equip regulators, developers, consultants, land users and managers with the knowledge and resources to avoid, minimise, mitigate and remediate the negative impacts of acid sulfate soils on water quality, aquatic environments, infrastructure and primary production.

The new guidance includes: methods manuals for the sampling, identification and chemical analysis of potential and actual acid sulfate soils; guidance for groundwater dewatering in areas underlain by acid sulfate soils; guidance for dredging of sulfidic sediments and the management of dredge spoils; and guidance for managing monosulfidic black ooze (MBO) in drains, waterways and wetlands.

The new and existing national guidance will be brought together under an Australian overview of national acid sulfate soils and a decision support tool to assist users identify what guidance is needed for their specific circumstance. The new guidance documents should be available later in 2017.

NatCASS also discussed ongoing and emerging challenges posed by climate change, urban development and agricultural land use practices on the disturbance of acid sulfate soils. NatCASS is preparing a discussion paper on these issues and on their management, which should be available later in 2017.

NatCASS November 2016

Ashley Webb, photos - Paul Shand

NatCASS meeting 33 held in Melbourne in November 2016 included discussion of 3 new National ASS guidance documents as mentioned above.

Drafts of the guidance docs were submitted (by CSIRO, contracted by DAWR) with comments from NatCASS members due by 23 December.

The Committee also looked at updating current ASS sampling and laboratory methods manuals.

The field trip visited Jarosite Beach at Anglesea.

Cliff exploration

So where's the jarosite then?

The interested crowd watch on as….

…Professor Leigh Sullivan digs a hole

Bones at famed Stone Age site are turning into jelly

The Star Carr site in Yorkshire mentioned in the article below is one of the most important Mesolithic sites in the world where the oldest Shamanic costume (11,000 years old) has been excavated together with one of the earliest known examples of engraved jewellery (see the article at the following link: https://www.york.ac.uk/news-and-events/news/2016/research/mesolithic-shale-pendant/).

Unfortunately, as the water table in the peat body at this site is dropping, the oxidation of pyrite is turning archaeological material to mush.

Micheal Price

http://www.sciencemag.org/news/2016/10/bones-famed-stone-age-site-are-turning-jelly

Ten thousand years ago, Stone Age hunter-gatherers built houses, tracked game, and conducted elaborate shamanic rituals among the wetlands of North Yorkshire in the United Kingdom. When archaeologists uncovered this Mesolithic dwelling known as Star Carr in 1948, they found well-preserved headdresses made of deer antler, as well as animal bones and wooden and bone tools.

Revisiting the site 50 years later, researchers discovered its waterlogged wood rapidly and mysteriously breaking down and many of its bones literally turned to jelly. These “jellybones,” as the authors refer to them in a paper published today in the Proceedings of the National Academy of Sciences, have only arisen recently because Star Carr’s mucky, low-oxygen wetland prevented the site’s archaeological treasures from breaking down. But as the land was drained for agricultural purposes in the late 20th century, the groundwater level lowered, creating dry zones and exposing sulfurous sediment to oxygen, producing sulfuric acid. The acid ate away the bones’ calcium, leaving behind spongy collagen fragments (like the one seen above).

To see how the materials might fare in years to come, the team put bone and wood samples in vats with various sedimentary compositions and acidities—each corresponding to environmental conditions found within different regions of Star Carr—and left them for a year. In wet, high-acidity vats, fresh bone turned to jelly and wood’s lignin—a molecular structure found in plants’ cell walls—deteriorated. In drier environments, the jellybones disintegrated entirely.

All signs point to the site’s preserved materials rapidly disappearing if Star Carr’s hydrology can’t be changed quickly—and that may already be impossible, as simply pumping more water back into the system might not be enough to reverse its acidity.

Soil sample request

Dr Angus McElnea

As part of trying to improve the standards of laboratories analysing ASS in Australia and the Pacific, ASPAC (The Australasian Soil and Plant Analysis Council) undertakes an annual inter-laboratory proficiency round – and are always after a range of soils from all around the country.

The Council is looking for ASS researchers and workers to send in soil samples (~20-30 kg is needed for each sample). The Proficiency Program will pay for the transport and will provide details of the courier company people can use to send their samples in.

We are looking for ASS that has started to acidify (and even has jarosite in it) as well as soils with some acid neutralising capacity.

Please contact Dr Angus McElnea (Senior Scientist), Chemistry Centre, Queensland Department of Science, Information Technology and Innovation for more information: angus.mcelnea@dsiti.qld.gov.au.

UPCOMING EVENTS

23rd International Symposium on Environmental Biogeochemistry, Palm Cove, Cairns (Qld)
24-29 September 2017.

The Symposium brings together environmental scientists with a diverse range of interests.

Call for abstracts is currently open – closing May 31.

Earlybird registration closes on the evening of Friday 28 July (AEST). Register at www.iseb23.info.

According to the organisers, the major attraction of the ISEB Symposia is the broad, cross-disciplinary coverage and single theme format. Attendance is typically 150 people.

2017 Symposium theme is: "From cells to Earth scale processes: traversing the breadth of temporal and spatial scales in biogeochemistry".

Topics covered in the 23rd ISEB Symposium are:

- Biogeochemistry of mined/industrial environments and impacts of resource extraction
- Frontier techniques in environmental biogeochemistry and microbiology (e.g. –omics)
- Aquatic and terrestrial microbiology including studies on extreme environments
- Impacts of pollutants on ecosystems and their remediation
- Biological interactions and transformations of metallic and organic contaminants in the environment
- Soil, water and landscape processes (including atmospheric fluxes/interactions)
- Microbe-mineral-organic matter interactions
- Marine and coastal biogeochemistry (special focus on tropical coastal systems e.g. reefs)
- Biogeochemical cycling of major (C, N, P, S) and minor elements - methods, applications, fundamental and applied studies.

Video links

- **The VR Project (Victorian Department of Primary Industries)**
- https://youtu.be/MM-RTWF7Zoc
- This animated clip has been around for a couple of years and shows how ASS is formed and how it becomes a problem - an option for explaining ASS to novices.
- **Luke Mosley (University of Adelaide)**
- https://youtu.be/NEKHwKXhvlw
- Clip of Luke's presentation "*The drought isn't over yet; prolonged recovery of acid sulfate soils and water quality in the Lower Murray*" at the SA Department of Environment, Water and Natural Resources' NRM Science Conference 2016.

Seeking new ASSAY articles

Scott Nichols

ASSAY is our collective national acid sulfate soils newsletter. It provides a valuable service by distributing information between the various stakeholders that have a keen interest in the ASS issue and emerging developments. By continually seeking to improve ASSAY, we collectively enhance communication and further develop knowledge-sharing opportunities within the national ASS arena.

At ASSAY we are always looking for interesting stories to include in forthcoming issues. While these can follow the established format of 1—2 page articles, we are also looking to include other types of updates that may be shorter in length.

As long as they are relevant for the field of ASS, you might think of sending through some anecdotes, thoughts or musings etc. Perhaps you have an unusual/interesting photograph to share? How about some experiences in the field or back in the lab? Alternatively, maybe you have a bigger story that could be split into parts and run over two or more issues.

As ASSAY is distributed electronically, we can include hyperlinks to key websites, detailed documents and reports. If you are keen to publish some new information, the use of images, graphs and photographs is strongly encouraged to add a user-friendly dimension to plain text. Some ideas for photos that work well include aerial overviews of landscapes; fine detail with macro close-ups; images of 'people doing things'; or time sequences such as 'before and after' remediation works etc.

The opportunity is there to inform the rest of the acid sulfate soil 'family' of some of the perspectives that YOU have about ASS. If you have an idea for a contribution for a future issue, then just send me an email (scott.nichols@dpi.nsw.gov.au) or pick up the phone (02 6626 1396) and we'll make it happen.

Latest publications

Al Zamel, A., Khalaf, F.I., and Gharib, I.M. (2017). Occurrence of jarosite within Quaternary coastal sabkha sediments in Kuwait, Arabian Gulf. *Arabian Journal of Geosciences*. 10(6): 138.

X-ray diffractometer analysis and SEM investigation confirmed the occurrence of jarosite and alunogen minerals in the Quaternary siliciclastic sabkha sediments of northern Kuwait within the Bahrah oilfield area, Arabian Gulf. Jarosite is relatively abundant in a near-surface whitish sticky tidal muddy sand layer about 60 cm thick that overlies the ferruginous sandstone of the Oligo-Miocene Ghar Formation. Jarosite occurs as clusters of euhedral pseudo-cubes of about 1 μm in size and as agglomerated nanoglobules of 250 nm in size. A hypogenetic origin related to the reaction of sulfuric acid produced by the oxidation of H_2S associated with hydrocarbon gas seepages with K and Fe leachates is suggested. The restricted occurrence of jarosite within near-surface sabkha sediments may be attributed to limited tidal inundation and prevalence of arid climatic conditions.

Dan, T.H. and Brix, H. (2017) Effects of soil type and water saturation on growth, nutrient and mineral content of the perennial forage shrub *Sesbania sesban*. *Agroforestry Systems*. 91: 173.

Sesbania sesban (L.) Merr is a perennial N2-fixing tree with high potential for use in agricultural production systems as a green manure and livestock forage. We studied the interactive effects of soil type and water level on the growth, biomass allocation, nutrient and mineral content of *S. sesban.*

Four-week old seedlings of *S. sesban* were grown for 49 days (n = 5) in a factorial mesocosm set-up with six soil types (sediment, sand, alluvial, acid-sulfate, saline and clay) and three water levels (drained, water-saturated and flooded). The soils tested represent the predominant alluvial soil types of the Mekong delta, Vietnam.

Sesbania sesban grew well with relative growth rates (RGR) around 0.08 g g−1 d−1 in all studied soil types, except the saline soil where plants died. In the low-pH (3.9) acid sulfate soil, that constitute more than 40 % of the Mekong delta, the RGR of the plants was slightly lower (0.07 g g−1 d−1), foliar concentration of calcium was 3–6 times lower, and concentrations of iron and sodium up to five times higher, than in other soils. The nutrient and mineral contents of the plant tissues differed between the soils and were also affected by the flooding levels. Foliar concentrations of nitrogen (50–74 mg N g−1 dry mass) and phosphorus (5–9 mg P g−1 dry mass) were, however, generally high and only slightly affected by water level.

The results show that *S. sesban* can grow well and with high growth rates on most wet soils in the Mekong delta, except saline soils where the high salt content prevents establishment and growth. The nutrient and mineral contents of the plants, and hence the nutritional value of the plants as e.g. fodder or compost crops, is high. However, soil type and water level interactively affect growth and tissue composition. Hence, optimal growth conditions for *S. sesban* differ in the different regions of the Mekong delta.

Glaspie, C.N. and Seitz, R.D. (2017). Multiple stressors associated with acid sulfate soil effluent influence mud crab *Scylla serrata* predation on Sydney rock oysters *Saccostrea glomerata*. *Marine and Freshwater Research*. 68(4): 743-751

Studies of long-term exposure to multiple stressors on predator-prey interactions are necessary to determine the effect of coastal degradation on organisms that have had generations to adapt and acclimate to change. In New South Wales, Australia, a natural gradient of multiple stressors produced by acid sulfate soil effluent was used to determine the impact of exposure to multiple stressors on

predator-prey dynamics between mud crabs *Scylla serrata* and Sydney rock oysters *Saccostrea glomerata*.

Wild oysters were collected from two polluted and two reference sites that varied in their distance away from a flood gate that acted as a point source of water with low salinity, low pH and low alkalinity. Oysters from sites affected by multiple stressors and those from reference sites were offered to mud crabs in 48-h laboratory no-choice feeding trials.

Oysters from affected sites had lower mortality than those from a reference site that was farthest from the source of polluted water. Linear models containing distance from flood gate best explained oyster mortality. Differences in rates of mortality were due to the decreased time crabs spent foraging on affected oysters.

Long-term exposure to acid sulfate soil effluent alters trophic dynamics between predators and prey, which may have consequences for coastal food webs.

Huang, Q.Y., Tang, S.H., Huang, X., Zhang, F.B., Yi, Q., Li, P., and Fu, H.T. (2017) Influence of rice cultivation on the abundance and fractionation of Fe, Mn, Zn, Cu, and Al in acid sulfate paddy soils in the Pearl River Delta. *Chemical Geology*. 448: 93-99.

Many of the areas dominated by acid sulfate (AS) soils in southern China have been reclaimed for rice cultivation and represent an important source of agricultural production and food security for the local population. In this study, we examined the abundance and partitioning of Fe, Mn, Zn, Cu, and Al in both rice paddy fields and uncultivated fields by using a six -step sequential extraction procedure.

Rice cultivation significantly reduced acidity levels at soil depths of 0-100 cm, but acidity at depths of 100-140 cm increased significantly. A substantial loss of Mn in the oxide and acidified soil layer (0-100 cm) compared to the underlying parent material was observed, but there were few changes in the concentrations of Fe and Zn throughout the soil profile. However, both Cu and Al were substantially enriched in the superficial soil (0-40 cm) compared to the underlying subsoil (40140 cm). In general, leaching of Fe, Mn, and Al was higher in the paddy fields because of intensified irrigation and flood conditions, whereas accumulation of Cu, mainly in the form of "acid soluble" and "crystalline iron oxide" Cu, was higher in the paddy fields than in the uncultivated fields.

The most marked declines in metal concentrations occurred in the "labile" and "acid soluble" fractions, as a result of rice cultivation, which increased leaching of the readily mobilized "labile" and "acid soluble" fractions of heavy metals in these soils.

Karikari-Yeboah, O. and Addai-Mensah (2017). Assessing the impact of preload on pyrite-rich sediment and groundwater quality. *Journal of Environmental Monitoring and Assessment*. 189: 58.

Pyrite-rich sediments would, invariably, undergo redox reactions which would lead to acidic aqueous environment containing solubilized toxic metal species. When such sediments are subjected to preload, a technique employed by geotechnical engineers to improve the load-bearing capacity of highly compressible formation, transient flow of pore water, accompanied by acidity transfer, would occur as a response. Despite the concomitant environmental and socio-economic significance, to date, there has been limited interdisciplinary research on the underpinning geotechnical engineering and geo-environmental science issues for pyrite-rich sediments under preload.

In this study, we investigate the effect of pyrite-rich sediment pore water transfer under preload surcharge on the receiving environment and the impact on the groundwater speciation and quality. Sediment samples were obtained at close depth intervals from boreholes established within pristine areas and those subjected to the preload application. Soil and pore water samples were subjected to

solid/solution speciation, moisture contents, soil pH and the Atterberg Limits' analyses using standard analytical techniques and methods. Standpipes were also installed in the boreholes for groundwater sampling and in situ monitoring of water quality parameters.

It is shown that the imposition of preload surcharge over pyritic sediment created a reducing environment rich in SO_4^{2-}, iron oxide minerals and organic matter. This reducing environment fostered organic carbon catabolism to generate excess pyrite and bicarbonate alkalinity, which would invariably impact adversely on soil quality and plant growth. These were accompanied by increase in pH, dissolved Al, Ca, Mg and K species beneath the surcharge.

Karimian, N., Johnston, S.G., and Burton, E.D. (2017). Effect of cyclic redox oscillations on water quality in freshwater acid sulfate soil wetlands. *Science of the Total Environment*. 581: 314-327.

Restoration of add sulfate soil (ASS) wetlands by freshwater re-flooding can lead to the reformation of various Fe(II) and reduced inorganic sulfur (RIS) species in surface soil layers. However, in many locations, wetland water levels undergo large seasonal fluctuations that drive extreme redox oscillations. Newly formed RIS species [e.g. greigite, mackinawite, nano-pyrite and S(0)1 and Fe(II) are vulnerable to rapid oxidation during dry periods and may generate substantial acidity. Rainfall following a dry period may then mobilise acidity and metal cations in surface waters prior to eventual recovery in pH by re-establishment of reducing conditions.

We explore this dry-wet transition by subjecting soil samples from two freshwater re-flooded ASS Wetlands to oxidative incubation for up to 130 days followed by re-flooding simulation for 84 days. During very early stages of re-flooding (up to 7 days) there was an initial pulse-release of aridity, and trace metals/metalloids (Al, Mn, Zn and As). This was followed by a rapid reversion to anoxia, and Fe(III) and SO_4 reducing conditions which generated alkalinity, ameliorated acidity and sequestered Fe, S, Zn, Mn and As. Field-observations of surface water quality in an ASS wetland at a sub-catchment scale also confirms re-establishment of SO_4 reducing conditions and recovery of pH within similar to 4-8 weeks of re-flooding after dry periods.

These observations suggest that retaining surface water in ASS wetlands for similar to 8 weeks after a dry-wet transition will allow sufficient time for alkalinity producing reductive processes to ameliorate most surface water acidity.

Although management of freshwater re-flooded ASS wetlands in a highly dynamic climate will remain challenging over the long term and the post-remediation effectiveness of the method depends on initial soil characteristics, knowledge of the timing of redox oscillations and the associated changes in water geochemistry can be helpful for mitigating the risks to downstream estuarine water quality.

Li, J., Yu, JY., Liu, JC., Yan, CL, Lu, HL., Spencer, K.L. (2017). The effects of sulfur amendments on the geochemistry of sulfur, phosphorus and iron in the mangrove plant (*Kandelia obovate* (S. L.)) rhizosphere. *Marine Pollution Bulletin*. 114(2): 733-741.

P (phosphorus) and Fe (iron) are limiting elements and S (sulfur) is an important element of the biogeochemical cycle in the mangrove environment. To assess the effects of sulfur on the geochemical cycling of Fe and Pat the sediment-plant interface, the speciation distributions of Fe, P and S in sediments were examined.

The data showed that higher proportions of amorphous Fe, Fe-bound phosphate, chromium reducible sulfur and elemental sulfur were found in the rhizosphere, while more crystalline Fe, exchangeable phosphate and acid-volatile sulfide were determined in the non-rhizosphere. Sulfate application induced an increase in the Ex-P concentration, high P accumulation and high iron plaque deposition in the roots.

In conclusion, sulfate applications had a significant influence on the geochemical cycling of Fe and Pin the sediments. It significantly curtailed the Fe and P limit to plant growth and enhanced plant resistance to the rugged surroundings in mangrove

McLennan, S. M., Giles, D., and Hill, S.M. (2017). Late Miocene-Pliocene coastal acid sulphate system in southeastern Australia and implications for genetic mechanisms of iron oxide induration. *Geoderma*. 294:1-18.

Ferricrete - sediment cemented by iron oxides and hydroxides - is common in subaerial weathering environments around the world. Formed under alternating oxidising and reducing conditions, ferricretes record pedogenetic processes of translocation and concentration of iron and trace elements in the soil. Given their stability and high preservation potential, ferricretes can provide insights to ancient soil forming and weathering processes.

In this study the key processes controlling ferricrete geochemistry in a Neogene strandplain are identified and interpreted in the context of a coastal acid sulphate weathering system. Textural and geochemical variations in sediment indurated by hematite and goethite represent a record of in situ induration, erosion, and reworking. This development took place within an environment of fluctuating pH and Eh and subaerial wetting and drying cycles. We distinguished depositional and post-depositional processes based on the results of whole rock geochemistry, hyperspectral mineralogy, and major and trace element maps of petrographic thin sections.

The ferricretes have three morphological types: flat-lying indurations, concentric pisoliths, and rounded nodules with fragmented internal textures. Successive laminae of Fe-oxides and hydroxides in all morphological types of ferricrete have variable Fe, Al, and Si abundances, reflecting cyclic precipitation and groundwater chemistry changes.

Episodic wetting and drying of near coastal sediments was superimposed on a long-term trend of marine regression and local tectonic uplift (from similar to 7 Ma to present). This resulted in the diachronous exposure of relatively reduced shoreline sediments and concomitant acid production due to ferrolysis and the oxidation of biogenic sulphide.

Local landform variations contributed to a wide variety of pedogenic processes and subsequent ferricrete formation. Acid sulphate weathering recorded by these indurated sediments is similar to conditions that are observed at present in the shallow water estuary of the Lower Lakes, near the mouth of the Murray River.

Santos, I.R., Zhang, C.M., Maher, D.T. Atkins, M.L., Holland, R., Morgenstern, U. and Li, L. (2017) Assessing the recharge of a coastal aquifer using physical observations, tritium, groundwater chemistry and modelling. *Science of the Total Environment*. 580: 367-379.

Assessing recharge is critical to understanding groundwater and preventing pollution. Here, we investigate recharge in an Australian coastal aquifer using a combination of physical, modelling and geochemical techniques. We assess whether recharge may occur through a pervasive layer of floodplain muds that was initially hypothesized to be impermeable.

At least 59% of the precipitation volume could be accounted for in the shallow aquifer using the water table fluctuation method during four significant recharge events. Precipitation events <20 mm did not produce detectable aquifer recharge. The highest recharge rates were estimated in the area underneath the floodplain clay layer rather than in the sandy area. A steady-state chloride method implied recharge rates of at least 200 mm/year (>14% of annual precipitation). Tritium dating revealed long term net vertical recharge rates ranging from 27 to 114 mm/year (average 58 mm/year) which were interpreted as minimum net long term recharge.

Borehole experiments revealed more permeable conditions and heterogeneous infiltration rates when the floodplain soils were dry. Wet conditions apparently expand floodplain clays, closing macropores and cracks that act as conduits for groundwater recharge. Modelled groundwater flow paths were consistent with tritium dating and provided independent evidence that the clay layer does not prevent local recharge.

Overall, all lines of evidence demonstrated that the coastal floodplain muds do not prevent the infiltration of rainwater into the underlying sand aquifer, and that local recharge across the muds was widespread. Therefore, assuming fine-grained floodplain soils prevent recharge and protect underlying aquifers from pollution may not be reasonable.

Shand, P., Gotch, T., Love, A., Raven, M., Priestly, S., and Grocke, S. (2016) Extreme environments in the critical zone: Linking acidification hazard of acid sulfate soils in mound spring discharge zones to groundwater evolution and mantle degassing. *Science of the Total Environment*. 568: 1238-1252.

A decrease in flow from the iconic travertine mound springs of the Great Artesian Basin in South Australia has led to the oxidation of hypersulfidic soils and extreme soil acidification, impacting their unique groundwater dependent ecosystems.

The build-up of pyrite in these systems occurred over millennia by the discharge of deep artesian sulfate-containing groundwaters through organic-rich subaqueous soils. Rare iron and aluminium hydroxysulfate minerals form thick efflorescences due to high evaporation rates in this arid zone environment and the oxidised soils pose a significant risk to local aquatic and terrestrial ecosystems. The distribution of extreme acidification hazard is controlled by regional variations in the hydrochemistry of groundwater. Geochemical processes fractionate acidity and alkalinity into separate parts of the discharge zone allowing potentially extreme environments to form locally. Differences in groundwater chemistry in the aquifer along flow pathways towards the spring discharge zone are related to a range of processes including mineral dissolution and redox reactions, which in turn are strongly influenced by degassing of the mantle along deep crustal fractures.

There is thus a connection between shallow critical zone ecosystems and deep crustal/mantle processes which ultimately control the formation of hypersulfidic soils and the potential for extreme geochemical environments

Webb, J.R., Santos, I.R., Robson, B., Macdonald, B., Jeffrey, L. and Maher, D.T. (2017). Constraining the annual groundwater contribution to the water balance of an agricultural floodplain using radon: The importance of floods. *Water Resources Research*. 53: 544–562.

The water balance of drained floodplains is highly dynamic with complex groundwater-surface water interactions operating over varying spatial and temporal scales.

Here we hypothesize that the majority of groundwater discharge will follow flood events in a modified wetland. To test this hypothesis, we developed a detailed water balance that quantifies the contribution of groundwater discharge to the annual water budget of an extensively drained agricultural floodplain.

A clear relationship between surface water radon measurements and groundwater level indicated alternating connection-disconnection dynamics between the drains and shallow groundwater. This relationship was used to develop a radon mass balance to quantitatively model groundwater discharge continuously throughout the year.

Groundwater discharge varied by four orders of magnitude over the study period, with daily average rates ranging from 0 to 27,200 m^3 d^{-1}, peaking just a few hours after floods receded. Flood events occurred only 12% of the time yet contributed 72-76% of the total groundwater discharge. During flood

recession periods, aerial groundwater discharge rates reached up to 325 cm d^{-1} which were some of the highest rates ever estimated. We proposed that the high drainage density of this site (12.4 km constructed drains km^{-2} catchment area) enhanced groundwater discharge during wet periods due to increased connectivity with the soil.

Overall, groundwater discharge contributed 30-80% to the total surface water discharge. This study offers insight into the dynamic behaviour of groundwater within an extensively drained floodplain, and the importance of capturing flood events to quantify total groundwater contribution to floodplain water balances.

Wisawapipat, W., Charoensri, K., and Runglerttrakoolchai, J. (2017) Solid-Phase Speciation and Solubility of Phosphorus in an Acid Sulfate Paddy Soil during Soil Reduction and Reoxidation as Affected by Oil Palm Ash and Biochar. *Journal of Agricultural and Food Chemistry*. 65(4): 704-710.

Understanding phosphorus (P) speciation and how redox conditions control P solubility in acid sulfate paddy soils with limited P availability is crucial for improving soil P availability. We examined P speciation and extractability in an acid sulfate paddy soil incorporated with oil palm ash (OPA) and biochar (OPB) during soil reduction and subsequent oxidation. Phosphorus K-edge X-ray absorption near edge structure (XANES) spectra of the soil samples revealed that P in the soil mainly occurred as P adsorbed to ferrihydrite and P adsorbed to gibbsite.

During soil reduction, gibbsite-bound P was transformed into variscite, which was back-transformed to gibbsite-bound P during soil reoxidation. Sequential extraction results confirmed the dominance of Fe/Al (hydr)oxides-bound P (average 72%) in the soils. The OPA incorporation increased the exchangeable P pool concurring with the decrease in gibbsite-bound P. The OPB incorporation enhanced the dissolved P from the residual pool presumably due to electron shuttling of biochar with Fe(III) minerals during soil reduction. Our results highlight P dynamics in paddy soils, which are of immense importance for effective P-management strategies in rice cultivation.

ASSAY contact details

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ACID SULFATE SOILS
information and awareness

Australian Government
Department of Agriculture and Water Resources

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