RECOMMENDATIONS FOR FSTPS AND CO-TREATMENT PLANTS IN UP

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ABBREVIATIONS

ABR	Anaerobic baffled reactor
ACF	Activated carbon filter
BOD	Biochemical oxygen demand
CCT	Chlorine contact tank
COD	Chemical oxygen demand
CSE	Centre for Science and Environment
DPR	Detailed project report
HLR	Hydraulic loading rate
HRT	Hydraulic retention time
FSTPs	Faecal sludge treatment plants
MBBR	Moving bed biofilm reactor
MoEF&CC	Ministry of Environment, Forests and Climate Change
NGT	National Green Tribunal
PPE	Personal protective equipment
PGF	Planted gravel filter
PSF	Pressure sand filter
SBR	Sequential batch reactor
SOP	Standard operating procedure
TBF	Tiger biofilter
TS	Total solids
TSS	Total suspended solids
ULB	Urban local body
UV	Ultra violet

Introduction

Centre for Science and Environment (CSE) conducted a six-month study in Uttar Pradesh to evaluate the faecal sludge treatment plants (FSTPs) and STP co-treatment plants in the state. Currently, there are 58 plants that are functional in UP. Out of the 58 plants, 10 FSTPs and three STP co-treatment plants were monitored to evaluate their performance. The FSTPs that were evaluated were based in Chunar, Basti, Deoria, Aligarh, Loni, Modinagar, Shamli, Amroha, Hapur and Shahjahanpur, and the STP co-treatment plants were from Gorakhpur, Saharanpur and Etawah. The study period spanned from January to June 2024, with samples collected every alternate months from all the treatment plants. Samples were collected from several stages: when the tanker unloaded sludge into the receiving chamber of the treatment plants, from the liquid part or leachate after solid-liquid separation, from the outlet or final treated water of FSTPs, and from the biosolids stored in the drying unit. Testing of the collected samples were done according to the standard methods prescribed for each of the tested parameters. The findings of the study are presented in the CSE report titled, *Monitoring and Evaluation of FSTPs and STP Co-treatment Plants in Uttar Pradesh.* [1]

RECOMMENDATIONS

Based on the problems identified during the site visit and the findings from the report, three types of recommendations have been provided. This includes design/process improvement, training and administrative recommendations.

Design recommendations

Specific design or process improvement recommendations have been provided for each FSTP on the basis of findings from the study report.[2] In the study, it was found that technology adopted by the treatment plants in UP are either nature-based system or a combination of advanced and nature-based system. Nature based or biological units found in the evaluated FSTPs are either anaerobic baffled reactor, sequential batch reactor, moving bed biofilm reactor, vermi filtration or a combination of these reactors. As treatment technology differs among the FSTPs, separate recommendations are provided for each treatment plant in **Table 1**.

Table 1. Design/process improvement recommendations

Locations	Design/process improvement recommendations
Chunar	• According to the detailed project report (DPR), the ***sludge feeding frequency*** in the planted drying bed must be maintained as ***six days.*** *An interval of six days will ensure effective TS removal (which is currently only 23 per cent), as well as ensure enough time for the plants in the bed to absorb the nutrients (nitrogen and phosphorus) from the percolating water.* • According to DPR, the ***hydraulic retention time (HRT)*** of ***planted gravel filter (PGF) is 0.9 days or 21 hrs***. This has to be maintained for the reduction of nitrogen and phosphorus in the final effluent from Chunar FSTP. *Currently, the nitrogen removal was observed to be only 48 per cent, which can be increased to 80–90 per cent by maintaining the HRT of 21 hrs in PGF.* • The efficiency of the filtration units must be assessed regularly. A standard operating procedure (SOP) must be followed for backwashing the filter units and changing the filter bed. Consultation with the private partner who constructed the FSTP is necessary to understand the operation and maintenance of filtration units. • It is essential to reduce the TSS in the effluent entering the UV disinfection unit as UV light cannot disinfect effectively as these particles interrupt the disinfection process in two ways i) absorbing or scattering light ii) shielding the microorganisms embedded in it [3] *Currently, the TSS removal is only 47 per cent, which implies that a considerable amount of TSS exists in the effluent entering the UV disinfection unit. Hence, it is essential to control the level of TSS in the effluent entering the disinfection unit.* • The intensity of UV light in the UV disinfection section must be checked regularly. *Currently, the disinfection efficiency is good as the indicator microorganisms were found to be below NGT standards. However, to ensure consistent performance, routine inspections of the UV light must be conducted.*
Basti	• A proper dosing unit and a regulator must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the final effluent. An SOP for disinfection stage is required and it needs to be followed for optimal performance. *Currently, the indicator microorganism is within the limit set by NGT and MoEF &CC. However, installing a dosing unit with a regulator helps in usage of optimal chlorine dosage as and when required for the treatment. This prevents under or over usage of chlorine.* • For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, the biosolids must be subjected for drying in sunlight for 15 days followed by pulverization of the biosolids to reduce the particle size. Reducing the particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days.[4] *Currently, moisture content of the biosolid collected from Basti is 35 per cent. Hence, adequate drying must be provided in order to reduce the moisture content.*

Locations	Design/process improvement recommendations
Deoria	• Optimization of flow rate in constructed wetlands and maintenance of HRT (as mentioned in the DPR) is required for reducing nitrogen levels in the effluent. *Currently, the nitrogen removal achieved is only 10 per cent. Maintaining the optimum flow rate and HRT as mentioned in the DPR will significantly help in nitrogen removal* • A proper dosing unit and a regulator must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the treated water. An SOP for disinfection stage must be followed for optimal performance *Currently, indicator microorganisms have been found to be above the NGT standards. Installing a dosing unit with a regulator helps in the usage of optimal chlorine dosage as and when required for the treatment. This prevents underdose or overdose of chlorine.*
Aligarh	• The efficiency of Tiger Biofilter (TBF) technology is significantly affected by flow rate, HLR and HRT.[5] Apart from these, other factors which influence the performance of TBF are optimum stocking density of worms, health and maturation conditions of earthworms. Maintaining optimal earthworm density is crucial for effective wastewater treatment, as low densities may not sufficiently stimulate microbial activity. Earthworms that are bigger in size can treat more efficiently compared to the smaller ones due to their voracious eating habits. *The **optimum stocking density of earthworms** lies between **15,000 and 20,000 worms/m^3** in a vermi filter bed.* [6] *Currently, the COD and BOD removal achieved is 79 and 76 per cent respectively. This removal percentage can be enhanced by maintaining the optimum earthworm density in TBF-I.* • Similarly, in TBF-II and PGF, the HLR and HRT must be maintained as mentioned in the DPR for effective action of microbes on organic matter present in the effluent from TBF-I. *Currently, the nitrogen and phosphorus removal are 75 and 57 per cent respectively. This can be improved by maintaining the optimum HLR and HRT as mentioned in the DPR.* • For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, biosolids must be subjected for sunlight drying for 15 days followed by pulverization of the biosolids to reduce the particle size. Reducing the particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days *Currently, the moisture content of the biosolid collected from Aligarh is 44 per cent. Providing adequate drying reduces the moisture content.*
Shamli	• Optimization of polymer dosing is required for efficient solid liquid separation so that the TSS can be reduced in the liquid entering the treatment module. • Optimizing the polymer dosing rate and concentration will bring the consumable cost to an economic level. Unoptimized use of polymer can either lead to i) increased polymer concentration in the dewatered biosolid which will result in ineffective drying and pathogen removal ii) lower polymer concentration while mixing with faecal sludge result in poor solid liquid separation *Currently, the TSS removal efficiency is 72 per cent. Optimizing the polymer dosage increases the TSS removal efficiency.* • A proper dosing unit and a regulator must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the effluent. The SOP for disinfection stage must be followed for optimal performance. *Currently, the indicator microorganism is within the limit set by NGT and MoEF &CC. However, installing a dosing unit with a regulator helps in the usage of optimal chlorine dosage as and when required for the treatment. This prevents under or over usage of chlorine.*

Locations	Design/process improvement recommendations
Amroha	• Optimization of polymer dosing is required for efficient solid liquid separation so that the TSS can be reduced in the liquid entering the treatment module. *Currently, the TSS removal efficiency is 78 per cent. Optimizing the polymer dosage increases the TSS removal efficiency.* • Anaerobic baffled reactor (ABR) performance is significantly influenced by flow rate and hydraulic retention time (HRT).[7,8] ***A flow rate of 1.3 m^3/hr and an HRT of 27 hrs in ABR*** (as mentioned in DPR) must be maintained for achieving considerable BOD and COD reduction. *BOD and COD (organic pollutants) removal occurs due to anaerobic microbial population present in the ABR. This anaerobic digestion occurs as a cascade of organic breakdown to simpler organics and gaseous products. Currently, the BOD and COD removal in Amroha is only 64 per cent, which implies that the HRT and flow rate are not optimally maintained* • Both flow rate and HRT are key factors in governing the performance of constructed wetlands.[9] In ***constructed wetlands system I, a flow rate of 1.3 m^3/hr and a hydraulic retention time of 7.5 hrs*** whereas in ***constructed wetlands system II, a flow rate of 1.3 m^3/hr and a hydraulic retention time of 24 hrs*** must be maintained for considerable reduction of nutrients such as nitrogen and phosphorus. *Partially treated water from ABR, when brought in to constructed wetlands, enables the conversion of the simpler dissolved nitrogen and phosphorus compounds to gaseous products by aerobic respiration. Currently, in Amroha, the nitrogen and phosphorus removal is only 23 and 12 per cent, respectively. Maintaining the prescribed the flow rate and HRT will improve the nitrogen and phosphorus removal* • The regular maintenance of the filtration units has to be carried out. Generally, ***maximum pressure drop allowed in the filter units is 0.5 bar***. If the pressure drop is above this value, backwashing must be carried out to remove the accumulated solids. Even after several backwashing, the pressure drop tends to increase, then changing of filter beds is recommended. *It is recommended that after five days of running the filters, one cycle of back wash is mandatory*. Consultation with the private partner who constructed the FSTP is necessary to understand the operation and maintenance of filtration units. A SOP must be followed accordingly. • A proper dosing unit and a regulator must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the effluent. *Currently, the indicator microorganism is within the limit set by NGT and MoEF &CC. However, installation of a dosing unit with a regulator helps in the usage of optimal chlorine dosage as and when required for the treatment.*

Locations	Design/process improvement recommendations
Hapur	• A submersible pump, if placed in the equalization tank, helps in proper mixing and homogenization of FS before it enters the polymer mixing tank. • The filtration units must undergo regular maintenance. ***Maximum pressure drop allowed in the filter units is 0.5 bar***. If the pressure drop is above this value, backwashing must be carried out. • If the pressure drop continues to increase despite multiple backwashing cycles, it is recommended to replace the filter beds. Consultation with the private partner who constructed the FSTP is necessary to understand the operation and maintenance of filtration units. The SOP must be followed accordingly. • A proper dosing unit and a regulator must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the treated water. The SOP for the disinfection stage must be followed for optimal performance of the hypochlorination unit. *Currently, the indicator microorganism is above the limits set by NGT and MoEF &CC. Following the SOP and applying optimal chlorine dosage will help in reducing the microorganisms in the final effluent.*
Loni	• The flow rate and retention times for all the cycles of the batch reactor (fill, react, settle, decant, sludge wasting and purge) of the sequential batch reactor (SBR) must be maintained as provided in DPR. *Currently, both BOD and COD removal is around 80 per cent, which shows fairly good performance of SBR. According to the DPR, the hydraulic retention time in SBR is 1.33 days which must be ensured so as to maintain consistent and stable performance in removing organics from incoming sludge.* • According to the process flow, there are two MBBR reactors running in series. It is essential to maintain optimal diffusion of air and HRT of four hours in each of the reactors. *MBBR performance is low when compared to SBR as the nitrogen and phosphorus removal was reported to be 59 and 45 per cent, respectively. Maintaining optimal diffusion of air and HRT will enhance nitrogen and phosphorus removal.* • The regular maintenance of the filtration units has to be carried out. A SOP need to be followed for backwashing the filter units and changing the filter bed. Consultation with the private partner who constructed the FSTP is necessary to understand the operation and maintenance of filtration units • The intensity of UV light in the UV disinfection section must be checked regularly. It is essential to reduce the TSS in the water entering the UV disinfection unit as ultra violet light cannot disinfect treated water effectively as these particles interrupt the disinfection process. • For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, biosolids must be subjected for drying by sunlight for 15 days followed by pulverization of the biosolids to reduce particle size. Reducing the particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days. *Currently, the moisture content of the biosolid collected from Loni is 33 per cent. Providing adequate drying reduces the moisture content.*

Locations	Design/process improvement recommendations
Modinagar	• During the visit to Modinagar FSTP, it was observed that a solid liquid separation unit is absent in the treatment chain. This unit is a very crucial segment in any FSTP as maximum COD and BOD reduction occurs in the solid liquid separation stage. It is recommended to include a simple decanter which can facilitate solid liquid separation so that only the liquid part enters the anaerobic stabilization or biodigester tank. The reason for the mandatory inclusion of solid liquid separator unit is provided below. *Currently, the per cent removal of TSS, COD and BOD are 66, 63 and 57 per cent, respectively. According to the DPR, an innovative anaerobic bacterial culture is added in order to completely degrade the organic matter present in the faecal sludge. However, it should be noted that the enzymes present in the bacterial culture act on fresh faecal sludge and not on previously digested matter.* *Faecal sludge collected from various onsite sanitation systems is a mixture of raw, partially digested and completely digested sludge. Faecal sludge which is emptied frequently from public toilets is either fresh or partially digested whereas the sludge that is accumulated in septic tanks over a period of years might have undergone complete digestion. Therefore, the anaerobic culture inoculated in the bio-digester of the FSTP cannot effectively act on the fully digested sludge matter. As a result, incorporating a solid-liquid separator can significantly enhance the removal of TSS, COD, and BOD.* • According to the DPR, subsequent to the biodigester, anoxic chamber is placed. However, the anoxic reactions do not occur in the anoxic chamber; instead, it functions as an equalization tank to balance the flow from the biodigester. Furthermore, it is not accurate to refer to the chamber as an anoxic chamber after the biodigester, as anoxic reactions (denitrification) typically occur after aerobic reactions (nitrification) to remove nitrogen compounds from wastewater. Therefore, it would be more appropriate to rename it as an equalization chamber rather than an anoxic chamber. • The efficiency of the filtration units has to be carried out regularly. The SOP needs to be followed for backwashing the filter units and changing the filter bed. It is essential to consult with the private partner who built the FSTP to gain a better understanding of the operation and maintenance of the filtration units. • As ozonation is the disinfection unit, ozone dose must be optimized. Additionally, the presence of TSS in the treated water entering the ozonation unit exert an ozone demand and shield the bacteria embedded in it.[10] This interferes with the disinfection process. *Currently, the indicator microorganisms are above the NGT and MoEF&CC norms. As mentioned above, TSS removal is 66 per cent, which implies that considerable amount of TSS still exist in the treated water. This can reduce the effectiveness of the disinfection process. Hence, optimizing ozone dose and reducing TSS helps in improving disinfection efficacy.*

<table>
<tr><th>Locations</th><th>Design/process improvement recommendations</th></tr>
<tr><td>Shahjahanpur</td><td>
• The design/ process flow needs to be corrected.
Currently, the flow of liquid is ABR → SBR → CCT → ACF & PSF → PGF

It is recommended to change the flow of liquid as:
ABR → SBR → PGF → ACF & PSF → CCT

• For correcting the design, it is advised to divert the flow of effluent from SBR to PGF instead of SBR to CCT. The treated effluent from PGF can then be filtered in the filtration units and finally disinfected in CCT

• There are four reasons for the above-mentioned changes:
1) In any treatment plant, disinfection is done in the final stage to reduce the pathogens.[11] According to the current flow, after disinfection in CCT, the effluent flows to filtration module and PGF. Hence, there are chances of recontamination from disinfected water.
2) Another scenario is that if chlorine remains in the partially treated water, the likelihood of recontamination is reduced. However, when chlorinated water enters the PGF, it can disrupt the biofilm development in the gravel system as well as it damages the root system of plants grown in PGF. Biofilm and the plant root system are essentially important to carry out the function of PGF.
3) Treatment of faecal sludge in ABR and SBR helps in the reduction of organic matter removal. However, some amount of organic matter and TSS still remains in the partially treated liquid which needs to be removed before the disinfection process. Organic matter exerts a chlorine demand and TSS shields the bacteria embedded in it [12]. This leads to poor disinfection of the partially treated effluent. Hence, the remaining organic matter and TSS has to be removed by PGF and filtration units. This ensures the effluent from filtration units have negligible concentration of organic matter and solid particles which subsequently allow the proper disinfection in the CCT.
Currently, the indicator microorganism is above the limits set by NGT and MoEF &CC. Hence, it is advisable to place the CCT at the end of the treatment stage of FSTP.

• After correcting the design, it is recommended to carry out back washing of filtration units to clean the filter and then operate the plant.

• For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, biosolids must be subjected for sunlight drying for 15 days followed by pulverization of the biosolids to reduce the particle size. Reducing the particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days.
Currently, the moisture content of the biosolid collected from Shahjahanpur is 45 per cent. Providing adequate drying time reduces the moisture content.
</td></tr>
</table>

Locations	Design/process improvement recommendations
Gorakhpur	• A proper dosing unit must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the effluent. There should be an SOP for the disinfection stage which must be followed for optimal performance. *Currently, the indicator microorganisms have been found to be high and above NGT standards. Additionally, outlet from the treatment plant is discharged into a water body. If proper disinfection is not ensured, the receiving water body also gets contaminated which poses a health hazard for people who are dependent on that water body. Hence, it is advised to disinfect the effluent effectively. The effluent must not be discharged to any water body if proper disinfection cannot be attained.* • For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, biosolids must be dried by sunlight for 15 days followed by pulverization of the biosolids to reduce the particle size. Reducing the particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days *Currently, the moisture content of the biosolid collected from Gorakhpur is 31 per cent. Providing adequate drying time reduces the moisture content.*
Saharanpur	• A proper dosing unit must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the treated water. An SOP for the disinfection stage must be made and followed for optimal performance. *Currently, the indicator microorganisms are found to be high as well as above NGT and MoEF&CC standards. Additionally, the outlet from the treatment plant is discharged into a water body. If proper disinfection is not ensured, the receiving water body also gets contaminated which poses a health hazard for people who are dependent on that water body. Hence, it is advised to disinfect the effluent effectively. The effluent must not be discharged to any water body if proper disinfection cannot be attained.* • For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, biosolids must be subjected to sunlight drying for 15 days followed by pulverization of the biosolids to reduce the particle size. Reducing particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days *Currently, the moisture content of the biosolid collected from Saharanpur is 60 per cent. Providing adequate drying time reduces the moisture content.*

Locations	Design/process improvement recommendations
Etawah	• A proper dosing unit must be installed in the hyperchlorination unit to ensure optimal chlorine dosage to eliminate the pathogens in the effluent from the treatment plant. SOP for the disinfection stage needs to be followed for optimal performance. *Currently, the indicator microorganisms have been found to be high and above NGT and MoEF&CC standards. Additionally, the outlet from the treatment plant is discharged into a water body. If proper disinfection is not ensured, the receiving water body also gets contaminated which poses a health hazard for people who are dependent on that water body. The effluent from the treatment plant must not be discharged into any water body if proper disinfection cannot be attained. Therefore, it is recommended to disinfect the outlet water thoroughly.* • For biosolids, drying must be done to reduce the moisture content and subsequently the pathogen load. Initially, biosolids must be dried using sunlight for 15 days followed by pulverization of biosolids to reduce particle size. Reducing the particle size increases the surface area and allows uniform sunlight penetration into the particles. Post pulverization, the biosolids can be further subjected to drying for a period of 15 days. *Currently, the moisture content of the biosolid collected from Etawah is 33 per cent. Providing adequate drying time reduces the moisture content.*

Training recommendations

Training recommendations are provided based on observations during the site visit in the six-month study period. During the site visit, several issues were observed, including negligence in using personal protective equipment (PPE) while handling sludge, non-compliance with the SOP for operating and maintaining treatment units, insufficient or no stock of chemicals used for treatment, lack of familiarity with polymer or chlorine dosing, and infrequent reuse of outlet water. Hence, the following recommendations are based on the above-mentioned observations.

1. The operators in the FSTPs need to ensure that they are wearing proper PPE while handling the sludge.
2. The respective ULBs or the concessionaire in charge of the FSTP should provide the operator with the SOP for operating all units of the treatment plant. If the concessionaire has transferred the plant to the ULB, it remains the concessionaire's responsibility to ensure the SOP is also handed over.
3. The FSTP operators should be trained on the maintenance of each unit of the FSTP.
4. Operators must be trained on maintaining registers to keep record of the incoming sludge, chemicals procured and chemicals used in the FSTP. This ensures that a sufficient stock of all chemicals (such as polymer, hypochlorite) are available during the treatment and smooth functioning of the plants.
5. The FSTP operator must be trained in polymer dosing in order to make them understand the optimum polymer concentration required for achieving efficient solid liquid separation in the screw press. This recommendation is applicable for the FSTPs which have adopted mechanical (screw press) dewatering stage.

6. The FSTP operator needs to be trained in hypochlorite and ozone dosing if the disinfection stage is chlorination and ozonation, respectively.
7. The operators must be trained in reusing the outlet water for gardening and cleaning FS tanker. The water used for cleaning the tanker must be pumped to the screening chamber of the treatment plant.

Administrative recommendations

Administrative recommendations are provided based on the observations during the site visit and findings of the study report. In the study, the selection criteria adopted for selecting the treatment plants was 'plants which utilize at least 20 per cent of their design capacity'. However, during the site visit, it was observed that, amongst the 13 treatment plants, the capacity utilization of two FSTPs, Basti and Deoria was less than 20 per cent. This shows that the capacity utilization is very less as the sludge is not received in the aforementioned plants regularly. Both the FSTPs have a design capacity of 32 KLD each and have adopted a hybrid (advanced + nature based) mode of treatment technology. From the findings, it was found that both Basti and Deoria have demonstrated good performance in removing the organics and other nutrients. Basti FSTP has demonstrated a removal efficiency of more than 90 per cent whereas Deoria FSTP has shown a removal efficiency of more than 80 per cent for removing organics. Since both FSTPs are performing well, it is advisable to increase the capacity utilization. The administrative recommendations mentioned below can help in bringing the FS to the FSTPs without fail and subsequently increase the capacity utilization of both the plants.

1. The ULBs (Basti and Deoria) have to ensure that desludging is done by recognized, registered desludging operators. If there are private desludging operators operating in the city, they need to be identified, empaneled and trained.
2. Awareness programs (among citizens) must be created to make the public aware of the existence of FSTPs in Basti and Deoria.
3. Proper contact information about the recognized desludging operators must be given to citizens.
4. All desludging operators should be required to empty their tankers exclusively at the FSTP. This ensures regular desludging operations, their transportation, treatment and safe disposal.

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